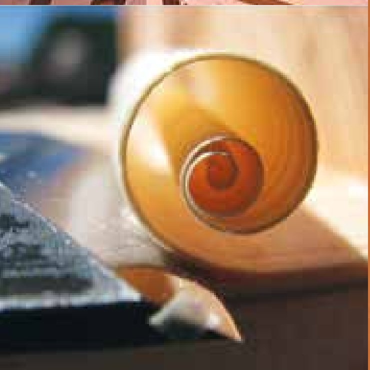

DESIGNING & BUILDING A LIGHT STRAW CLAY HOUSE

THE EcoNest HOME

Paula Baker-Laporte and Robert Laporte

Praise for *The EcoNest Home*

I have found this publication extremely inspiring, easy to comprehend and well-illustrated. The authors describe their sophisticated LSC wall system in great detail and place it convincingly in a wider context based on their philosophy. Impressive is the systematically future-focused advancement of timber construction in conjunction with natural climate control and principles of Baubiologie/Building Biology combined with ambitious aims of aesthetic design. This masterpiece is recommended to novices and experts respectively.

— Franz Volhard, architect, and author, *Leichtlehmbau*

We are moving away from eating synthetic foods and applying synthetic cosmetics because we believe that what we put into our bodies matters to how we feel and function. We can taste the difference between an irradiated, genetically modified tomato and one naturally grown. So why do we live in synthetic buildings and breathe synthetic air? We have discovered the magic of living and working in EcoNests. The gatherings we host in these inspiring and refreshing spaces produce completely different outcomes than those we convene in synthetic environments. In this remarkable book, Paula and Robert offer a radical paradigm shift worth seriously considering for better health and a more sustainable world!

— Cindy Mercer, co-founder, Planet Heritage Foundation www.planetheritage.org

Imagine a house more comfortable, and comforting, than any you've ever been in before, so well built it could last for centuries, and a house that, at the end of its life, could be absorbed back into the earth as simply and safely as an apple core. Now imagine two people who have been designing and building such houses for 25 years sharing all of their hard-won lessons. *That's* what this book is.

— Kevin Ireton, former long-time editor, *Fine Homebuilding*

Paula and Robert's updated book allows us the privilege of benefiting from their evolution as authors, teachers, architects, craftspeople and pioneers in the natural building movement. Through their work they manage to balance the artful and rare combinations of progression and tradition, professionalism and grass roots. *The Econest Home* is made from well designed, sophisticated techniques rooted in simplicity. This book demonstrates the outstanding results that arise to their steadfast commitment to creating healthy, natural homes.

— Adam Weismann and Kay Brice, Directors/Founders of Clayworks and Cob in Cornwall, authors, *Using Natural Finishes* and *Building with Cob*

Paula Baker-Laporte and Robert Laporte have created a beautiful and exceptionally detailed and useful guide to the design and construction of light straw clay houses. With a thorough coverage of the background philosophy and principles behind their approach and practice, they provide a wealth of technical and practical information about the process as well as many gorgeous examples of the results. Their longstanding commitment to designing for both human and ecological health, durability, energy and resource efficiency and effectiveness is evident throughout this book. This is an invaluable addition to the literature and practice of building natural, high quality, low impact homes.

David Eisenberg, Director
Development Center for Appropriate Technology

Through their exceptional work Paula and Robert have laid out sound principles by which to design and build. In *The EcoNest Home* every aspect of creating a beautiful, sensible, and healthy home is explored and demonstrated with elegance and clarity. Filled with practical information of how an EcoNest is constructed, *The EcoNest Home* is at once informative, beautiful and inspiring.

— Martin Hammer, architect;
co-author, Light Straw-Clay and
Strawbale Construction appendices
in the International Residential Code;
co-director Builders Without Borders

The EcoNest Home brings into print the most recent developments in this accessible building technique, including building products not available until recently. The authors, also experienced architects, builders and workshop teachers, share what is needed through design, building to the finishes. The workshop checklist is especially valuable as a guide for creating effective workshops. A great new book for the ecological designer, builder and homeowner.

— Sukita Reay Crimmel, co-author, *Earthen Floors: A Modern Approach to an Ancient Practice*;
and developer, Claylin www.claylin.com

Stepping into a home built to EcoNest specifications and proportions, one passes from nature into natural, from life into living. An EcoNest home exists beyond green and sustainable, it is a living machine, a steward of the earth, and the earth repays EcoNest's occupants by supporting their good health and invigorating their sense of wellbeing. I have experienced this myself, and time and again I have seen the awe it inspired in students of my organization's Natural Healthy Building Seminar, which was co-written and is co-instructed annually by Paula Baker-Laporte. My fondest hope is that Paula and Robert's book will inspire countless more on a quest for an EcoNest home.

— Michael Conn, Executive Director,
International Institute for
Building-Biology® & Ecology

THE EcoNest HOME

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THE EcoNest HOME

DESIGNING & BUILDING A LIGHT STRAW CLAY HOUSE

Paula Baker-Laporte and Robert Laporte

new society PUBLISHERS

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Resources, Notes and Appendices

This book is dedicated

to the pioneers

of the worldwide

natural building renaissance.


CREDIT: ECONEST CO.

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We also want to thank our dear friends in the natural building movement with whom we have celebrated and commiserated over the years in what might otherwise have been a rather difficult journey: Ianto Evans, Michael Smith and Linda Smiley for birthing the new cob movement; Matts Myhrman and the late Judy Knox and Bill and Athena Steen for their pioneering work in straw bale; David Eisenberg, who has been a tireless ombudsman bridging the gap between natural building and the country's building officials; Martin Hammer for his dedication to bringing natural building into the nation's building codes; Catherine Wanek, a formidable champion, catalyst, writer and photographer; SunRay Kelly, the barefoot builder; Cedar Rose Geulberth, author and purveyor of natural building supplies; Carol Venolia, author and architect; David Easton, father of the North American rammed earth revival; Dale Brotherton, Japanese carpenter and teacher extraordinaire; Charlie Carruthers, natural plaster pioneer and master craftsman; and countless others whom we have failed to name.

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Special thanks go to Jonathan Shaw and Kim Kurian who provided many of the beautiful photographs of finished EcoNest homes in this book. We are also grateful to all of our students who allowed us to use their workshop photos, notably Zac Coventry, Jens Wiegand, Jackson Porretta, and Jon Byrd.

Thanks to Cooper Harless and Mae Yuuki who worked so many patient hours with us to produce the illustrations.

To the 1,500 or more people who have taken our workshops: You know who you are, and we thank you! You have been a constant inspiration and reminder that together we can and will make a difference.

Finally we wish to thank New Society Publishers for bringing books such as ours to print—books that may never be #1 best sellers but will, we believe, play an important role in bringing to light a new, just society in which humans have the tools to hear, respect, and follow the wisdom of nature.

Foreword

by Sim van der Ryn

In *The EcoNest Home*, Paula and Robert Laporte have produced a rich, practical, beautiful and well-organized manual and guide for anyone who wants to build a healthy ecological home that relates to place, nature and people. Starting with the 25 principles of Building Biology that define the principles of a healthy home and its connection to producing and conserving its own food, energy, water and materials, they cover in a clear and practical way every aspect of the light straw clay building system as evolved by Robert Laporte in 25 years of building hand-crafted natural buildings in workshop settings.

The Laportes have long experience in conducting building workshops around the world, and this book is richly illustrated with real examples and detailed explanations of this elegant and time-tested building method that has now been accepted into the International Residential Building Code.

Our human building heritage started with materials at hand, and careful, simple craftsmanship. Since the Industrial Revolution, home building is just another standardized, mechanized process for profit which leaves a trail of destruction, waste, ugliness and health risks to people and living systems.

The EcoNest Home is a much-needed practical bible to shift the home design and building process from today's tired, toxic, and wasteful practices to a human-, natured-centered and mindful collaborative approach.

Paula and Robert have planted the seeds for a hopeful future in home design and building. The roots and stems they have planted through Building Biology will provide a flowing and positive change in home design and construction as well as improving the health of humans and the natural environment.

Sim Van der Ryn *is a visionary, author, educator, architect, and public leader. He has been described by the* New York Times *as an "intrepid pioneer on the eco-frontier." For more than 40 years, Sim has been at the forefront of integrating ecological principles into the built environment. He served as California's first energy-conscious State Architect, authored seven influential books, and won numerous honors and awards for his leadership and innovation in architecture and planning. Sim's collaborative approach and meta-disciplinary accomplishments help point the way to an evolving planetary era that values both the integrity of ecological systems and the quality of life. He is Professor Emeritus in Architecture at the University of California where he taught from 1961 to 1995, and president of the Eco-Design Collaborative (ecodesign.org) based in Inverness, California.*

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Introduction

Over the years we have had many requests for an up-to-date "How to Build an EcoNest" book. Since Robert first wrote the original *Mooseprints: A Holistic Home Building Guide* in 1992, our processes have evolved. More than 1,500 students have participated in an EcoNest Natural Building Workshop over the past 25 years, and each has made a contribution—left us "a $50 tip"—that has improved or streamlined the process of crafting a successful nest. Wall framing and stuffing, which once took three weeks is now accomplished with a workshop of 12 in just four days.

In Section II we will give you clear step-by-step, easy-to-follow instructions for building a successful Light Straw Clay (LSC) structure. We have a secret hope, however, that the content of this book will entice you to experience one of our workshops in person, because a workshop is an opportunity for you to bask in the camaraderie, dedication, and craftsmanship that magically develop in the good company of like-minded earth stewards with a passion for building a better future.

This is also a "*Why* to Build an EcoNest" book.

The era of green building is burgeoning. With cutting-edge technologies, ever-more efficient mechanicals, high-performance synthetic wall systems, super-insulating foams, stickier tapes and tighter vapor barriers, why on earth would we choose to build with earth…and straw, timbers, and stone? Why cling to a building system that uses natural, unadulterated materials when state-of-the-art lab-tested synthetic building products are so readily available and convenient?

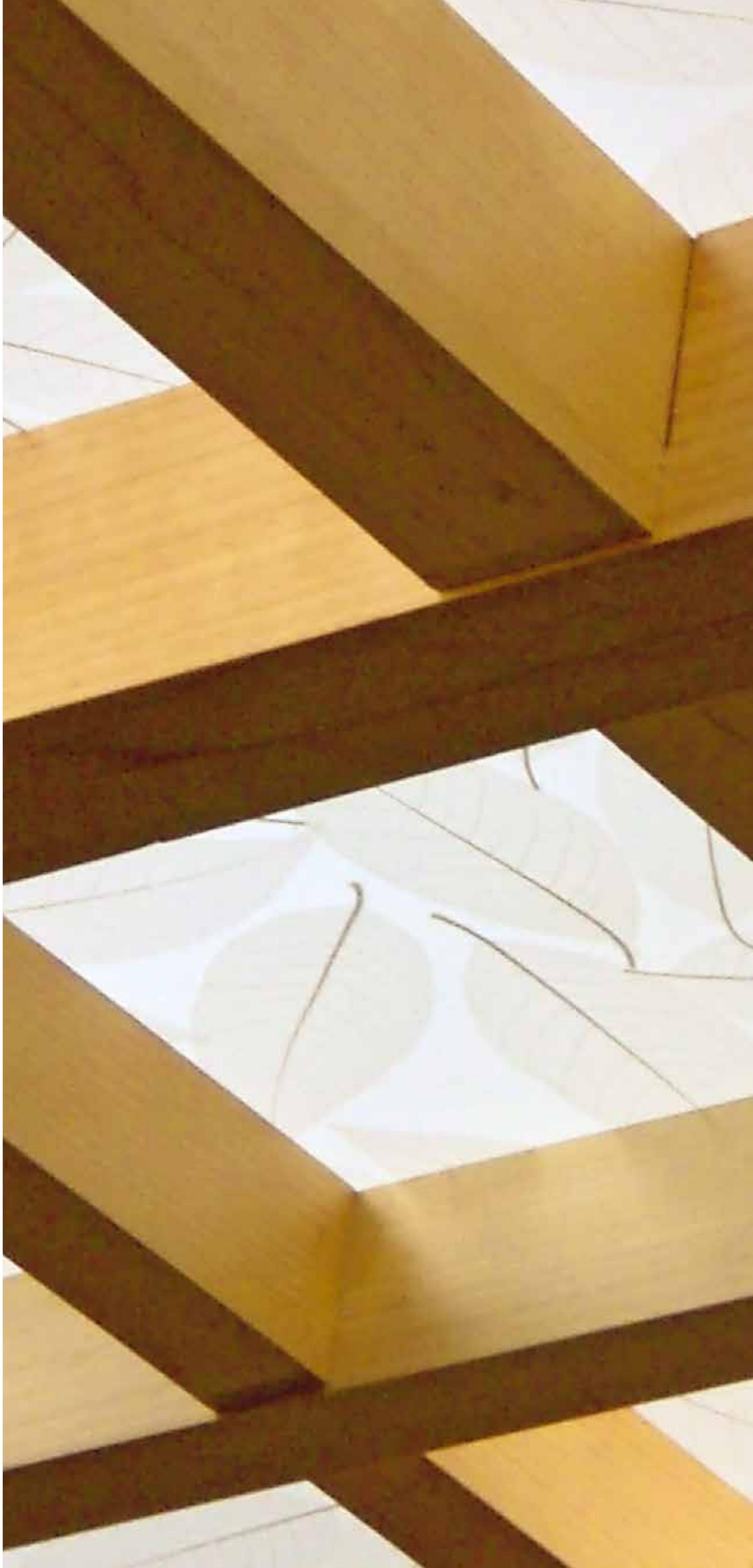
Our answer lies in the fact that we have repeatedly witnessed something so profound that it has shaped and inspired us to embrace nature in our homes and dedicate our work to helping others do the same. For the past 25 years we have opened our door to countless strangers: building professionals, aspiring builders, eco-home seekers, soon-to-be homeowners, the chemically sensitive, and the curious. We have seen the transformation that occurs over and over again as these people discover, for the first time in their lives, just how good, how strangely familiar and right, a natural home feels. We have also experienced the ongoing enrichment that our nest has provided us in our own quest to be the best that we can be.

Unlike Europeans or Asians, who grow up in historic settings steeped in time-honored building traditions that are often crafted from nature, most North Americans have never had the opportunity to experience the timeless and nurturing quality of the natural home. All but forgotten, or never really understood, is the fact that we are *a part of nature*—the ultimate model of sustainability and ecological regeneration. When we build with nature's unadulterated materials and a deep understanding of her laws, we can build homes that nurture us and respect her. We call these *biological homes.*

Our mission is to make this kind of home a familiar and mainstream North American alternative to conventional mechanically dependent and petrochemically based construction.

SECTION 1

The EcoNest Philosophy



CREDIT: PAULA BAKER-LAPORTE

Chapter 1

Defining the Biological Home

Biological Food/Biological Home

If your interest in exploring a natural way of building has led you to this book, chances are that you already understand the benefits of investing in local organic food and grasp the relationship between our health and good ecological citizenship. Thinking this way about our shelters is less common but every bit as important for our own well-being and in our quest for a sustainable future.

The story of food and the story of shelter parallel one another. Both underwent a radical break from age-old regionally defined traditions in the post-war petro-chemical era. In the process, our health suffered and the environment suffered. By comparing conventional and natural food side by side with conventional and natural building, we hope to further clarify why biological building benefits both the occupant and the environment.

For many years there has been a popular and successful movement in North America characterized by a return to natural or biological food. Many have made the informed decision to shun cheap "denatured" processed foods because of the costs—social, environmental, and health. We have witnessed a burgeoning of local farmers markets and community-supported agriculture throughout North America. When Michael Pollan, best-selling author of *The Omnivore's Dilemma* and *In Defense of Food*, was asked about the relationship between health and ecology with regards to food, he stated: "I discovered that

It has been estimated that it takes an average of 10 calories to produce 1 calorie of the Standard America Diet. Our grocery stores are full of food products that are neither healthy nor ecologically sound.

CREDIT: PATRICK OWEN

It has been our experience that the biological home fills most North Americans with awe and delight and most Europeans with a nostalgic longing for home.

in most…cases the best ethical and environmental choices happen to be the best choices for our health." [*In Defense of Food: An Eater's Manifesto*, Penguin Press, New York, 2008, p. 2]

Remarkably, more than 40 years earlier, the founders of Building Biology made a parallel observation about the built environment stating: "There is almost always a direct correlation between the biological compatibility of a given [building] material and its ecological performance." In other words, environments that are deeply nurturing to human health, *by their very nature* excel in ecological performance.

Just as we have discovered that the soil sterilization and chemical fertilizers of factory farming are a very poor substitute for rich, living organic soils, Building Biology notes the failure of industrialized building technology to create vital environments with the synthetic materials and systems that are prevalent in conventional construction today.

Unfortunately, unlike food products, homes do not have labels revealing their ingredients or "nutritional value." If they did, a list far more disturbing than the fine print on a box of junk food would expose the use of carcinogens and neurotoxins. What goes into our homes in the way of chemical additives is virtually unregulated. The EPA lists more than 88,000 chemicals in common use today, and, to quote the Environmental Working Group: "As amazing as it may seem, there are no mandatory pre-market health testing

CREDIT: PAULA BAKER-LAPORTE

If homes had mandatory labels like food products do, then a list, far more disturbing than the fine print on a box of junk food, would expose the use of carcinogens and neurotoxins. We would be empowered to ask for better.

or approval requirements under any federal law for chemicals in cosmetics, toys, clothing, carpets or construction materials, to name just a few obvious sources of chemical exposure in everyday life."[1]

How has this affected us?

- There are an estimated 42.6 million Americans living with hay fever and/or asthma; 87 percent of American homeowners are not aware that pollution may be worse inside their homes than outdoors. [American Lung Association, healthhouse.org/iaq/facts.cfm]

- The rate of asthma doubled from 1980 to 1995 and has remained steady since then, at historically high levels. [cdc.gov/nchs/pressroom/06facts/asthma1980-2005.htm (2006)]

- Of the 21.8 million people reported to have asthma in the US, approximately 4.6 million cases are estimated to be attributable to dampness and mold exposure in the home. [Berkeley Lab Research News, May 24, 2007, from Berkeley Lab and EPA joint study]

- The US Environmental Protection Agency reported that about one-third of people working in sealed buildings claimed to be sensitive to one or more common chemicals. [my.clevelandclinic.org/health/diseases_conditions/hic_Multiple_Chemical_Sensitivity_Fact_or_Fiction]

Reducing the toxins in the air of a home is a worthwhile goal. It will decrease the number of people, especially children, who suffer from building-related illness. However, absence of illness is not the same as radiant health; absence of toxics is only a first step toward creating a truly nurturing biological home.

Whenever we opt for locally crafted natural materials over the manufactured, denatured assemblage of products that go into the conventionally built home, there are beneficial repercussions for the health of the ecosystem, the health of the occupant, and those involved in all aspects of the construction of our homes.

Imagine a world in which we have regained what was thrown out with the bathwater of industrialization. Imagine a home built by a community of master craftsman to last for centuries. Imagine a home that requires little energy to operate comfortably while reinforcing the occupants' health and connection to nature. This is the promise of the natural building renaissance that we call *the biological home.*

The growing popularity of farmers markets and the authentic food movement is a testimonial to a realized need unmet by the factory farm and conventional food processing industry. While so many of us have rediscovered the value of local, unadulterated foods, why do North Americans so unwittingly settle for so much less in their homes? We look forward to the day when the housing market catches up to the farmers market.

Farmers markets thrive because consumers realize the value of fresh, organic, and local food.

CREDIT: PAULA BAKER-LAPORTE

CREDIT: ROBERT LAPORTE

The door to Dr. Anton Schneider, founding director of Institut fur Bau Biologie und Okologie in Neubeuern, Germany.

Building Biology: Nature as the Gold Standard for Health

We have coined the term *biological home* to describe a home that pays homage to the principles of Building Biology.

Both Robert and Paula, long before they met, were each on a journey of discovery. Paula was looking for ways to design healthier buildings, and Robert was looking for ways to build with natural materials. What they each found separately was the same holistic approach to the design and building of home called *Building Biology.* Building Biology is both a building philosophy and a science that originated in Germany in the early 1960s, as *Baubiologie.* At that time, long before building-related health problems were recognized or understood in North America, it was becoming alarmingly evident in Europe that a growing segment of their population was chronically unwell from being indoors in the mass-produced industrialized housing that went up post World War II. A multidisciplinary gathering of concerned citizens and professionals systematically compared newly constructed "sick buildings" with the solid, often earthen, pre-war building stock. What resulted was the first set of scientific standards for evaluating indoor environmental quality and 25 principles for building new homes, workplaces, and communities. Baubiologie founded the birth of the European healthy home movement.

The main focus of Building Biology is human health—and achieving deep ecology is a corollary of this. In other words, buildings that deeply nurture every aspect of human health in production, occupation, and post-habitation will also excel as models of sustainability.

Principles of Building Biology

We can sense when an environment feels good to us, but it is rare to find indoor environments where we feel the vitality we experience in nature. Why? Because the natural environment embodies a delicate balance of chemical, electrical, and biological energies that has sustained life through the millennia. Humans, along with all living things, thrive in natural


CREDIT: PETER MUSTY, CHARETTE CENTER

The Commons Co-housing, Santa Fe, NM. Dense planned community with landscaped pedestrian pathways give a feeling of being surrounded in nature even at 6+units/acre.

environments with fresh air, temperature variation, humidity range, a complexity of colors and shapes, and the subtle electrical pulse of the planet. The ideal role of our buildings is to shelter us from climatic extremes without sacrificing these life-nurturing qualities. In short, the natural environment *is* the gold standard for human health, *and* it's the ultimate model of sustainability. To the extent that our indoor environments measure up to the natural environment, they will nurture us.

There are 25 principles of Building Biology. Each is multi-faceted and worthy of many books. The sum total is a formula for built environments that promote profound health and ecological balance.

Here are those principles, arranged into the four main categories:

Site and Community Design

1. Verify that the site is free of naturally occurring health hazards.

2. Place dwellings so occupants are undisturbed by sources of man-made air, soil, water, noise, and electro pollution.

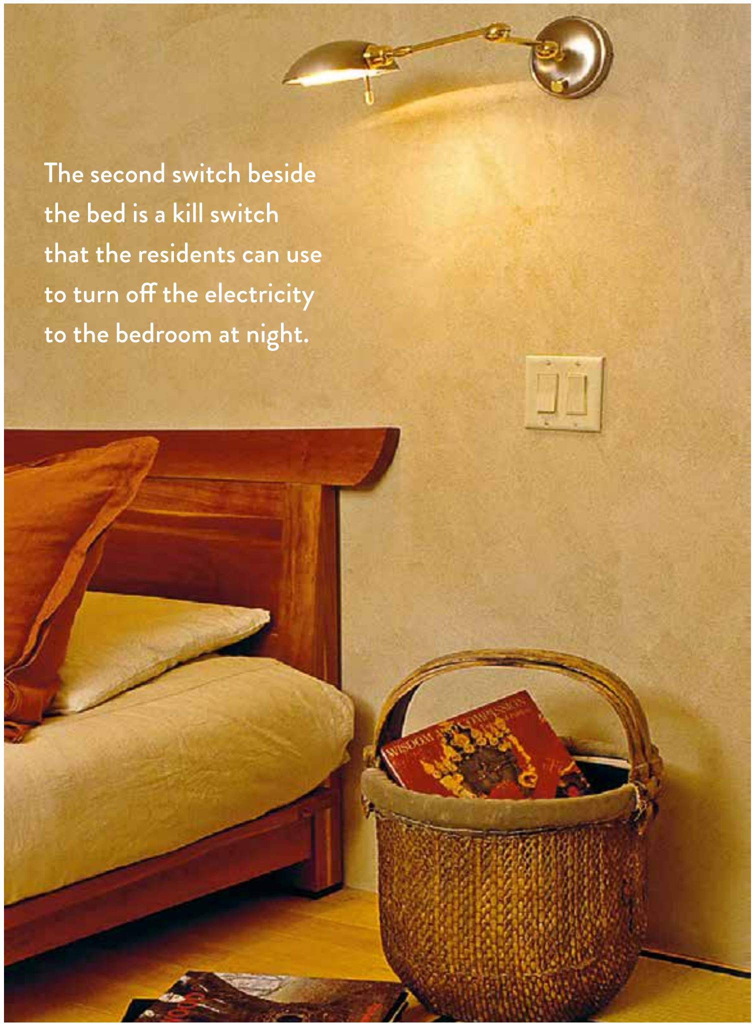
CREDIT: PAULA BAKER-LAPORTE

An LSC wall will sprout as it dries, demonstrating synergy to working with natural materials. The sprouts help the water to dry. Their roots bind.

3. Place dwellings in well-planned communities that provide ample access to fresh air, sunshine, and nature.
4. Plan homes and developments considering the needs of community, families, and individuals of all ages.

Occupant Health and Well-Being

5. Use natural and unadulterated building materials.
6. Allow natural self-regulation of indoor air humidity, using hygroscopic (humidity-buffering) building materials.
7. Assure low total moisture content and rapid desiccation of wet-construction processes in new buildings.
8. Design for a climatically appropriate balance between thermal insulation and thermal storage capacity.
9. Plan for climatically appropriate surface and air temperature.
10. Provide for ample ventilation.
11. Use appropriate thermal radiation strategies for heating buildings, including passive solar wherever viable.
12. Provide an abundance of well-balanced natural light and illumination while using color in accordance with nature.
13. Provide adequate acoustical protection from harmful noise and vibration.
14. Utilize non-toxic building materials that have neutral or pleasant natural scents.
15. Use appropriate water- and moisture-exclusion techniques to prevent interior growth of fungi, bacteria, dust, and allergens.



The second switch beside the bed is a kill switch that the residents can use to turn off the electricity to the bedroom at night.

CREDIT: LAURIE DICKSON

CREDIT: ECONEST CO

Irreplaceable natural resource—the last remaining redwood forests. Building Biology asks us to consider the environmental consequences of our materials choices in building.

16. Assure best possible potable water quality by applying purification technologies, if necessary.

17. Utilize physiological and ergonomic knowledge in interior and furniture design.

18. Consider proportion, harmonic measure, order, and shape in design.

Natural and Man-Made Electro-Magnetic Radiation Safety

19. Minimize indoor interference with vital cosmic and terrestrial radiation.

20. Minimize man-made power system and radio-frequency radiation exposure generated from within the building and from outside sources.

21. Avoid use of building materials that have elevated radioactivity levels.

Environmental Protection, Social Responsibility, and Energy Efficiency

22. Construction materials production and building processes shall provide for health and social well-being in every phase of the building's life-cycle.

23. Avoid the use of building materials that deplete irreplaceable natural resources or that are harvested in an unsustainable manner.

24. Minimize energy consumption throughout the life of the building, utilizing climate-based and energy-efficient design, energy-and water-saving technologies, and renewable energy.

25. Consider the embodied energy and environmental life-cycle costs when choosing all materials used in construction.

When the 25 principles are applied, it has been our experience that the resulting biological home fills most North Americans with awe and delight—and most Europeans with a nostalgic longing for home.

Green Building and Our Health

In North America, our need to build healthier buildings is a more recent concern and has made some headway as a subsection of a green building movement. As awareness of human impact on planetary ecology grows, it has become increasingly evident that we need to consume less. North Americans are notorious for consuming far more than their share of the planet's resources, and the operation of our homes and workplaces are by some accounts the single most important focus for decreasing our impact. The green building movement has become a major force, with a multi-faceted focus on the ecological impact of our buildings, including the negative impact that conventional building has had on our health. Many people in the building industry have worked hard to come up with systems for assessing the "greenness" of a building. Health is one small subcategory of the green building agenda, but to those who have become chronically ill from their living and work environments, a healthy environment is the single most important and most elusive thing they seek.

The green building movement has developed its own scorecards to evaluate success; there is almost always a section on these scorecards for "indoor environmental quality," which requires or rewards a dependable supply of fresh air and reductions in the use of toxic substances. But is this enough to lead to buildings that deeply nurture us? The main emphasis in the green building movement is to create more energy-efficient homes by making improvements to the light-frame construction techniques that are the product of a uniquely North American building industry. Unfortunately, a "green" home certification is not a guarantee that a home will support the optimal health of its occupants.

CREDIT: REINHARD KANUKA-FUCHS

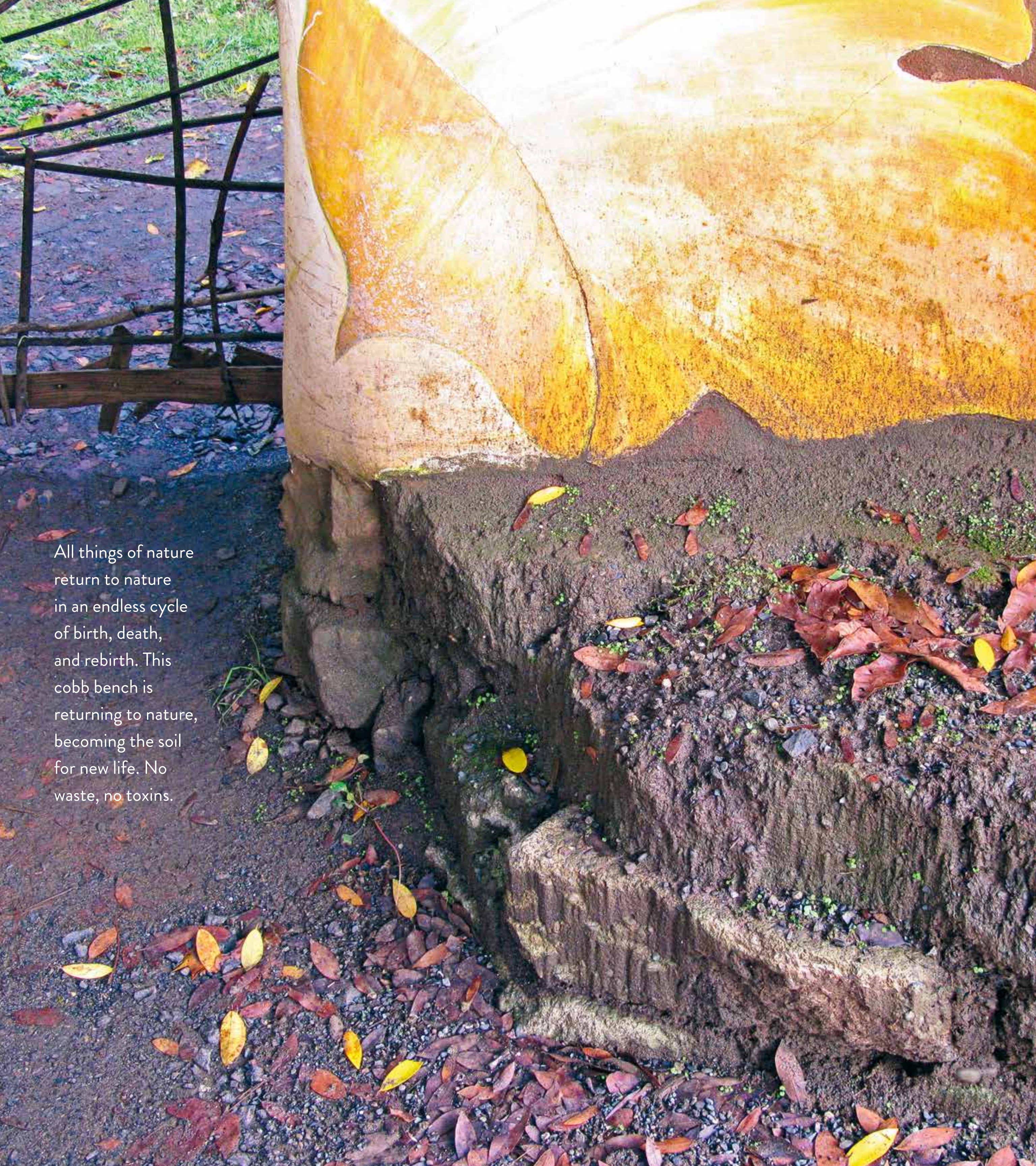
Building Biology sees the building envelop as our third skin. You wouldn't let your child play in a plastic bag. Why house them in one?

While some of these Building Biology principles parallel and precede criteria used in various green building evaluations, others do not mesh well with our common building practices in North America and demand a re-examination of the core values of conventional light-frame construction. Understanding the Building Biology principles and the emphasis placed on vapor diffusion, safe electro-climate, inclusion of thermal mass, etc., gives insight as to why our light-frame methods of building are so fraught with problems that often lead to envelope degradation from moisture intrusion and (simultaneously) to occupant health issues. They also explain why biological buildings feel so comfortable and peaceful to be in.

The Third Skin Concept of Building Biology

Building Biology considers the envelope of a building to be analogous to our third skin, clothing being the second. Our own skin is our largest organ. This miraculous surface is our interface with the environment and is in constant interaction with it. Our skin is able to shapeshift—creating goosebumps when we are cold in order to form tiny pockets, trapping air for insulation. Skin is permeable, but on its own terms. We can take a leisurely soak in the tub without gaining an ounce, yet when our bodies are too hot, we freely perspire to create evaporative cooling. Anyone who has seen the James Bond movie *Goldfinger* knows what happens when a body is completely covered with a non-permeable substance. In the case of Goldfinger's young and beautiful but unfortunate victim, it was a thorough seal of gold paint that was her demise. She died because her skin could no longer regulate her body temperature. We can thrive only when our skin is able to mediate conditions between the outer world and our inner metabolism.

Similarly our third skin, the walls of our home, must mediate between the indoor and outdoor climate. Here too permeability is directly related to longevity, and Building Biology advises us to build an interactive and permeable skin free of vapor barriers.



All things of nature return to nature in an endless cycle of birth, death, and rebirth. This cobb bench is returning to nature, becoming the soil for new life. No waste, no toxins.

Chapter 2

Applying the Principles of Building Biology to EcoNest

In our opinion, there are three misconceptions in the world of conventional construction that have allowed our culture to develop a petrochemical- and product-based approach to construction. The first is that we are all-powerful—able to conquer nature through chemistry, creating synthetic building products that can successfully hold her at bay indefinitely. The second is a belief that we have been successful enough with the first approach to continue using it as the model to improve upon, in order to achieve sustainability. The third (ironically) is a belief in our relative insignificance. It is only by falsely imagining our impact on the planet to be infinitesimally small that humans could ever sanction the use of construction materials such as foams and hazardous chemicals destined to become harmful, persistent landfill.

> *Our ancestors, when about to build a town or an army post, sacrificed some of the cattle that were want to feed on the site, proposed and examined their livers. They never began to build…in a place until after they had made many such trials and satisfied themselves that good water and good food had made the liver sound and firm.*
>
> —Vitruvius, Roman architect circa 20 BC, *The Ten Books on Architecture*

Building Biology reminds us that all things of nature return to nature. Ideally, our homes, too, should be biodegradable and return to nature, once their useful life has finished, taking their rightful place in the grand cycle of birth, death, and rebirth.

Bio-degradability does not mean that a natural earthen home has to have a short lifespan. On the contrary, natural homes with origins pre-dating the European discovery of America thrive throughout the world. This is a testimony to the longevity that is achievable when natural materials are combined with an intrinsic understanding of the natural forces that play upon them.

Site Selection

Before deciding where to build, our ancestors and their ancestors before them paid close attention to the site to determine how well it would support their health and well-being.

Romans slaughtered their cattle and examined the organs looking for guidance; the ancient Indians, being more kindly disposed toward cows, simply observed their behavior. If cows, left to graze on the potential site, grew amorous, this was one good sign. The Vedic scriptures prescribed a whole roster of additional tests for evaluating a site including the taste, color, and smell of the soil, the sound of the ground when tapped, and the health and species of the vegetation. Far from superstition and ritual, these tests evaluated important attributes of a site including fertility, compaction, water flows, and presence of soil gasses.

Building Biology also pays close attention to the health qualities of natural site conditions and advises us to avoid building over *geopathic stress zones.* These zones are caused by disturbances under the earth's surface such as ore bodies, crevices, and underground water and can result in anomalies in the geomagnetic field emanating from the earth. Measurable surface characteristics associated with these underground features include deviations in the earth's magnetic field, increased electrical conductivity, and increased radon. Geopathic stress zones have been associated with weakened immunity in individuals who sleep over them. Observations of flora and fauna on a site can indicate the presence of geopathic disturbance. Cancerous growth on trees or a group of trees that lean away from a spot and evidence of lightning strikes can all be indicators. Animal behavior may also be indicators. Dogs tend to avoid areas of geopathic disturbance while cats and ants tend to gravitate to them.

PRINCIPLE: *Verify that the site is free of naturally occurring health hazards.*

Although dowsing may be considered to be unscientific, mankind has a long history of dowsing as a form of site investigation. Aside from a human dowser, there is no single instrument that can measure all of the physical parameters associated with naturally occurring geopathic stress zones. However, a geomagnetometer is an instrument that measures direct DC magnetic fields and can be used to detect anomalies in the earth's magnetic field that are indicative of geopathic disturbance.

Modern-Day Siting Concerns

Unfortunately, the health consequences from the natural conditions of almost any site pale in magnitude when compared to potential hazards created by humans. But choosing the right site is the first step in creating a healthy home. Listed below are some guidelines to consider for selecting your home site.

- Investigate water quality in the area.
- Choose a location where the air is relatively unpolluted. If you are living in an urban setting, this will be challenging. By carefully selecting and nurturing the plant community on your site, you will be able to use nature to help create cleaner air. Depending on your location, you may need to consider whole-house mechanical air filtration as well.
- Crest locations generally have better air quality and more air movement than valley sites.
- Determine the direction that prevailing winds blow and how they change seasonally. Consider what is upwind from you.

A cow to us, but for our ancient ancestors this doubled as a state-of-the-art site evaluation instrument. Observation of animal behavior has been used in many cultures to discover the health of a site for human habitation.

CREDIT: PAULA BAKER-LAPORTE

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Building Biology calls for placement of dwellings so occupants are undisturbed by sources of man-made air, soil, water, noise, and electro pollution.

- Evaluate levels of light and noise pollution.
- Avoid industrial areas, power plants, airports, agricultural lands with heavy pesticide use, and other major pollutant producers.
- Avoid proximity to high-voltage power lines, microwave relay stations, and cellular phone and broadcast towers. In general, one-tenth mile from high-voltage power lines and one-half mile from microwave cellular and broadcast towers is adequate.
- Avoid sites adjacent to parking lots and traffic corridors.
- Analyze your neighborhood in terms of present use and future development. How are nearby empty lots zoned? Do the neighbors use pesticides? Is there substantial smoke pollution from wood stoves and fireplaces in the winter?

You don't have to figure this all out by yourself. There are consultants who can work with you to help you in this holistic analysis of your site.

Resources:

- *A geotechnical engineer* can determine the bearing capacity of your soils.
- *Local zoning and planning departments* or *consultants* will have information about building restrictions and current and future potential neighborhood developments.
- *A permaculture expert* can offer insight into the natural patterns and flows of your site.
- *Public utilities* provide free site measurements for background magnetic field levels. Ensure that measurements are taken at a time when power lines in the area are operating at peak load, or have the magnetic field calculated based on peak-load projections. Utility companies should provide this information in writing.
- *A building biologist* can measure other EMR (electro-magnetic radiation) site impacts.

- *A dowser* can find a well location and potential geopathic stress zones.

Once you own a site, there are many design strategies that can enhance the property so it extends your living space, grows your food, filters your air, surrounds you with pleasant sounds, sights and smells, collects your water, and provides a sanctuary for a diversity of benign wildlife.

Using Natural Unadulterated Building Materials

In 1990 Robert went to Europe in his quest for a natural building system with which to enclose his timber frames. He was seeking an eco-friendly replacement for the pressboard and petro-foam panels known as SIPS (structural insulated panels). He took along some samples of good Iowa clay. Not being familiar with foreign travel, he decided that he should bake the clay to "sanitize" it. Once there, he had an audience with Hugo Huber, a leading world expert on clay construction, who scrutinized this sample with great disdain. "This is dead," he said. Robert then remembered that he also had a little sample of raw clay that he had scraped off the side of the road on an impulse, en route to the Iowa airport. Upon being offered this second sample, Monsieur Huber's eyes twinkled as he indicated that this clay was of the finest quality. This was Robert's first lesson on the value of "unadulterated" building materials and an insight into why the European founders of Building Biology have this as one of the principles of healthy building.

CREDIT: JACKSON PORRETTA

A living wall of natural unadulterated straw/clay. As the wall dries the sprouts die, indicating that the walls are ready for plaster.

We have a cultural obsession with improving upon nature, often without considering the consequences of our actions. In the case of clay, baking it destroyed many of its natural properties. It transformed it from a material with great abilities to handle atmospheric moisture to one that was vitrified and impervious. It turns out that this *hygric buffer capacity* (the ability to take on and then release moisture as atmospheric moisture levels fluctuate) is the secret to longevity for the historic earth-based buildings throughout Europe and Asia. It is the lack of this same capacity that has caused so many moisture problems in our light-frame construction in North America. Using raw clay also results in a building with fabulous acoustics, balanced electro-climate, healthy humidity ranges, and very low embodied energy, especially when compared to its baked alternative—the brick.

On that same odyssey to Europe, Robert had the honor of meeting Dr. Anton Schneider, one of the founding fathers of Baubiologie. When Robert asked him about the health and longevity of buildings, he gave Robert his simple answer gleaned from a lifetime dedicated to research. He said: "A home will be successful to the degree we use unprocessed natural building materials in its creation." Living in homes based on this principle over the past two decades, we have come to know this simple statement to be true and of great value.

Healthy Materials Selection

It is not complicated to build a home out of healthier materials. Building products without toxic chemicals have become more readily available as the housing industry responds to tougher regulations and consumer demand. However, the use of toxic substances in construction is still standard. If you want to avoid harmful chemicals in your new home, it is up to you to educate yourself and your design/build team about the proper materials to use and procedures to follow. You can also greatly influence the longevity and healthfulness of any home *after* you move in.

PRINCIPLE: *Utilize non-toxic building materials that have neutral or pleasant natural scents.*

- Use healthy products in your personal care, home cleaning, and laundry.
- Perform regular maintenance and repair.
- Practice integrated pest management rather than applying herbicides and pesticides.

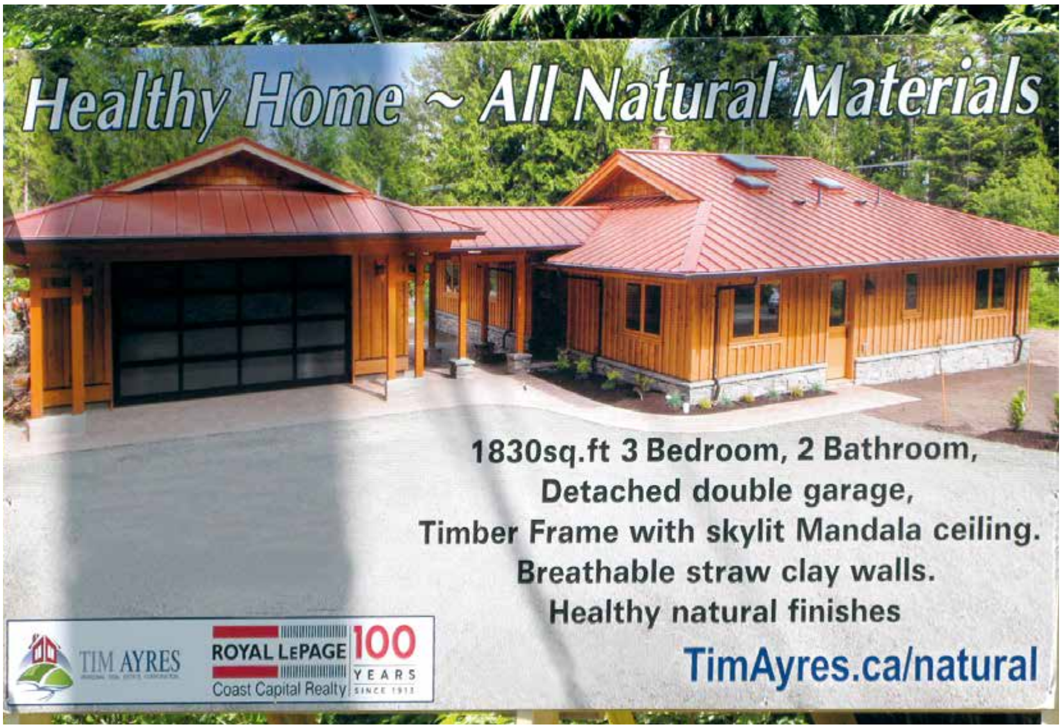
See Paula's *Prescriptions for a Healthy House* for a detailed guide to creating a non-toxic home. [Baker-Laporte, Elliott, and Banta, New Society Publishers, 2008]

Selecting Materials with a History of Use

In our fast-paced and ever-changing culture, we seldom have the luxury of making choices based on a long track record of success. This becomes quickly apparent in choosing building products. Paula recently called a major manufacturer to find out what was *in* a new product developed to prevent mold growth on framing lumber. She wanted to avoid the use of biocides for a chemically sensitive client. The rep said with great pride that the product had now been out for six months and that they hadn't received even one warranty complaint! Building Biology advises us to evaluate the history of building materials. The appropriate test of time, though, is not six months, but decades and centuries.

PRINCIPLE: *Construction materials production and building processes shall provide for health and social well-being in every phase of the building's life-cycle.*

Because the history of petrochemical-based products is brief, and they are produced by a handful of very large corporations, we must often put our trust in new products,



CREDIT: KEARY CONWRIGHT

Job sign of EcoNest affiliate Keary Conwright for a spec house. He felt that the real estate market was ready and that healthy and natural were qualities worth advertising. He was right!

expecting them to do what the manufacturers claim they will do. Time-accelerated lab testing can help us to project how a material may behave over time, but it is not an exact science, and nothing can surpass the real test of time.

New "smarter" products for building our homes are being invented all the time and, while advertising campaigns continually grind out tantalizing lists of benefits for the latest and greatest, the manufacturers are silent about the millions of homes that were built on yesterday's promises—those products that failed to become the "super endurables" they were initially advertised to be: waterproofing materials that have been conveniently renamed "water resistant"; construction tapes that lose their "stick" over time; foams that get tunneled by insects; insulations that shrink away; products that leach chemicals; and so-called harmless chemicals that were later found to be harmful.

CREDIT: ROBERT LAPORTE

Now over 800 years old, this building of clay, straw, timber, and lime wash will be completely biodegradable at the end of its long life.

In contrast, the pre-industrialized buildings that populate the old world, intact and serving for centuries, are the product of thousands of years of building evolution that preceded them. They represent holistic systems that were perfected for their local climate, from their local resources and by their local craftsmen. They are made of natural non-proprietary materials, and they have successfully weathered the test of time. They embody the principles of sustainability by their very nature. This valuable heritage of accumulated wisdom is little understood or acknowledged in current North American building, and it has become the precious baby that got thrown out with the bathwaters of industrialized building assembly.

Many of us who have embraced natural building have found that, contrary to what manufacturing interests would have us believe, we can not only use time-tested materials and traditional craftsmanship to build our homes, we can create enduring spaces that nurture us, nurture the environment, and serve our modern lifestyles well. We can still build buildings that will pass the test of time if we learn from the past and heed our future. In the words of the famous architect Frank Lloyd Wright: "Study Nature, love nature, stay close to nature. It will never fail you."

Natural Climate Control

In the quest for more and more energy efficiency, conventional buildings are sealed tighter and tighter, while lightweight insulation values are increased. As a result, it's now necessary to provide mechanical air exchange so that the humans within these sealed buildings can maintain health. In the process of "technologizing" our buildings, we have become overly dependent on mechanical strategies, using them as a form of critical "life support" and creating buildings that cannot function without them.

We have the opportunity to benefit from the best of what technology has to offer without dependency on it. By combining the prudent use of mechanics with natural built-in interactive climate controls, we can achieve comfort, health, and energy efficiency. These natural built-in features come with lifetime

PRINCIPLE: *Minimize energy consumption throughout the life of the building, utilizing climate-based and energy-efficient design, energy- and water-saving technologies, and renewable energy.*

warranties and assure us that our buildings can function silently and comfortably—even if the power fails and long after their automated mechanical counterparts have become landfill artifacts.

At the time of this writing, we have built EcoNests in 17 states and four provinces

CREDIT: CATHERINE WANEK

South-facing sun bump, earth-coupled floor mass, mass walls, and ample cross ventilation all work together to create a home that creates four-season comfort with very little mechanical intervention.

in Canada. Although these climates range from mild to extreme, they are all part of the temperate climate zone characterized by four seasons, cold winters, and hot summers. *None* of the EcoNests have mechanical cooling or ducted heating. They provide for, and welcome, owner interaction with the natural environment in the creation of a comfortable indoor climate.

Re-evaluating R-value

When approaching new-building departments—which usually have an orientation and understanding of building performance based on lightweight conventional construction—the first question we are asked is "What is the R-value of a light straw clay wall?" The envelope walls of an average EcoNest weigh approximately 20 tons. The R-value (insulation value) of a 12"-thick wall will vary depending on density but will be average, not spectacular—roughly equivalent to that of conventional home with six inches of fiberglass insulation. But the mass and insulation in a light straw clay wall form a dynamic partnership that works synergistically to create high performance and comfort that is "off the radar" of most energy analyses. Our data comes as a result of observation from over 25 years of living in our light straw clay (LSC) homes while visiting and comparing comfort levels in the conventionally built homes of our friends and neighbors throughout the seasons.

Although in the green building movement there is much emphasis placed on a home's R-value (thermal resistance, or the amount of insulation in the envelope), this is only one of many factors that will affect both comfort and performance of a home.

Natural climate-control strategies used in an EcoNest are well known to Building Biology but rarely implemented in conventional North American building. Strategically combining these elements results in a home with lower energy demands and an extremely nurturing year-round comfort. It can support optimal health, with only minimal reliance on fossil fuel-powered technologies.

This family of elements that we incorporate into the design for natural climate control includes:

- Thermal mass
- Radiant heat
- Solar orientation
- Size and shape
- Design and zoning of room configuration (no need to heat unoccupied space)
- Passive climate controls including summer shading and winter solar gain
- Window and door size, placement, and operation
- Vegetation and landscaping
- Occupant education and behavior

Incorporating Thermal Mass into the Energy/Comfort Equation

Building Biology recommends a climatically appropriate balance between thermal mass and thermal insulation in order to achieve maximum comfort and energy efficiency.

Thermal insulation works by trapping small pockets of air within a matrix of insulating material; its purpose is to slow the movement of temperature through an envelope. Fiberglass, spray foams, mineral wool, and natural fibers are all options for providing thermal insulation.

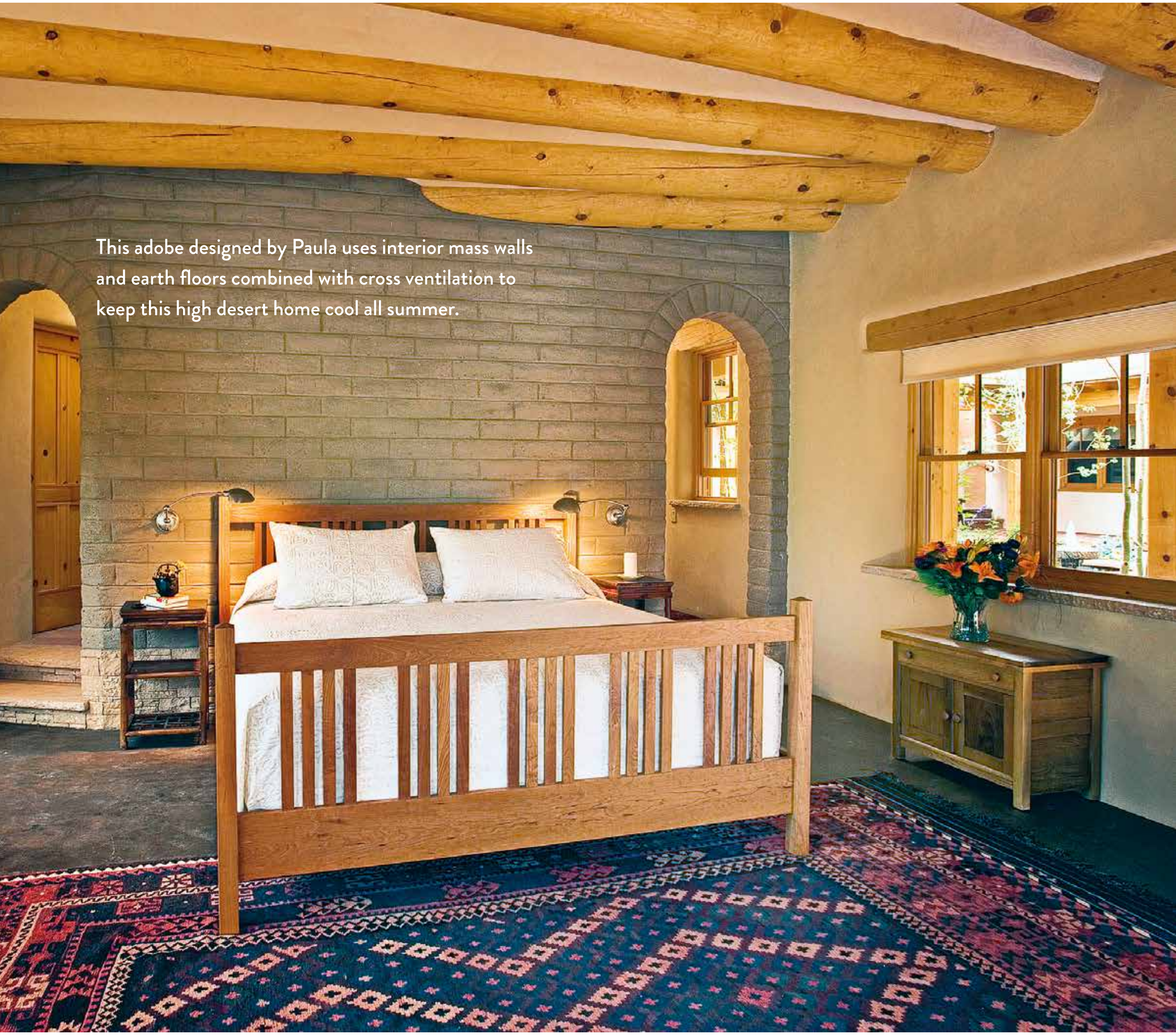
PRINCIPLE: *Design for a climatically appropriate balance between thermal insulation and thermal storage capacity.*

Thermal mass is heavy, dense material that acts like a "storage battery" and serves as a buffer against temperature fluctuation. Materials such as adobe, brick, clay, stone, and water can be incorporated into buildings to improve thermal mass storage capacity. The perfect balance of mass and insulation will vary, depending on the climate.

In the tropics, thermal insulation is far less important than in cold climates. In a desert, where there are large daily temperature swings, mass in the building envelope is very effective in buffering these swings. It can slow down the temperature movement, creating a flywheel effect so that it heats the

The large roof overhang shades the walls in summer and creates a covered walkway around this yoga studio.

CREDIT: PAULA BAKER-LAPORTE



This adobe designed by Paula uses interior mass walls and earth floors combined with cross ventilation to keep this high desert home cool all summer.

CREDIT: ROB RECK

interior at night and cools it during the day. In extremely cold climates, the insulation in the thermal envelope is of primary importance. Thermal mass on the inside when combined with radiant heat will further enhance comfort levels.

Mass and insulation are both important in the temperate climate zones and act together to achieve maximum results.

Conventional construction is based on lightweight materials that are centrally manufactured and must be transported great distances. The typical finished home contains relatively little thermal mass as a result. Because mass wall construction is not standard, it is "under-valued" and not rewarded in most of the popular green building rating systems, which are meant to incentivize improved conventional construction. But the occupants of homes with plenty of thermal mass are rewarded daily in terms of their comfort. A thermally massive home will remain cooler in the summer, especially in climates with a diurnal temperature swing. In winter, a home with a combination of mass and radiant heat will maintain a constancy of temperature and comfort. (See "Healthy Heat" below.)

Natural Heating and Cooling Strategies

Healthy Heat

When it comes to cozy, nothing beats the presence of a toasty fire. The deep, penetrating radiant heat, dancing flames, and crackling roar delight our senses. Having a relationship with this powerful element evokes a deep sense of home. The hearth is the heart of home. This is why so many homes have a fireplace, even though most produce very little heat and lots of smoke pollution. But there *is* a way to have

PRINCIPLE: *Use appropriate thermal radiation strategies for heating buildings, including passive solar wherever viable.*

CREDIT: PAULA BAKER-LAPORTE

A Tulikivi masonry heater is centrally located in this high desert home. It contributes 5,800 pounds of mass to the center of the home contributing to a comfortable climate in winter and summer.

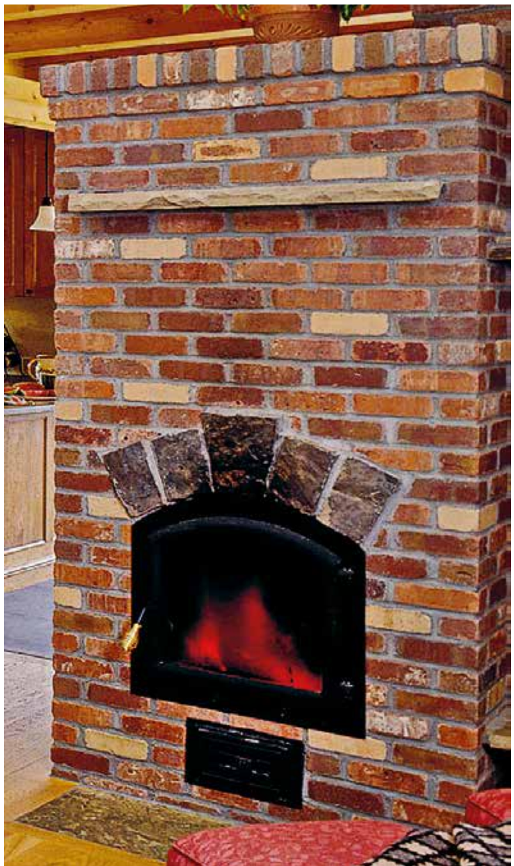
it all—the romance of fire, optimum health, and energy efficiency. Our favorite way to heat an EcoNest is with a radiant heat source called a *masonry heater*.

Northern Europeans experienced their first energy crisis in the 13th century, when it became evident to our ancestors that their fuel supply was not endless and that, in fact, they would soon be shivering in misery if they did not curb their rapid consumption of the remaining forests. This is when the evolution of the masonry heater began. The German Kachelofen, the Finnish Tulikivi, the Swedish Kachelung, the Russian stove—each country invented a way to provide efficient, healthy home heat with a sustainable use of wood fuel. These heaters have continued to serve Northern Europeans generation after generation—with pyro-wisdom, passed down and perfected over a 700-year evolution.

The masonry heater uses the principles of full combustion, contra flow, thermal mass storage, and increased surface area to maximize efficiency and minimize pollution. The heated mass continues to radiate warmth for many hours after the fire is spent. From a Building Biology perspective, this is ideal heat.

CREDIT: TULIKIVI

Cutaway of a Finish, Tulikivi Masonry heater, showing how fire is fully combusted while circulating through the internal chambers in a contra-flow pattern to a flue opening in the bottom of the unit. Heat is stored in the very dense soapstone walls and then re-radiated into the living space for many hours. Smoke pollution is only a fraction of EPA limits, and no more carbon is put in to the atmosphere than the same amount of wood, left to rot in the forest, would release.



CREDIT: LAURIE DICKSON

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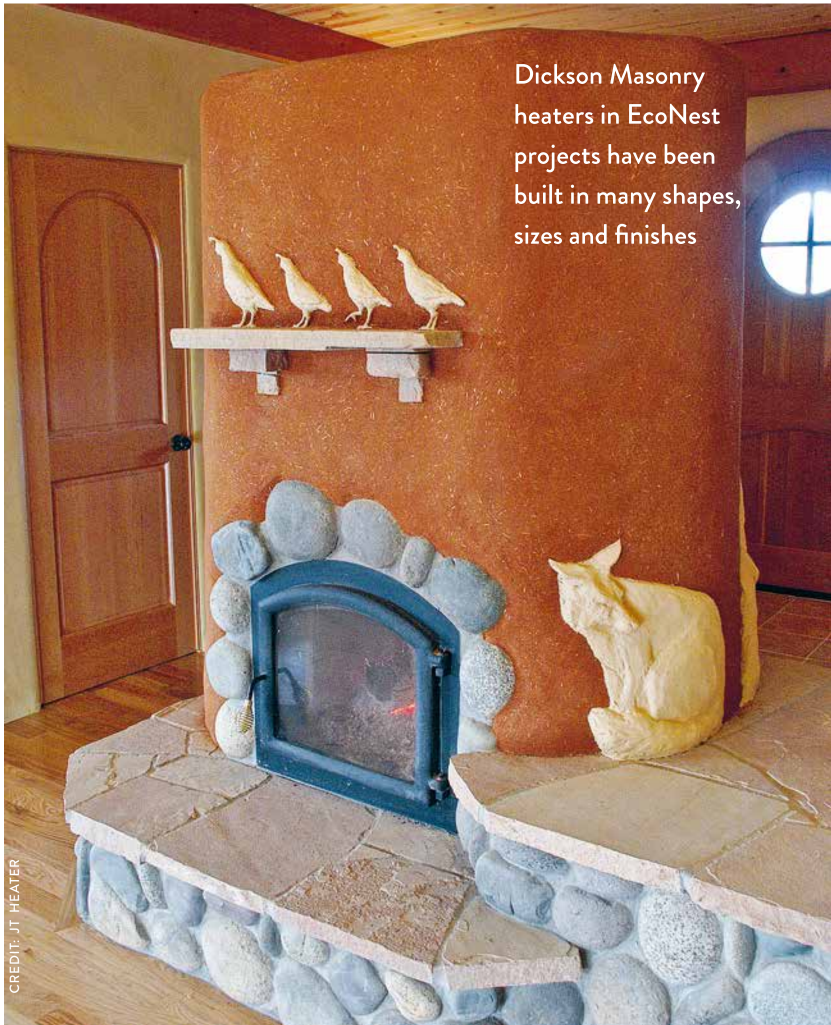
CREDIT: LISL DENNIS

CREDIT: SUSAN GLAZER



CREDIT: JT HEATER

Dickson Masonry heaters in EcoNest projects have been built in many shapes, sizes and finishes

Building Biology, using nature as the gold standard, has deduced the qualities of ideal heating for human health and planetary ecology. Consider how nature heats us. The sun is our renewable source of radiant heat. Life on Earth is possible because that heat is stored in the mass of the Earth, sustaining us through the night and the winter. It is because radiant energy heats bodies, and not the air, that we can be comfortably warm on a sunny day, even when the surrounding air is cool.

Here are the qualities of a healthy heating system:

- Provides radiant heat that warms bodies, not air.
- Uses mass storage to buffer temperature swings. (In nature, this is the mass of the Earth.)
- Is free of toxic combustion by-products and fried dust.
- Maintains a natural ion balance.
- Uses a renewable fuel source.
- Maintains a constant temperature from head to foot.
- Provides healthy temperature variation at different locations.
- Is quiet.

Compare these criteria with the characteristics of the most common form of home heating in North America, forced air, and you will understand why this form of heat is far from ideal for our health and comfort.

- Forced air heats by convection. It heats air, not bodies. Air, being a natural insulator, is an inefficient medium.
- Forced air does not radiate or get stored in mass for temperature buffering.
- Furnaces (unless direct vent) can release toxic by-products of combustion into the building envelope.
- Furnace elements get hot enough to "fry" dust.
- Negative ions cling to ductwork as air circulates through them, depleting the electro-climate in the home.
- Ductwork is often leaky, dirty, hard to access, and hard to keep clean.
- Heated air rises, and the air tends to be warm on the head and cold at the feet.
- Forced air contributes to noise pollution with its blowing air and cycling motors.
- Forced air is dry, and humidification of central air often leads to ductwork mold.

Ideally, a gentle hydronic radiant heat would be located in mass walls in the interior of the home. Along with a variety of masonry heater options, Europe has commercially available systems for in-wall hydronic heating with specialized blocks designed to house heat tubing, and built-in mass to store the circulating heat, providing gentle, even radiation. We, unfortunately, do not yet have such systems readily available in North America.

Most EcoNests are equipped with hot water radiant tubing in the floors for back-up heating, and they are "zoned," so that the system can be used only where needed. We have found in our own homes that between the passive solar collection from the sun bump (discussed below) and our masonry heater, we are able to comfortably heat a home without the radiant tubing. We use our in-floor heating only as a pampering supplement in the bathroom or as a back-up system to keep the house at a minimal safe level if we are gone for an extended time in winter.

If you have the opportunity to build from scratch, you owe it to yourself to experience the comfort of radiant heat combined with thermal mass walls.

Sun Bump

In an EcoNest, a large roof overhang protects the straw and clay wall system from the elements. To enable a "sun bump" heating effect, we often project a glass portion of our south-facing wall to within 14–20" of the roof edge. With the overhang properly sized for latitude, it will block summer sun but allow the glazing to collect the sun in the winter to help heat the home. The interior side of the sun bump can be designed differently to adapt to various micro-climates and owners' lifestyles. For example, it makes a wonderful spot for a window seat with storage below, or it can be used as a greenhouse area for plants.

CREDIT: JONATHAN SHAW

The sun bump projects out under the large roofhang to within 18" of the roof edge, the right distance for this structure at this location to invite in warming sunlight in the winter and provide shade in the summer when the sun angles are higher. A wide black granite sill absorbs heat and makes a perfect home for plants.

Cooling

Although mankind has been tempering interior environments with the addition of heat for thousands of years, the species somehow managed to survive without the wide use of mechanical air cooling until the past 60 years or so. With standard lightweight frame construction, there is rarely consideration for design or orientation, and air conditioning has become so commonplace that many environmental score cards will penalize a building that is designed *without* mechanical air conditioning, even if it is unnecessary. Some climates are too hostile to support natural climate controls and still meet the parameters of temperature that North Americans have come to expect. Historically these were the areas of the country that had

CREDIT: ROB RECK

Flagstone floors will transmit the coolth from the constant ground temperatures in this high desert adobe. In the winter, radiant heat tubing embedded under the floor will provide comfortable warmth.

a very small, rugged, population base. That changed with the affordable availability of air conditioning. For decades, low electrical costs have allowed home designs throughout North America to ignore the natural climate and assume an endless supply of cheap electricity to create thermal comfort.

For example, Phoenix, Arizona—which has average July night-time lows in the 80s, and 110 days a year of daytime temperatures exceeding 100°F—had a population of just 107,000 in 1950. This jumped to 1,159,000 by 1996, mainly due to the availability of cheap air conditioning.

In the EcoNest, we employ four major design strategies to help keep our homes comfortably cool without mechanical air conditioning:

1. Large roof overhangs, trellises, and plantings shade the walls throughout most of the day. The overhang above our solar bump is sized so that the majority of summer sun misses the windows.

2. Mass exterior walls create a flywheel effect so that the walls slowly transfer heat gained during the day and radiate it into the home once the outdoor temperatures cool down. The cool night air slowly cools the massive walls which radiate "coolth" during the heat of the day.

3. Ample cross ventilation and interior mass walls allow the occupant to open the home up at night and move cool air through the building, storing it to provide thermal comfort in the heat of the day.

4. On-grade floors take advantage of the constancy of earth's temperature (a technique called *earth coupling.*) In hotter climates, we tend to use floor materials that transfer coolth through their mass—like stone, earth, or ceramic—while in colder climates, wood and cork are better choices because they are more insulated.

PRINCIPLE: *Plan for climatically appropriate surface and air temperature.*

How comfortable? This begs the question as to whether constant temperature 24/7/365 is the ultimate goal. We believe that some temperature range is healthy and have observed that people who are adapted to temperature range are more comfortable in a variety of conditions. Certain climates are easier to control naturally. Hot, dry climates with large temperature swings from day to night do very well with this combination of mass and air movement, whereas hot/humid climates that have very little drop in night-time temperatures are much more challenging. Having lived without air conditioning, we personally find cold, dry, blowing air to be uncomfortable and noisy in any climate and the constant transition between mechanically cooled spaces to the natural climate to be very unhealthy. By designing a variety of spaces for indoor and outdoor living, we not only extend the available area for living, we provide a greater range of options for comfort in various climatic conditions.

Natural Cross Ventilation

How much fresh air is necessary to maintain our health? The truth is that no one really knows, and the amounts are going to vary tremendously with the number of occupants, their activities, and the presence or absence

PRINCIPLE: *Provide for ample ventilation.*

of outgassing chemicals. Arbitrary standards have been set, and new regulations are in place to ensure that air exchange occurs in homes.[2] One way this is being done is with the Heat Recovery Ventilators (HRVs) that are becoming more and more commonplace and are even mandatory in some states. These mechanically operated devices provide a set amount of air exchange through ductwork into the home while tempering the incoming air stream with temperature exchange from the outgoing air.

Cross ventilation allows the cooler night time temperatures to flow through this bedroom and cool the mass walls and earthen floors.

CREDIT: JONATHAN SHAW

Although we have no objection to providing fresh air, and acknowledge the usefulness of a regular, tempered supply in harsher climates, we must point out that air traveling through ductwork, propelled through a motorized device, is not quite the same as, or a substitute for, fresh air on demand. Mechanical systems use energy, and sooner or later they break down. For much to most of the year, in most of the country, well-placed operable windows and human participation works incredibly well. The same combination also works reliably should the power fail or the automated mechanics break down (which is often unbeknownst to the occupants until there is a serious health or moisture problem). We believe that a home should provide for self-sufficiency and occupant empowerment. Incorporating good cross ventilation is a strategy that will operate long after the HRV has died.

We have discovered that, in a home heated by radiant heat with mass walls, windows can be opened and air exchanged, even in winter with very little drop in temperature or loss of comfort.

Internal Mass for Thermal Comfort, Acoustical Balance and Hygric Buffering

Adding earthen mass to the interior of the home has contributed to the comfort, sound attenuation, and atmosphere of many EcoNest homes. We have used three building

Marguerite Wilson's interior adobe wall provides sound proofing between her breakfast area and her bedroom on the other side of the wall. The mass adobe will soak up the heat radiated from her wood stove and re-radiate it back into bedroom and breakfast area long after the fire is out.

CREDIT: PAULA BAKER-LAPORTE

PRINCIPLE: *Provide adequate acoustical protection from harmful noise and vibration.*

techniques to add interior mass: adobe, wattle and daub, and unfired bricks. High density interior walls also offer acoustic privacy between rooms, and, if unfinished or finished with sorbent finishes, will create ideal acoustics within spaces. In combination with a radiant heat source and proper window placement for both solar heat gain in winter and cross ventilation at night in summer, these walls can store heat or coolth as needed and have a built-in (fossil fuel-free) moderating effect.

Maintaining a Healthy Indoor Climate with Natural Finishes

The ideal relative humidity range for our health, according to Building Biology, is somewhere between 35 percent and 55 percent. In modern life, we have introduced many new sources of moisture into our homes. Daily showering, laundry, cooking, and dishwashing tend to create concentrated bursts of moisture. Conventional construction can tolerate very little increase in humidity without condensation and resulting mold problems.

PRINCIPLE: *Allow natural self-regulation of indoor air humidity using hygroscopic (humidity-buffering) building materials.*

At the same time, most heating systems tend to make the air too dry for optimum health, so during the heating season supplemental moisture is required. The conventional solution is to add humidity mechanically to one part of the home while sucking it out mechanically from another.

The Building Biology solution is to work with natural materials to help maintain a balance. Certain building materials such as unfired clay, wood, and natural fibers have the ability to naturally regulate indoor humidity—provided they are not sealed with impermeable finishes. They can effectively capture humidity when the levels are too high and then release it again once the ambient levels drop, thus buffering the extremes and re-creating a natural humidity balance. This explains one aspect of the value of using natural, unadulterated building materials, finishes, and furnishings. Although we still provide mechanical ventilation, it is supplement and not a dire necessity for the health of a home or its occupants. Naturally hygroscopic materials and operable windows are built in and always available.

PRINCIPLE: *Utilize non-toxic building materials that have neutral or pleasant natural scents.*

There is a trend in conventional construction to make everything impervious for ease of cleaning and maintenance. Surfaces are covered with a thin layer of plastic in the form of various types of acrylic and latex paints and sealers. These wet-applied finishes were once a great source of indoor pollution, but there are now many choices for low or zero VOC (Volatile Organic Compounds) synthetic finishes. Although with careful selection it is now possible to apply synthetic finishes without releasing poisonous gasses, there are a number of subtle consequences to consider when coating large surface areas of our home's interior with synthetic films. These include:

- an imbalance in the electro-climate, which manifests in frequent electric shocks.
- reflective surfaces that have a negative impact on the acoustics and can create visual glare.
- a loss of hygroscopicity, which increases dependency on mechanical installations for obtaining healthy humidity levels.

In EcoNest homes, we use natural finishes on natural wall and floor surfaces. These include unsealed clay plasters on the wall and natural waxes and oils on wood surfaces and on our earthen floors. We avoid any finish where a finish is not necessary. For example, where we have wooden ceilings or timber frames, we leave them unsealed. The benefits of natural finishes are not just visual appeal, they also include great acoustics, natural humidity balance, no electro-shocks, and abundant balanced ions. More maintenance…yes.

CREDIT: ECONEST CO.

Cherry cabinetry is finished with a natural "breathable" oil, *Block Brothers.* Maple floors are sealed with a natural oil by *Rubio*, while timber frame and ceiling woods are left unsealed.

We occasionally re-oil sills or cabinet faces, but for us, the quality of life that these natural finishes reward us with daily is well worth our extra efforts. It is a lifestyle choice. Note: It is true that we have no grandchildren to run around and spill grape juice on these more delicate surfaces!

CREDIT: PAULA BAKER-LAPORTE

Daylighting

Windows are the eyes of our home. We can welcome light, air, views, and meaningful connection to our natural surroundings through good window placement. Thoughtful

CREDIT: CATHERINE WANEK

Above right: An illuminated ceiling in the McGowan Residence. Light from attic skylight filters through a central "mandala." Transluscent panels have real leaves embedded in them. Right: Robert's light-filled shop in New Mexico never required additional electric lighting during the day.

PRINCIPLE: *Provide an abundance of well-balanced natural light.*

window placement can contribute to a sense of well-being while providing good natural day lighting and reducing dependency on electricity. Energy savings and comfort are achieved when windows are placed to prevent overheating and facilitate cross ventilation and seasonal solar gain.

Designing a home that does not require artificial ambient lighting during daytime is a goal in every EcoNest design. In our single-story homes we use a light-filled attic with carefully placed translucent ceiling screens to create even, diffused light, thus gaining maximum light distribution from just a few skylights. We also design each room with natural light on at least two sides to eliminate glare and facilitate cross ventilation.

Light and Color in Accordance with Nature

Living indoors with smooth, uniformly painted surfaces and artificial light is a very recent phenomenon; environments with so little visual stimulation are deadening to our senses. It is no wonder that we find such solace in nature.

Building Biology calls for the use of light and color in accordance with nature. Nature creates incredible pattern, but never exact

CREDIT: PAULA BAKER-LAPORTE

Nature creates incredible patterns but never exact replication. Lively and ever-changing light patterns play out on the rich hue and color variations found in every natural object.

Celebrating natural color with mineral pigments, plant life and a variety of woods.

CREDIT: JONATHAN SHAW

PRINCIPLE: *Provide well balanced natural illumination and use color in accordance with nature.*

replication. Lively and ever-changing light patterns play out on the rich hue and color variations found in every natural object.

How can we introduce nature's vibrancy of color and light into the home? One very effective way is by choosing natural materials: stone instead of ceramic, wood instead of vinyl, earth instead of wall-to-wall carpeting, and naturally pigmented plasters instead of paint, to name just a few examples. The finishes of a home can be a celebration of nature, re-introducing her visual delights into our living environment.

A Healthy Electro-Climate

Of all of the health principles that Building Biology advocates, concern for the indoor electro-climate is perhaps the least understood or discussed. To our knowledge, there is not one green building evaluation scorecard in North America that even acknowledges this concern. Yet, as a healthy-building consultant,

PRINCIPLE: *Minimize indoor interference with vital cosmic and terrestrial radiation.*

CREDIT: PAULA BAKER-LAPORTE

This cast-away wooden fence post top from Bali becomes a treasure of texture, color, and history, especially when mounted against naturally pigmented plaster.

Paula has seen a very significant rise in people suffering from EHS (Electro-Hypersensitivity Syndrome) as a result of exposures to commonly occurring Electro-Magnetic Radiation (EMR), and mounting scientific evidence gives great cause for concern. Although the causes and forces at play are complex, there are simple things that we can do to create a healthier electro-climate within our homes.

- Before settling on a building site, have a site assessment done that measures man-made radiation levels and levels of elevated naturally occurring geopathic stress. (Look in the Resources section to find an expert and books on this topic.[3])
- Find out if *smart meters* (electronic meters used to measure a home's electrical usage and relay that information back to the utility company) are required and/or if there is an opt-out plan in effect in your area. If smart meters are required or in use by your neighbors, then consider a plan to shield your home.
- *Prescriptions for a Healthy House*[4] lays out simple protocols to follow during construction to ensure that household electricity does not create elevated fields. It also lays out special wiring procedures for bedrooms so that the electricity to them can be turned off at night.
- Hardwire your home so that wireless transmissions are unnecessary or learn to shut off wireless broadcasters at night.
- Minimize indoor interference with vital cosmic and terrestrial radiation.
- Avoid use of building materials that have elevated radioactivity levels.

PRINCIPLE: *Minimize man-made power-system and radio-frequency radiation exposure generated from within the building and from outside sources.*

CREDIT: ECONEST CO.

The switch on top is a kill switch that turns off the electricity to the bedroom at night. The smoke detector is on a dedicated circuit and remains on. Creating a sleeping sanctuary that is free of man-made electro-magnetic interference is simple to do when building a new home.

We have found that thick earthen walls and metal roofs are quite effective in blocking most wireless transmissions from outside sources. In fact, we have experienced very poor cell phone reception inside our homes (to the dismay of some, and the delight of others!). Each of our new-home plans comes with a specification for household wiring and instructions for creating a special switch to turn off electricity to bedrooms at night. All of these efforts can be quickly negated if homeowners are not educated on the issues and behaviors necessary to maintain an EMR-free zone, at least during sleep time.


NORTH

CREDIT: ECONEST CO.

Chapter 3

Designing Your Nest

Initiating a Legacy

If you have always dreamt of living in a home tailored to your needs, your site, your values and aesthetics, then creating from scratch is a wonderful adventure—one that has often been compared to giving birth! For those who'd prefer to build an EcoNest home without the labor pains, we have created a series of stock plans. These can also be used as a starting point for a more tailored custom design process.

Working with a Design Professional

Making the most of this unique opportunity to create a home takes preparation and self-exploration. The more clearly you can define the home that you want, the better the tools you provide your design professional. Two types of information are needed. You might imagine this information being gathered in two types of books: a notebook and a scrapbook. Creating the notebook is a predominantly left brain, logical process, while creating the scrapbook is predominantly a right brain, creative process. Most people will find one of these tasks more challenging than the other. Often, we see couples balancing one another's strengths and weaknesses in the home-creation process.

The Notebook

The Left Brain: The left brain is the logical, quantitative, reasoning side that will help define the *functional* requirements for your home. So, your notebook would contain answers to questions like these:

- Are there covenants, architectural committees, homeowner's association, zoning or regional by-laws like height or size restrictions that will impact your design?
- What does the site require in terms of utilities, grading, and clearing?
- How many rooms do you need? What is their function and estimated size? Measure and note the size of the rooms that work for you currently. You may alter these as the design process unfolds, but this is a valuable starting point. Providing some actual rough measurements can prevent miscommunication between you and the designer. A "large closet" for one person could be a walk-in that is 5' × 5'; for another, a 10' × 10' closet would require drastic wardrobe reductions.
- What special requirements do you have? Examples are space for a sauna, handicap accessibility, grab bars (or preparation for their later installation), 220-volt outlets, a root cellar, or wine storage.
- Are there special objects or pieces of furniture that you want to make space for? Photos with measurements of these special pieces will help you and your designer to more easily incorporate them into the design. One example of an architect's nightmare (one that Paula actually experienced) is finding out after presenting the first round of design ideas that there was no room for the grand piano the client forgot to mention!
- Do you wish to include alternative technologies such as solar hot water or photovoltaics?
- What is your budget? You may need to meet with a lender to find out what you can borrow and an appraiser or real estate agent to find out what your current property is worth prior to beginning the design process. The design process is most efficient when it begins with a realistic budget.

The Scrapbook

The Right Brain: The right brain is the creative half. It will help you conjure the "feel" you'd like your home to have.

The right brain doesn't always function in full sentences. It is intuitive. It is qualitative rather than quantitative. It is where you dream. Invite it into the process of creating your home. Write prose or poetry, sketch, do flow diagrams…anything it takes to document the feel and qualities that you resonate with. For example, you might write, "I want a sunny, warm, cozy spot to curl up in on a winter's morning to read a book."

A useful exercise is to go through magazines, books, and specialty websites like houzz.com. Find images of spaces that inspire you—that open your heart and create a longing to live in such a space. Collect not just spaces, but also details that appeal to you. Don't worry too much about analysis. Put them all in your scrapbook. After a while, certain clues will emerge. Your collection will show patterns of scale, color, lighting, surfaces, etc. This is a critical and informative first step.

Use your scrapbook to dream, but also be realistic. Don't scrutinize *Palaces from Around the World* if your goal is to build a humble ecological home! Look for inspiration from sources that inform *your* values.

CREDIT: ROBERT LAPORTE

Seminar attendees exploring spaces that they resonate with.

Phases of Design

There are three phases to designing a custom home:

1. **Preliminary Design Phase**

   During the preliminary design phase, you will present your designer with information that he/she needs to know about you, your site, your budget, your aesthetics, and your spatial requirements. Your designer will then present you with several preliminary sketches. Together, you will refine the plans until they feel "just right." This phase should be very open-ended and creative; it is best to take the time to savor the process. Visualize living in and "feeling" the spaces. Remember that it is far more cost efficient to refine drawings—especially at the preliminary phase—than it is to make changes once construction begins.

   For anyone not adept at visualizing space from 2-D drawings (i.e., floorplans and elevations), preliminary 3-D renderings can be a very valuable tools. These are drawings done in perspective so that you can see what the building would look like in three dimensions. These could be free-hand drawings or computer models. You may want to invest in getting your designer to provide these in addition to the floorplans.

   Schedule two to four months for this phase. If it's possible, we recommend an even slower pace—give yourself time to "digest" a design.

2. **Construction Drawing Phase**

   This is the most labor-intensive period for the design team. The construction drawings detail all the information for the permitting and construction of your home. From structural elements to light switches, the home is built on paper. As the design team is drawing, you will have the opportunity to choose finishes, appliances, fixtures, faucets, lighting, etc. During this phase, the design team will need your feedback and input as the design takes shape. This phase takes about two to six months, though it could take longer, depending on the scope of your project and the manpower available.

3. **Construction Phase**

   The design team and the builder will coordinate throughout the construction as your home goes from drawings and written specifications to the built reality. Should you choose to make substantial changes during construction, it is always prudent to have your designer present the builder with a revised, drawn proposal to get a price from the builder before proceeding. This process is known as a *change order.*

Making Choices

You will be called upon to make myriad choices in designing your custom home, including the selection of plumbing fixtures, faucets, lighting, surface materials, color, doors, appliances, and cabinetry. All of these design decisions will affect your health, budget, ecological impact, ease of maintenance, and the beauty and overall value of your home. When all is said and done, you will have placed your unique signature on the final product.

The process can feel overwhelming at times. It is not something that most people have the opportunity, training or occasion to do and, although your design/build team will be there to assist you, this is your opportunity to make your mark! There are several "filters" that can help you evaluate and hone your product choices.

Building Biology has 16 criteria for materials selection. These are:

1. **History of Performance:** Has this product been used with a history of success or is it the "latest, greatest"?

2. **Ecological Impact:** What is the impact on the environment during every stage of its production, transportation, installation, use, and post-use? Does choosing one product over another help support the local economy and/or local craftsman? How far away does this product come from?

3. **Embodied Energy:** How much energy was used from the time the raw material was derived from nature and then transformed into the product? What are the environmental costs to transport it? What are the environmental costs to maintain or operate it during its lifetime?

4. **Thermal Properties:** Is the product a good choice for your climate?

5. **Radioactivity:** Both man-made and natural products can have radioactivity associated with them. Examples include fly ash (in concrete), some granites, and some drywalls. What is the acceptable amount of radioactivity? Building Biology suggests: As Low As Is Reasonably Attainable (ALARA). Because radioactivity cannot be seen, smelled, or felt, it must be measured.

6. **Electrical Properties:** Besides the obvious wireless and electrical installations that can introduce a constellation of man-made electrical interference into our homes, there are other, more subtle disturbances that can distort the naturally occurring electro-climate. Some examples include metal springs in mattresses, which can alter the DC magnetic fields, and "plastic" surface coatings, which can alter the DC electric balance because negative ions can cling to them.

7. **Moisture Content/Drying Time:** If wet materials are to be selected, is there a plan for drying them out so that they do not create damp conditions in the occupied home?

8. **Natural Occurrence:** Building Biology gives high value to products that are *minimally* processed from their natural state.

9. **Acoustical Properties:** Will this product be reflective, causing echo and sound distortion, or will it help to absorb sound—making a pleasant and stress-free acoustical environment?
10. **Microwave Permeability:** Will the product emit harmful microwaves inside the home? Will it assist in blocking man-made EMRs from outside installations that are now ubiquitous?
11. **Diffusion:** Diffusion is the ability of molecules to travel from the area of highest concentration to lowest. Is the substance/product vapor-open, allowing molecules to flow freely through it, or will it trap moisture, causing condensation and mold?
12. **Hygroscopicity:** Can this product absorb and hold moisture without harm, and then re-release it into the atmosphere when conditions change, thus contributing to healthy humidity levels?
13. **Sorption/Regeneration:** A few materials have the ability to take toxins out of the air and transform them, actually helping to clean the air. These include certain plants, certain naturally occurring minerals such as clay and zeolite, certain essential oils, and some specialized titanium dioxide formulas. What a gift these are for our indoor environments!
14. **Toxicity:** Will this product release unhealthy VOCs (Volatile Organic Compound) or SVOCs (Semivolatile Organic Compounds) into our home or at any stage of its manufacture and installation?
15. **Smell:** Building Biology advises us to select only substances with a neutral or naturally pleasant smell. The nose can be a very powerful ally in making healthy selections.
16. **Skin Resistance:** Electrodermal testing uses instrumentation that can test subtle changes to the electrical response of a person's skin as a result of an extremely low level of exposure to a particular substance. This type of non-intrusive diagnosis, although available in North America, is more popular in Germany. Paula often relies on such information when working with very chemically sensitive clients who could become ill if they had to sniff-test every material in order to determine if it was safe to use in their home. People with MCS (Multiple Chemical Sensitivities) can have negative reactions to chemical exposures that would normally be undetectable to others, and sensitivities vary considerably from one person with MCS to the next.

Beyond these 16 valuable criteria, we add the following:

1. **Budget:** Everyone has a budget! For every beautiful tile, for every good appliance, and for every fine door handle, there is another, even more beautiful one for twice

the price! Your contractor will be able to give you "allowances" for all the items you will need to select, and this will serve as a guideline to help keep you on budget. Your job will be to avoid seduction, constantly prioritizing how you want to distribute the funds under your control.

2. **Ease of Maintenance:** Will this product be a good value in terms of longevity? Is this product easy to clean and maintain?

3. **Resonance:** Does this choice resonate with you? We have seen this principle of resonance come in to play, especially with color and texture in selecting finishes. What "sings" for one person can create dissonance for another.

4. **Overall Composition:** How well does a selection relate to or harmonize with the other choices you have made to create a coherent whole?

Supporting an Ecological Life Style

A thoughtful home design can help you to achieve an ecology-based lifestyle.

Growing Food

Growing our own organic food is a lifestyle choice that many of us have embraced for our health, our taste satisfaction, and for the sake of lowering our ecological footprint. We can reduce the transportation from 1,000 miles down to a few yards, with the added benefits of incredible freshness. We can also have peace of mind in knowing that we have optimized the nutrition in our soil and eliminated biocides and GMOs.

There are a number of strategies you can use to enhance the relationship between your new home and a food garden.

- In dry climates, rainwater collected from the roof can be stored and used for watering the garden. Now is a great time to figure out the best configuration of gutters and cisterns.

- Gardening requires vigilance! Can you see the garden from your kitchen window? Is there a door from the kitchen out to the garden?

- Having a sink in the garden area for cleaning up produce will save time and add convenience.

CREDIT: ROBERT LAPORTE

Home vegetable garden

- Where should the compost pile go? Creating an easy route from the garden and the kitchen to a compost pile will ensure that this valuable resource gets maximized.
- A protected area outdoors adjacent to the kitchen is very useful for seasonal food preparation such as canning or dehydrating when the produce is fresh and the weather is hot. Designing-in an outdoor summer kitchen can economize on costly indoor kitchen space and avoiding overheating the home.
- Where does surplus produce get stored? Is there a grade change where a root cellar could easily be built?

CREDIT: PAULA BAKER-LAPORTE

A door from the kitchen leads through a sheltered patio to the vegetable garden. Note the food dehydrator and solar oven, extending the kitchen to the outdoors in the summer months.

Storing Food without Refrigeration

How much refrigeration do you really need?

A year-round garden utilizing row covers or more elaborate greenhouses will cut down on trips to the grocery store; because you can simply go outside to gather some of your food, you have less need for a refrigerator big enough to hold a carload of food. Refrigerators are typically the largest energy-consuming appliance. A smaller refrigerator will lower environmental costs. At the same time, your home garden will boost taste and nutrition.

Dehydrating, fermenting, and root cellaring foods extend summer harvest and superior nutrition well into the winter—without requiring refrigeration or high embodied energy in the food preparation. What is required is space to store preserved foods.

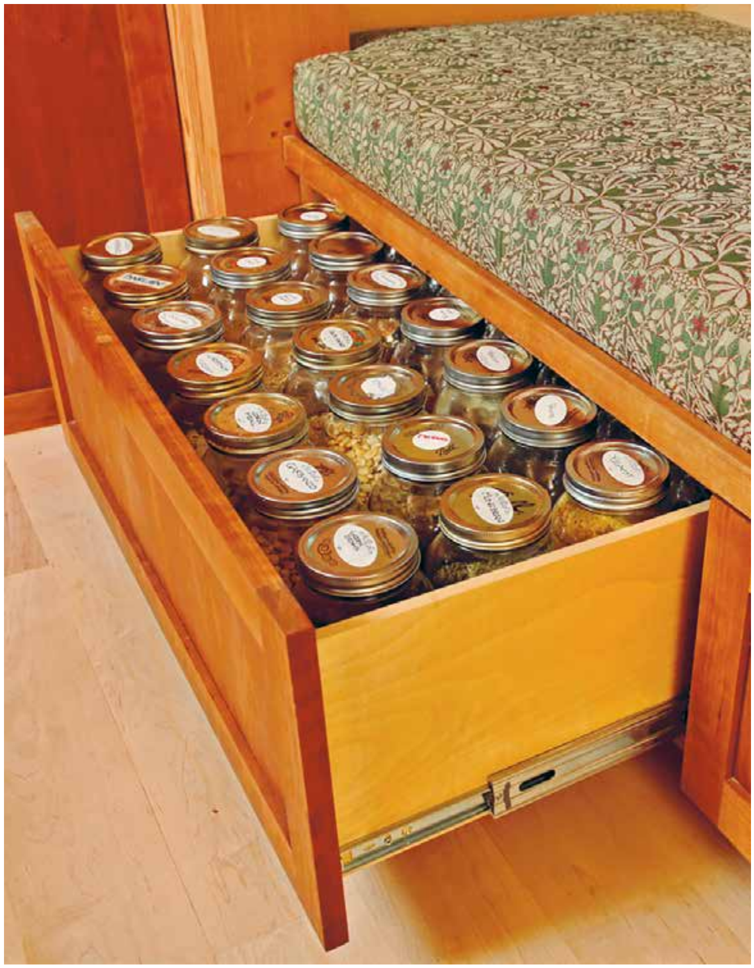
In winter, when extra food purchases are more likely, providing access to an area just outside the kitchen that is weather protected and buffered from temperature extremes can provide a venue for safe, unrefrigerated food storage.

Recycling: Create a Convenient Recycling/Sorting Center

The design of your recycling center should be specific to your location. For example, where we live there is weekly co-mingled collection for papers, metals, and plastics, but plastic bags and hard plastics go to a "round-up" center semi-annually. My kitchen is designed to easily transport the weekly recycling and stage the collection of the longer-term things.

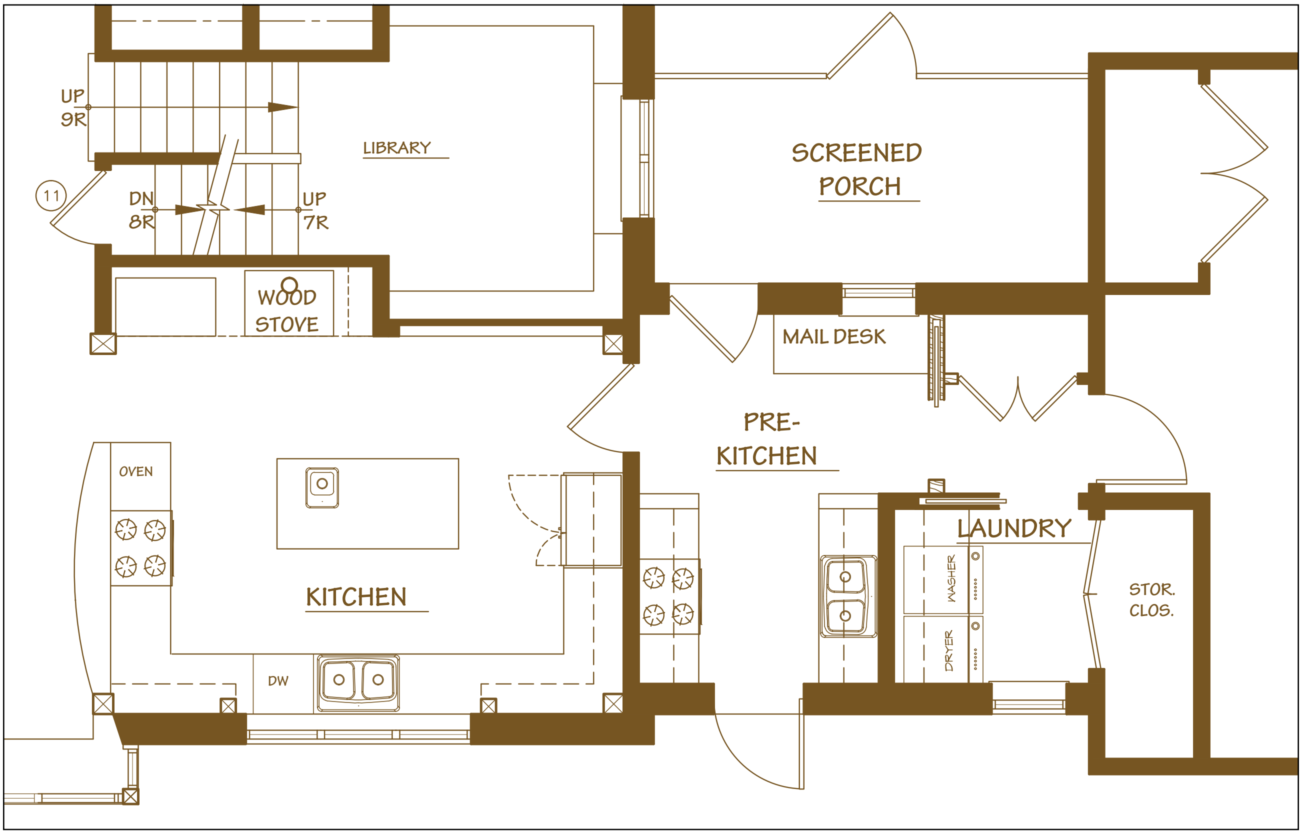
Solar Clothes Drying

Clothes dried in the sun have the benefit of fresh smell and zero fossil fuel consumption. While this is very appealing to the ecologist in us, it can be an inconvenient commitment



A drawer under this window seat becomes a pantry for dry goods.

CREDIT: JONATHAN SHAW



This partial plan illustrates how this Missouri family designed a nest that reflects their desire for food and energy independence. Canning, preserving, and garden produce prep all take place in a pre-kitchen area, keeping the heat and compost out of the kitchen. A door leads to the garden on one side of the pre-kitchen and to a screened porch on the other side. The laundry room is also located in this part of the home, making it convenient to carry clothes to a clothes line for drying. The wood stove for winter cooking is set into a kitchen wall, with plenty of room for wood storage beside it.

in our all-too-busy lives. The clothes drier is such a convenience! Consider that perhaps an ecological life is created by many thoughtful actions more than by a few large eco-purchases. That it is about consciously consuming less rather than redirecting our consumption. A pleasant and easy path from washer to clothes line will more likely result in more frequent ecological citizenry in the laundry department.

Design for "Domestic Ecology"

Ecology begins at home in the richness of the relationships we cultivate with our own soul and with our family. Our homes can either nurture family relationships or contribute to family tensions. Good design, tailored to your individual family needs, and foresight into how those needs will evolve over time is potentially one of the greatest joys and challenges of creating a custom home.

Accommodating the family mix gracefully: Designing a home for young children, teen-agers, parents, and extended family involves careful zoning so that diverse lifestyles can

CREDIT: LAURIE DICKSON

To the left is the door to our daughter's bedroom. An adobe wall separates it from the meditation space beyond the Shoji screen. A teenager in love with hip-hop and a meditator in love with silence were able to live in harmony back to back because of the acoustic privacy that the adobe provided.

Paula and Robert in their favorite board-room.

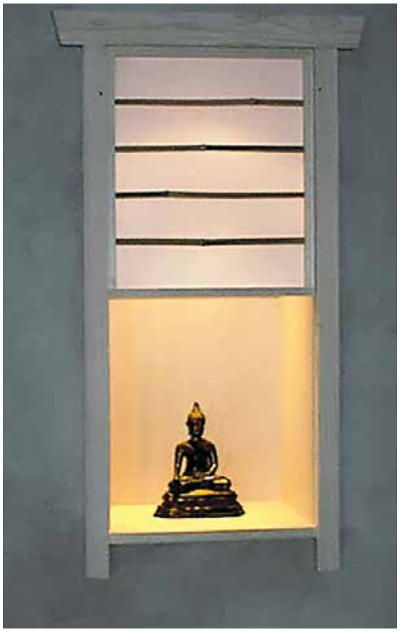
CREDIT: KASANDRA CLEMENTE

co-exist harmoniously. In the first home that Robert and I designed together, we surrounded our teenage daughter's room with adobe walls, allowing her to enjoy her music and us to enjoy the silence.

A nook in the master bedroom can serve as a temporary nursery for a newborn and later become a quiet office alcove. Creating inviting spaces for family gatherings is equally important.

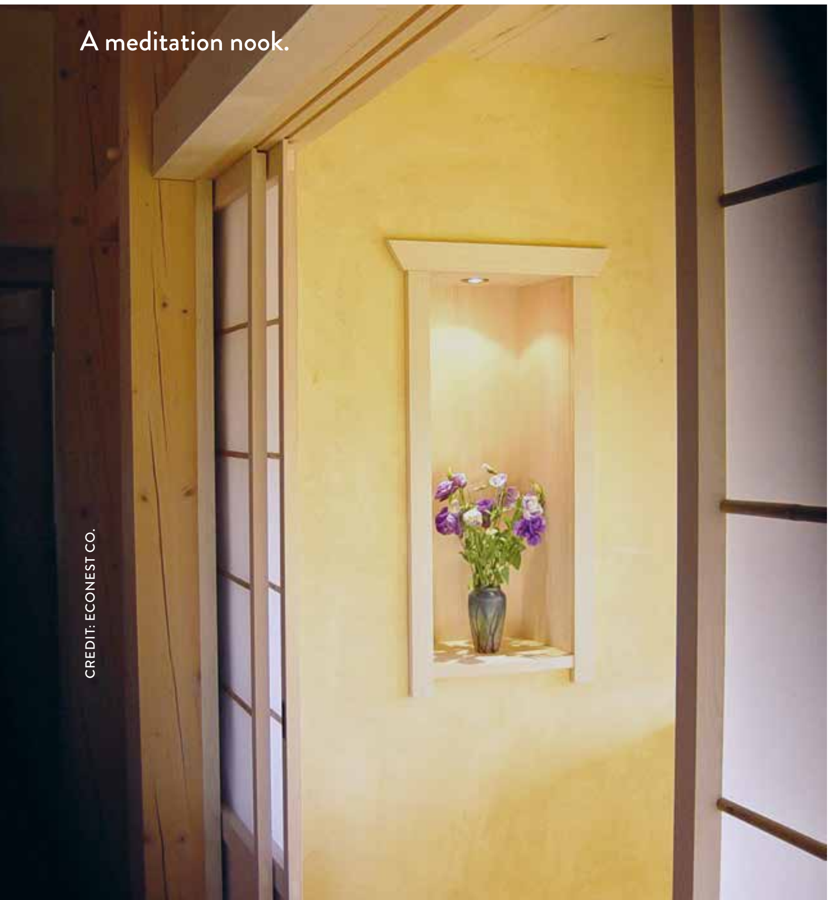
Special moments: Robert and I love to soak in the tub together at the end of a busy day. By candlelight, our "Tea for Two" soaking tub is a place for us to relax, let go, catch up on the

CREDIT: PAULA BAKER-LAPORTE



CREDIT: PAULA BAKER-LAPORTE

Special places for special things.



A meditation nook.

CREDIT: ECONEST CO.

CREDIT: JONATHAN SHAW

news, or just enjoy each other. Many a fruitful plan has been hatched while enjoying quality time together in our tub! What are the opportunities for enriching those intimate moments in your life?

A room of one's own: Are there members of your family who engage in activities that are sacred to them, requiring privacy? Yoga, prayer, meditation, composing music, writing, and creating visual art are all examples of activities that warrant special attention in the design of a nurturing home.

Soulful gestures: What is the form of your connection to spirit? How is this expressed in

CREDIT: KEVIN IRETON

Built in storage helps eleviate clutter and the need for extra furniture in a compact space.

your home? Often, a small design feature can create a meaningful impact—a handcrafted shelf for fresh flowers, a niche for a special sculpture, or an altar for photos or statues. What objects deserve a place of honor in your new home?

Making a Small Footprint Work

It is easy to accommodate individual autonomy through a luxury of space that provides isolation and privacy. It is an art to design a small footprint that enriches the opportunity for cozy interconnectivity. Most people come to us with a fixed budget. We come to the table with a higher level of quality inherent in a handcrafted natural house. Since size/cost/quality are intrinsically related, we work hard on the size component of the equation to make every inch count. We have found that when a home is well designed we are able to fit a lot more house into a smaller footprint. The following design elements help us to achieve our goal of minimizing size while maximizing the feel and function of spaciousness.

- **A defining timber frame structure:** The timber frame is a beautiful structuring element that allows us to define place within an open space. Varied ceiling heights, color,

The timber frame and varied ceiling heights and finishes help to define place within an open space, making a small footprint feel spacious.

Making this hallway a little wider allows it to play double duty as a photo gallery for the owner's fine collection.

CREDIT: KIM KURIAN

CREDIT: ECONEST CO.

Built-in storage helps alleviate clutter and the need for extra furniture in a compact space.

CREDIT: ECONEST CO.


CREDIT: LAURIE DICKSON

and unique features such as niches, the hearth, and window seats render a coziness and uniqueness to the various places within the open space plan.

- Cross views: Providing views through the building and to the landscape beyond contributes to a sense of spaciousness that belies a small footprint. *Light from several directions* helps to give the space an airy feel.

- Minimizing circulation space: We find that we can reduce circulation space in a number of ways. Plans are arranged to minimize hallways, and short hallways are often widened to become functional for other purposes.

- Maximizing storage: Storage under window seats, beds with pull-out drawers, built-in furniture, and space-efficient pantries help to economize space and reduce clutter.

Outdoor Living

One of the least expensive, most enjoyable, and healthiest spaces to build is an outdoor place. A home that is designed to be responsive to its surroundings will provide a fuller range of opportunities for the occupants to reap the health benefits of nature. Simple and inexpensive design gestures such as adding a sheltered porch, a shaded trellis, a roof overhang, or a cozy corner that collects morning sun and afternoon shade can add some of the most enjoyable living spaces while acting as climatic buffer zones around the home. Outdoor dining, summer kitchen, bed under the stars, yoga porch, reading space, garden viewing shelters—these are all eagerly embraced by our clients when they are given the opportunity to integrate these outdoor spaces into their design.

A small home feels and acts larger when it incorporates views and access to and through outdoor places.

Extending the design process to include surrounding landscaping can incorporate vegetation to provide shade in summer, allow winter sun inside, block harsh winds, or funnel helpful breezes. Edible vegetation can double as an organic food source for occupants and birds.

Bringing nature into the home is the welcome corollary to extending the home out into nature. A “winter garden” or solarium space provides an opportunity for greenery and helps heat the home in winter.

CREDIT: PAULA BAKER-LAPORTE

Challenges and Rewards on the Road Less Traveled

Creating a biological home from scratch is an opportunity to enrich your life while contributing an inspirational example for others. Keep in mind these three things:

- You are a pioneer.
- You are not alone.
- When you build it, they will come!

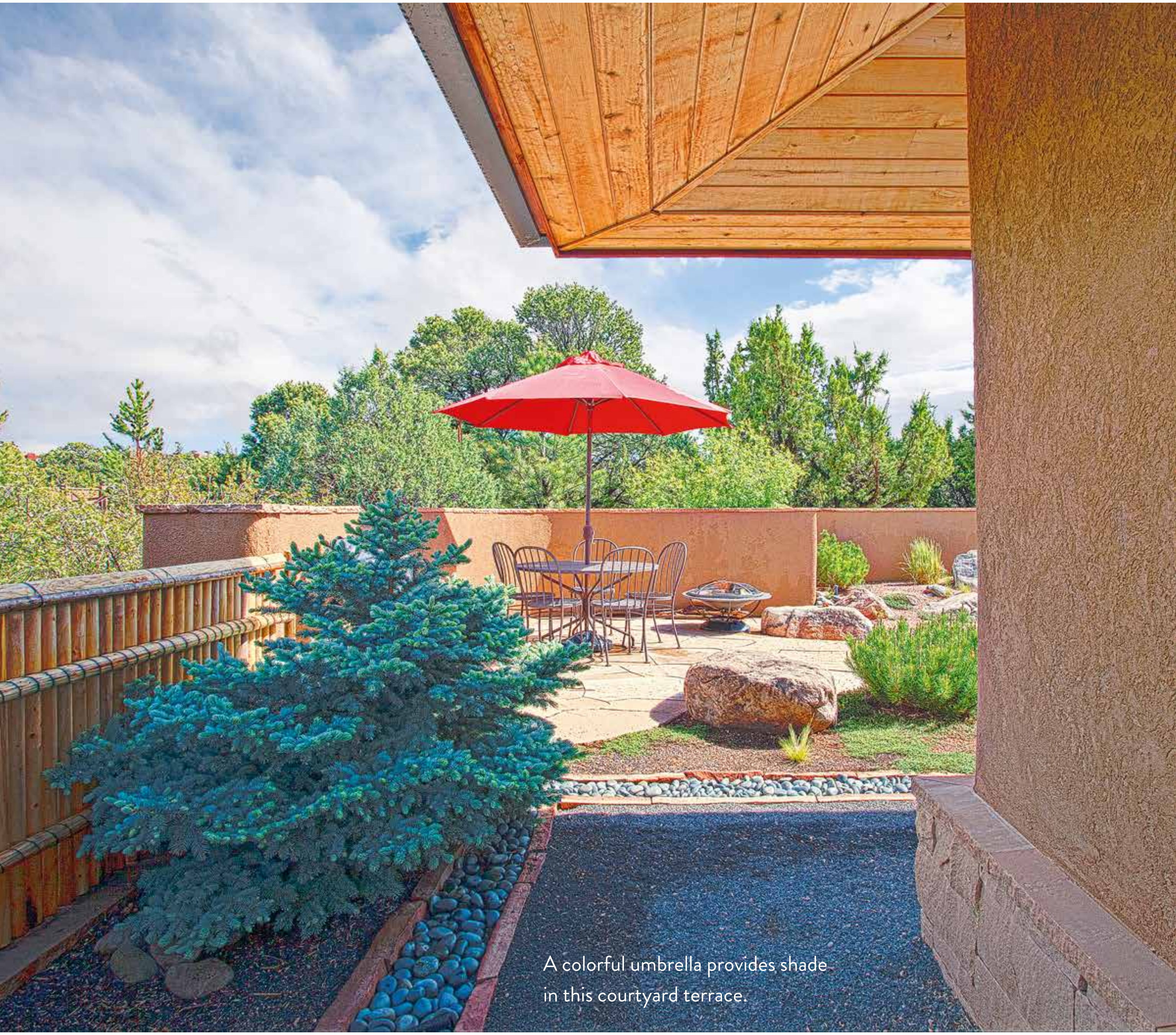
You are a pioneer: Being a pioneer involves breaking new ground. Expect challenges. Finding a design and build team who share your vision will be the first challenge. You may need to educate and seek permission from building officials who are unfamiliar with the alternatives you have chosen. Your lender may need to "work harder" to get an approval. Your appraisal will not reflect the value of the health, comfort, and energy independence incorporated into your home. People who are well-meaning and care about you, but do not share your vision, will be skeptical, giving you their best advice to do something more conventional.

You are not alone: Much of this "road less traveled" has already been paved for you. Keeping your vision alive is easier when you find good shoulders to stand upon. There has been a fruitful grassroots movement creating natural ecological homes in this country for the past 25 years. Thousands of natural

This East deck portal under its large sheltering roof overlooks a courtyard and the views beyond. A perfect place for sun salutations.

A trellis provides shade in this little courtyard defined by herb gardens and a french bread oven.

CREDIT: ROB RECK

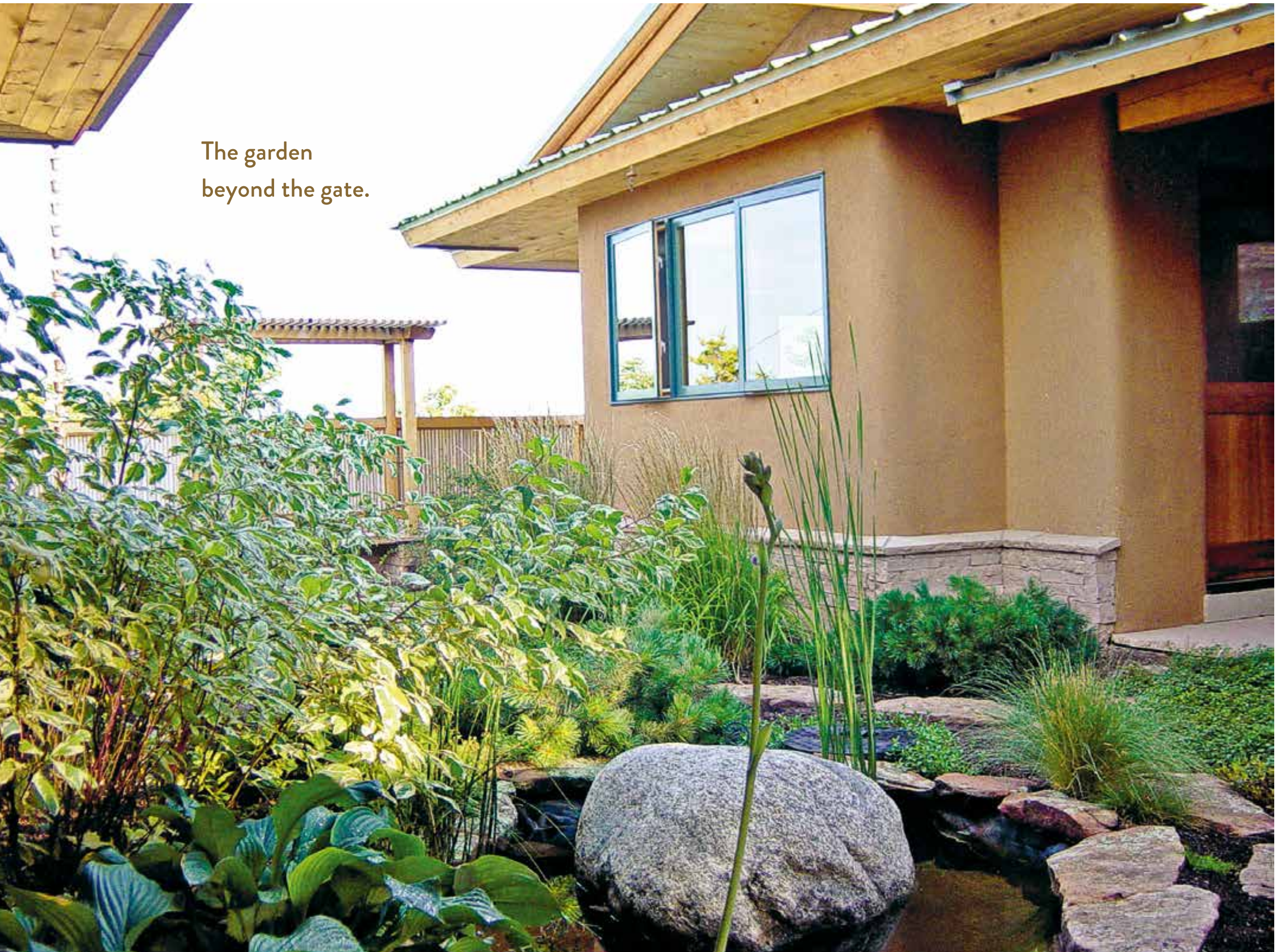


A colorful umbrella provides shade in this courtyard terrace.

CREDIT: JONATHAN SHAW

Gate to an entry courtyard.

CREDIT: CATHERINE WANEK



The garden beyond the gate.

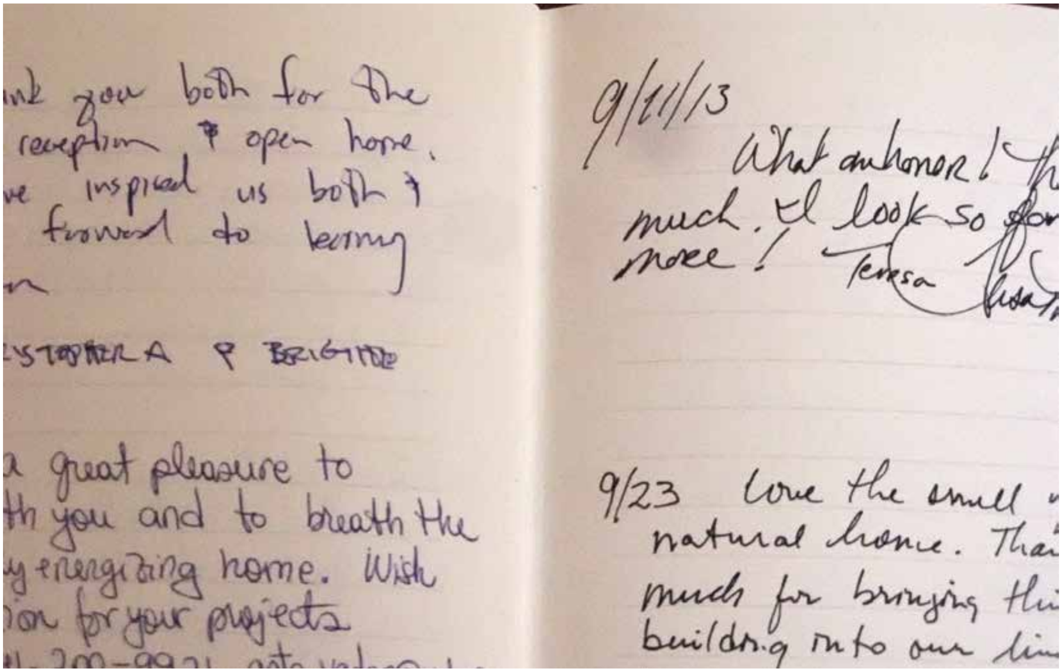
CREDIT: PAULA BAKER-LAPORTE

CREDIT: ECONEST CO.

The East deck extends a porch area off of the kitchen. The shade trellis also provides a bench.

CREDIT: ECONEST CO.

A place to sit and view the garden.



CREDIT: PAULA BAKER-LAPORTE

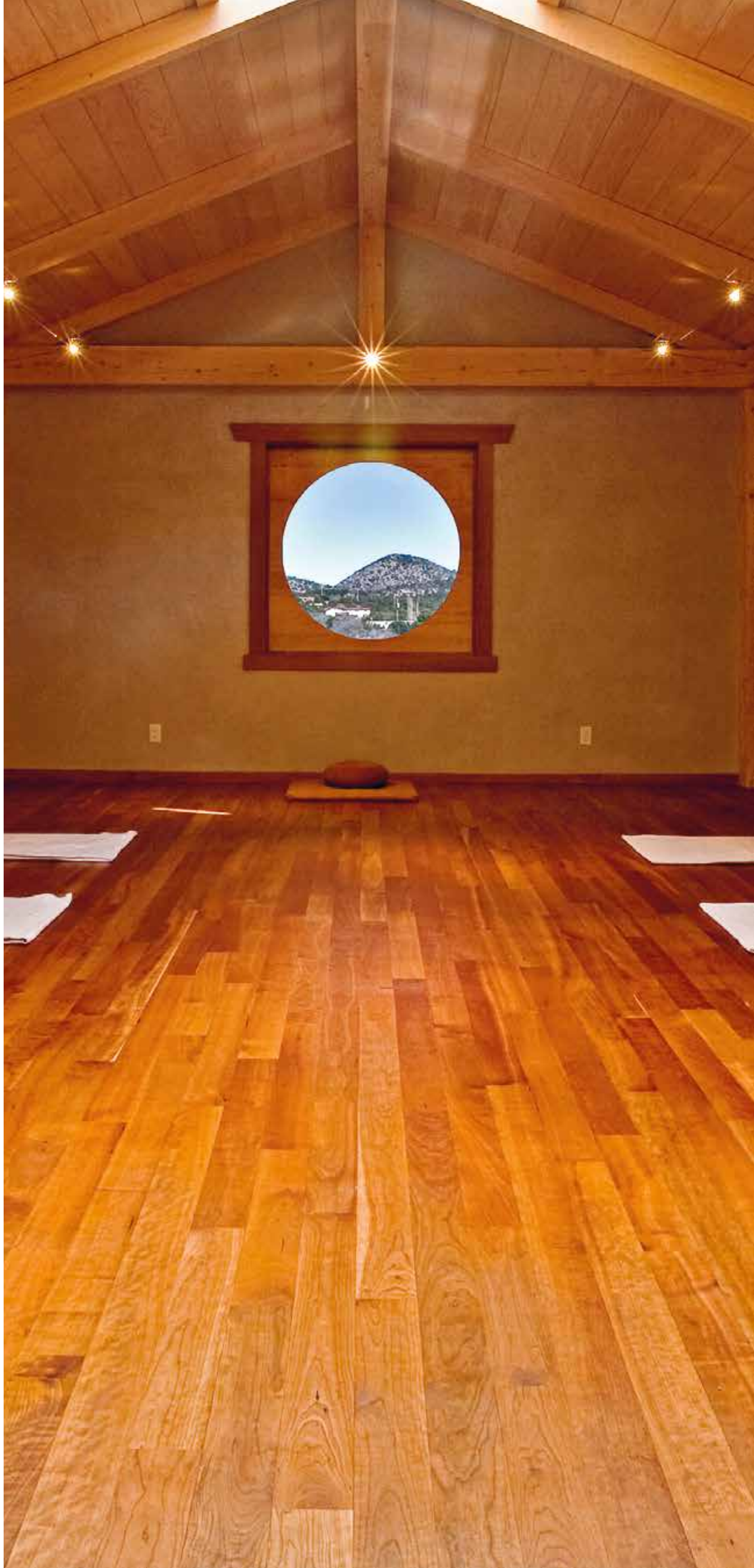
A glimpse into Robert and Paula's guest book. Over the years they have opened their home to many visitors from near and far interested in experiencing a biological home.

homes have been built successfully, and there are enthusiastic professionals and homeowners who are more than willing to share their experiences with you. New books with fine examples are published regularly. The nation's building codes are beginning to include alternative building methods, making permitting easier.

When you build it, they will come: Take our word for it! It is our experience that people in this nation are longing to experience a "biological" home, especially when they have never actually experienced anything other than conventional construction before. Just as you found EcoNest in your search for a healthier, more natural way to create your home, others will be searching for what you will create. Upon completion of your home, you will most definitely get lots of requests for visits. Your new home will speak of your passionate commitment to a better future. It is both generous and necessary to share your accomplishment with others. To the extent that you are willing—through writing, photos, home tours, school outings, etc.—you will help influence the course of the future in a positive way. What could be more rewarding?

SECTION 2

How to Build an EcoNest



CREDIT: KIM KURIAN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Chapter 4

The Workshop Experience

At EcoNest, we hold four Natural Building Workshop sessions each year. Students are invited to hone the innate builder within. Whether the entry point is "screw gun 101" or refining complex wooden joinery skills, the environment is created and the tone is set for enrichment, but not just of building skills. There is something significant that happens on a soul level when we come together to build with common vision—a vision of working in balance with nature.

Paula relates her experience at a recent workshop.

CREDIT: KEVIN ROWELL

EcoNest Workshop, Costa Rica

Last winter I had the rare opportunity to be a full workshop participant in Costa Rica. I "unplugged" from my office, where the design and administration keeps us busy, and I experienced a profound reminder of why we choose to do this work. Here are some of the memories I took away with me:

I am seated on a bag of rice husks across from Kat, whom I will come to know well over the next few days. Today, we are making mud patties destined to become the walls of our building. Sooney joins us in the work and teaches us a song of gratitude for food. As we learn, Kat chimes in with beautiful harmony. I find my own voice, underused, rusty, in and out of tune, but appreciated none the less. This is not the only time this week that I will step outside my comfort zone. Our patty work takes on the rhythm of the song. We decide to sing this song at dinner for Jorleni and Flori, the two village women who have been consistently churning out incredible meals for our group of 15. Even though they won't understand the words, we feel certain they will feel our appreciation, so we practice in earnest. The work never stops. As we sing together, our pile of patties grows to an impressive mountain. This camaraderie creates an afternoon of light-hearted pleasure I am never afforded sitting alone with my computer, my usual portal of communication and creative expression. I feel alive. My body is working. I am outdoors and in the heart of nature with butterflies, strange birds, and even a daily inspection from the village deer named Bambi. This time, in this place, the walls are of wattle and daub and bamboo. Back home in Ashland, the workshop experience repeats itself in an equally beautiful bio-region with a more substantial clay/fiber and timber frame fit for the vicissitudes of that climate.

At the end of the week, a new building stands in this little village. It models a sustainable way of building an elegant structure with the materials at hand. It models working in community, building skills, and building bridges inward and outward.

We sang our song, and the kitchen ladies smiled shyly, a little teary-eyed. Not too bad at all!

Modern-day Precedents for Building-Craft Revival

We believe that crafting a home that will serve for centuries is a noble pursuit, worthy of our deepest respect. In contrast, standard conventional home construction involves the assembly of pre-manufactured components into homes with brief warranties. Most construction work is seen as a "blue-collar affair," not a real profession. Is there a place for the true artisan in our fast-paced consumer culture?

We have seen a growing interest and acceptance of our work because there is a growing segment of the population that chooses quality over quantity, and simplicity over life in the fast lane. These are people who have an abiding desire to steward the environment, and they realize that meaningful change begins at home.

This small but growing segment of our population is the support system for the rebirth of the American artisan and a culture based in respect for nature.

We have been deeply inspired by the precedent set by our European and Asian contemporaries who have kept the ancient building traditions of their cultures alive. Through the Timber Framers Guild, we have been exposed to master craftsmen from around the world. In Japan, we witnessed the Kezurou-Kai

CREDIT: ROBERT LAPORTE

A crowd of carpenters watch with admiration as master carpenter Senga-san produces a silk-like shaving at Kezurou-Kai planing competition in Japan.

hand-planing event. In India, we observed Shilpis carving stone temples and statues in granite with the perfection of their ancestors.

The Way of the Craftsman

At our workshops, we have the opportunity to introduce students to "the way of the craftsman." For many, it is the very first time that they learn to hold a tool with reverence and to approach a piece of wood with humility. For some, this experience is the first step on the road to a passionate career. Dale Brotherton is an accomplished artisan in Japanese woodworking, and we have the great privilege of having him as one of our instructors. The following article written by Dale illuminates our sentiments.

CREDIT: ROBERT LAPORTE

A master plane carpenter in traditional posture using all limbs to create a plane block.

CREDIT: ROBERT LAPORTE

Dale Brotherton in action, assembling a porch roof with a student at an EcoNest workshop.

The Way of the Craftsman

by Dale Brotherton
Takumi Company, Japanese Traditional Carpentry

For most of us, it's easy to forget that our modern approach to learning is very different from that taken by the majority of humans throughout history. Even when pursuing a traditional craft like woodworking or carpentry, the tendency is to study as much as possible, then, relying heavily on the perfect tool, carefully attempt to produce the "perfect" finish from day one. Such an approach inevitably results in only shallow and fleeting satisfaction.

On the other hand, those who have trained in the old ways or have accumulated much experience know that careful craftsmanship is ideally a product of the trained hand. The development of that skill is far more valuable than accomplishing any particular project, for in the process of developing basic skills, one also acquires patience, a deep understanding of materials, broader vision, and, most important, the capacity of mindless creation. It might sound strange, but only when the mind takes a back seat do the hands become free to express what's most important.

So how do we develop basic hand skills? First, submit to competent guidance. Ideally, an instruction that is well grounded in a time-tested tradition. One whose results are readily available and naturally appeal to you. Next, practice, practice, practice. Follow the guidance, and repeat the moves as much as possible. Let the body learn, and, with enough repetitive practice, learn it will. Our bodies are amazingly versatile and capable of fulfilling almost any physical task if we can just trust, appreciate, and point them in the right direction.

What do we mean when we say basic hand skills? For a carpenter or woodworker, most important is the ability for the hands to move in a straight line. Of course, having the developed strength to hold and guide a tool at the same time is necessary. Beyond that, one can further develop control while the hands move in complex patterns and or in various orientations. To achieve this requires whole body balance. In fact, development of one's *Ki* (core strength) is crucial to bringing refined control to any movements while using tools.

In the Japanese tradition, *blade sharpening* practice is the first step to developing hand skills. It's something like the *Kata* (basic movement) in martial arts. The whole body assumes a balanced stance; with intention and focus the blade is rhythmically moved across the sharpening stone without the use of guides. The abilities derived from sharpening apply to pushing and pulling other tools such as chisels, saws, and hand planes. This is an ancient approach to learning that is grounded in the physical. Our minds might point the direction, but ultimately the vital lessons are given by nature, as facilitated through our bodies.

CREDIT: ECONEST CO.

Morning exercise is a wonderful way to begin the day, creating focus and grounding. Simple yet effective yogic stretches serve the body during the course of the workshop day.

Building the Builder

As aspiring artisans we have an undeniable urge to create beauty. Mastery of a craft is a journey of a lifetime. It makes sense that if we love this craft of building and we aspire to reach mastery, we should strive to maintain a healthy, strong, and agile body that will support us.

There is a marked difference in the body of an elderly Japanese craftsman and the aging American builder. In Japan, we witnessed elderly craftsmen working on the floor, using both arms and both legs, their fingers and toes, limber and adept. Ask any builder over 40 in the US if they have back problems, and you will almost always hear a long tale of woe. Have you ever seen a professional athlete compete without first warming up? Have you ever seen a builder warm up before starting a day of hard physical labor? Building involves a balance of physical and mental work.

Lesson number one that we teach our students is mind/body awareness. We do warm-up exercises each morning. We focus our minds and create limber bodies so that the building activities bring strength and not the eventual

Burt and Ray taking time out to cool down.

CREDIT: ECONEST CO.

injury that is inevitable when hard physical activity is performed without awareness.

The worksite is quiet, clean, and respectful of the business at hand. It is a safe environment in which to do our best. Comradery runs high as friendships are forged.

The EcoNest workshop training is designed to awaken craftsmanship, build teamwork, and inspire leadership. The teachers are clay, straw, and timber.

Hosting a Workshop

Every year, we are asked to lead workshops. We work with former students and EcoNest affiliates who have the training required to plan and deliver a successful workshop experience. To guide the project coordinator or the workshop host, we have produced a checklist template. See "Workshop Checklist" in Appendix A.

Below: Feasting after a hard day work.
Opposite above: Janet and Tim Kroeker, after participating in a workshop near Toronto, hosted their own EcoNest workshop near Winnipeg. Their planning included a circus tent for rainy weather, food prep for their 22 students and a celebration with music and feast.
Opposite below: Students breaking bread together after a hard day's work in Humbolt, CA.

CREDIT: JONATHAN SHAW

CREDIT: ROBERT LAPORTE

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Chapter 5

Foundation Systems: "A Good Pair of Boots"

The Role of the Foundation

There is wisdom in the old English adage, "A good hat and a good pair of boots makes for a long-lived building." The purpose of the foundation, or "boots," of a building is twofold. First, it must support and anchor the structure by extending below the frost level. Second, it must hold wall materials, which are vulnerable to moisture decay, safely above grade.

We begin the LSC (Light Straw Clay) construction well above grade level so that the walls are safe from water damage. The height of the stem walls (the vertical portion of the foundation system) will depend on the climate. While the large roof overhangs act in concert with the foundation in protecting the walls from bulk water in the form of rain or snow, we will make the stem wall higher where we expect to encounter drifting snow.

Although a stone foundation is the most natural type of foundation, the energy transfer through it cannot be justified given the need to achieve energy efficiency. Our preferred foundation material is wood-insulated concrete forms, a solution that minimizes the use of concrete.

Why Minimize Concrete

For EcoNests, we choose foundation alternatives that minimize the use of concrete. The production of Portland cement, which is the "glue" in concrete, is an extremely energy-intensive process because the raw materials must be mined, transported, crushed, and then heated to 2,700°F.

The popular "green building" practice of substituting fly ash in place of some of the cement replaces a product that is high in embodied energy with an industrial waste product with questionable health consequences because it may contain heavy metals and radioactivity.[5] Therefore, reducing concrete in our buildings significantly reduces our ecological impact. We do this in two ways.

Wood-Insulated Concrete Forms

Wood-insulated concrete forms are "foam-free" masonry units made of cement-bonded

A completed foundation showing WICF stemwall and thickened footings to support masonry heater and mass interior walls.

CREDIT: ECONEST CO.

clay-treated wood chips. In use since 1945, they are produced by many manufacturers throughout Europe, where the system is popular. In the USA, they are manufactured by Faswall and in Canada by Durisol. These forms are composed of cement-bonded, recycled, wood chips that have been clay-impregnated; they reduce the use of concrete and also increase insulation value. A mineral wool insulation sleeve toward the outside of the block adds further insulation and reduces the volume of concrete required in the core fills. This builder-friendly product is lightweight, interlocking, and dry stacked. Blocks are easily cut and assembled and hold standard nails and screws. Because they provide 12"-wide, vapor-permeable walls (above grade) that are easily plastered, they interface well with the LSC. We have been using them for over 25 years with excellent results.

Rubble Trench Construction

Rubble trench foundations are an ancient technique that was re-popularized in modern times by Frank Lloyd Wright. A well-drained trench is dug down below frost level and filled with compacted stone rubble. The rubble trench creates a dry, stable base upon which a reinforced concrete grade beam and stem

CREDIT: JONATHAN SHAW

The Faswall or Durisol blocks are lightweight masonry units composed of cement-bonded, recycled,wood chips that have been clay-impregnated. The interlocking blocks are dry stacked. The mineral wool insulation sleeves located towards the outside of the block create a high insulating value while reducing the amount of concrete required to fill the cores. Here a specialized corner block with a connection designed to receive a block running perpendicular to it.

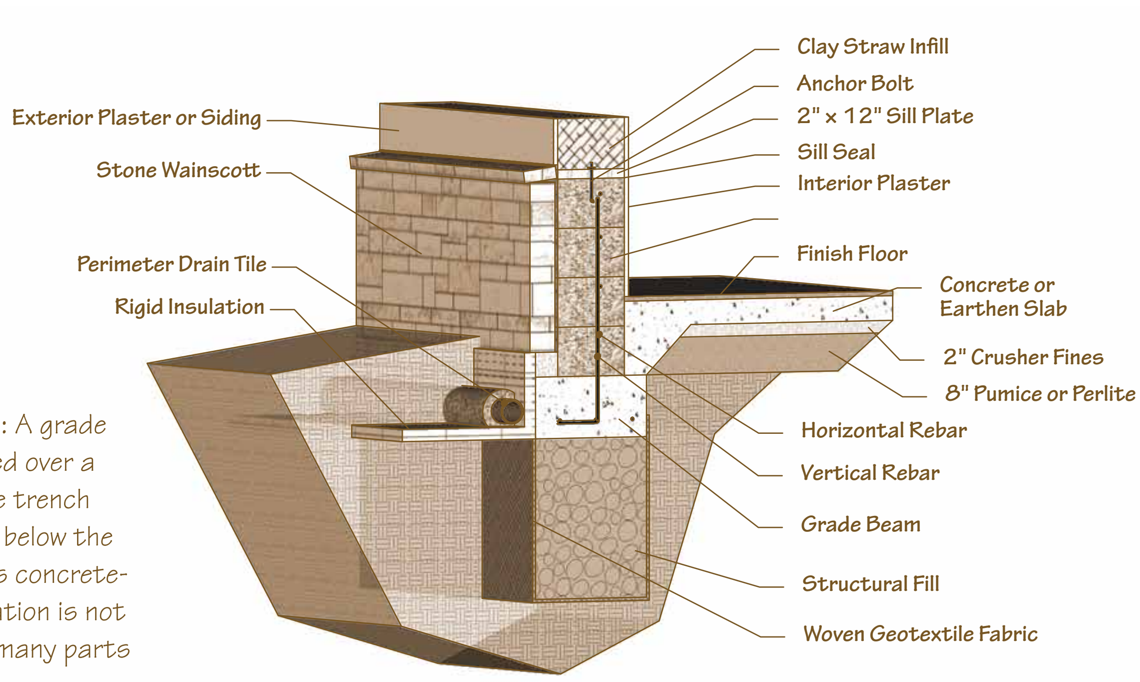


Figure 5.1
Rubble Trench: A grade beam is poured over a drained rubble trench that extends below the frost line. This concrete-saving foundation is not permitted in many parts of the country.

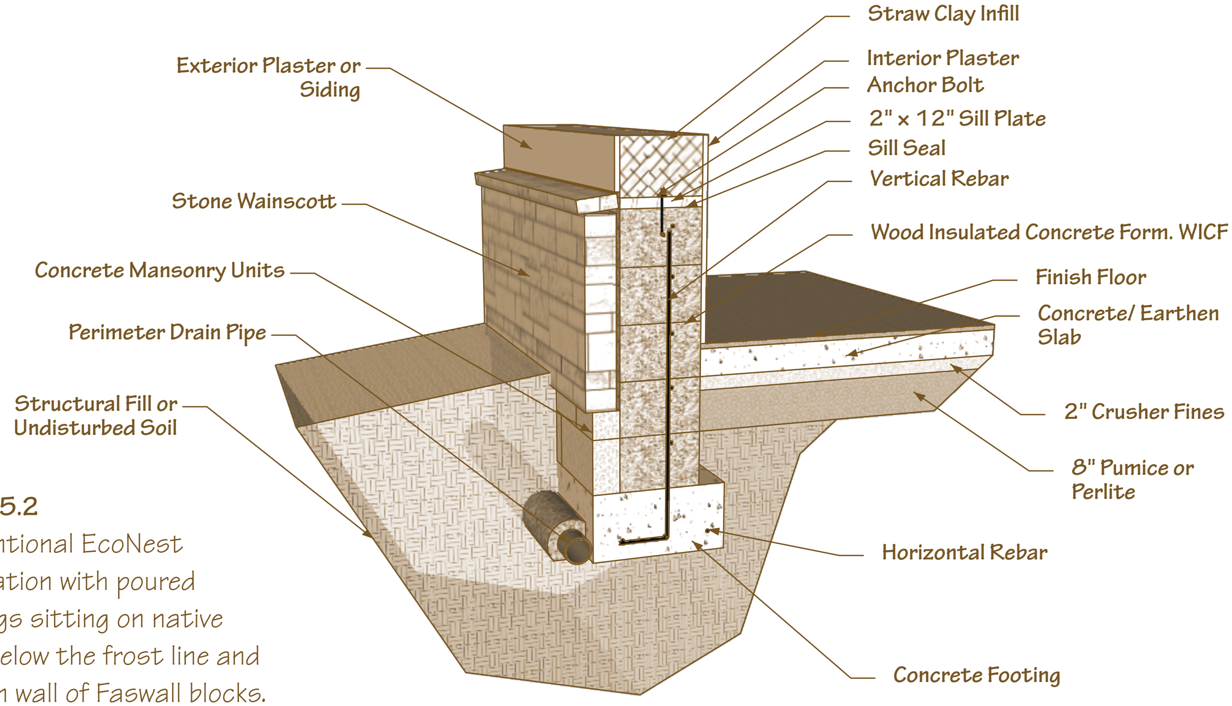


Figure 5.2
Conventional EcoNest foundation with poured footings sitting on native soils below the frost line and a stem wall of Faswall blocks.

wall are built. Where geological and seismic conditions allow, this system is one of the most ecological foundation solutions because it significantly reduces the use of concrete. Not all building officials will permit this type of foundation, so it is important to check with your local building department.

Foundation Water Management

Water intrusion is a serious cause of building degradation and ill health. Good foundation water management is one key to the longevity of a building. It consists of a family of strategies designed to work together to keep the foundation dry. These include:

- an impervious top layer and positive drainage away from the building along its entire perimeter.
- an effective (and non-toxic) water-resistive coating on below-grade stem walls.
- an engineered drain plane and/or protected gravel backfill system to capture and move any water that penetrates the ground to a drainpipe.
- a drainpipe at the bottom of the rubble trench or footing to capture water and move it away from the footings.

CREDIT: ECONEST CO.

The LSC walls that are more vulnerable to water damage sit well above grade on a Faswall Stemwall.

CREDIT: ECONEST CO.

Chapter 6

The Timber Frame

Introduction to the Modern Timber Frame

Timber framing is the craft of post-and-beam construction connected with mortise and tenon joinery. Coveted from generation to generation, the natural strength and warmth of a handcrafted frame graces a home with a profound connection to the forest, invoking a deep sense of serenity.

In the USA, timber framing fell out of popularity in the mid-18th century, when the invention of the headed nail and circular saw made light-frame construction possible. Efficiencies were gained, but something was lost.

It was only revived as a lost art in the 1970s by pioneers like Tedd Benson, Jack

Sobon, Steve Chappell, and Ed Levin, who pieced together the forgotten craft by re-searching old books and buildings. In 1985, the Timber Framers Guild was founded by approximately 200 craftsmen. Today it has a worldwide membership of 1,500, and timber framing continues to gain recognition as a viable craft in a modern age.

About the Sustainable Use of Wood

Unlike conventional building, in which the framework is covered up, concealing the workmanship, in a timber frame the timbers and joinery are completely exposed to the interior, where the beauty of the wood and the careful craftsmanship can be appreciated. The lifespan of a timber frame can be measured in centuries—200, 500, 1,000 years—outliving the lifetime of a tree in the forest. Although historic timber frames were exposed to the weather, a timber frame wrapped by an LSC wall system is completely protected from the weather, potentially extending the life of the wood even longer. When the building has outlived its original purpose, the timbers can be repurposed through disassembly and re-assembly elsewhere.

An exposed timber frame brings the forest element into the home, quietly reminding us of Mother Nature, the sustaining force of all life on the planet.

CREDIT: KIM KURIAN

Interior of the Marr Residence in Pecos NM. The rich fir timber frame is surrounded by light straw clay walls and completely exposed to the inside, where it creates a rhythmic composition.

The EcoNest Timber Frame

The EcoNest building system began its evo-lution in 1990 when Robert—an avid timber framer—sought an alternative to structural insulated panels (SIPS), a popular enclosure system for timber frames. The stress skin panels of foam sandwiched between press-board, although very energy efficient, felt antithetical to the ideals of a crafted building. He wanted to surround the timber frames that he was building with a nature-based, energy-efficient wall system. Robert set off to Europe, where there was an immense resource of pre-industrial and current post-and-beam construction. In Germany he discovered

Baubiologie (Building Biology). He also found a contemporary natural building system that was being developed for use with post-and-beam construction that followed the Building Biology principles. This *leichtlehmbau*, or light clay building, was what he had been looking for. It was non-toxic, free of chemicals, had a proven history of use, was natural, unadulterated, and hygroscopic (allowing for the free flow of moisture vapor through the wall). It caused no harm at any stage of its manufacture.

It is Robert's adaptation of this light straw clay technique as a wrap that is at the heart of this book, and the timber frame that is the heart of every EcoNest we design.

From his experience in Germany, Robert developed the EcoNest Larsen truss "outsulation" system that is described in the next chapter.[6] It quickly became evident that the Larsen trusses themselves, if spaced on 24" centers, could be load-bearing, making a perimeter timber frame not absolutely necessary.

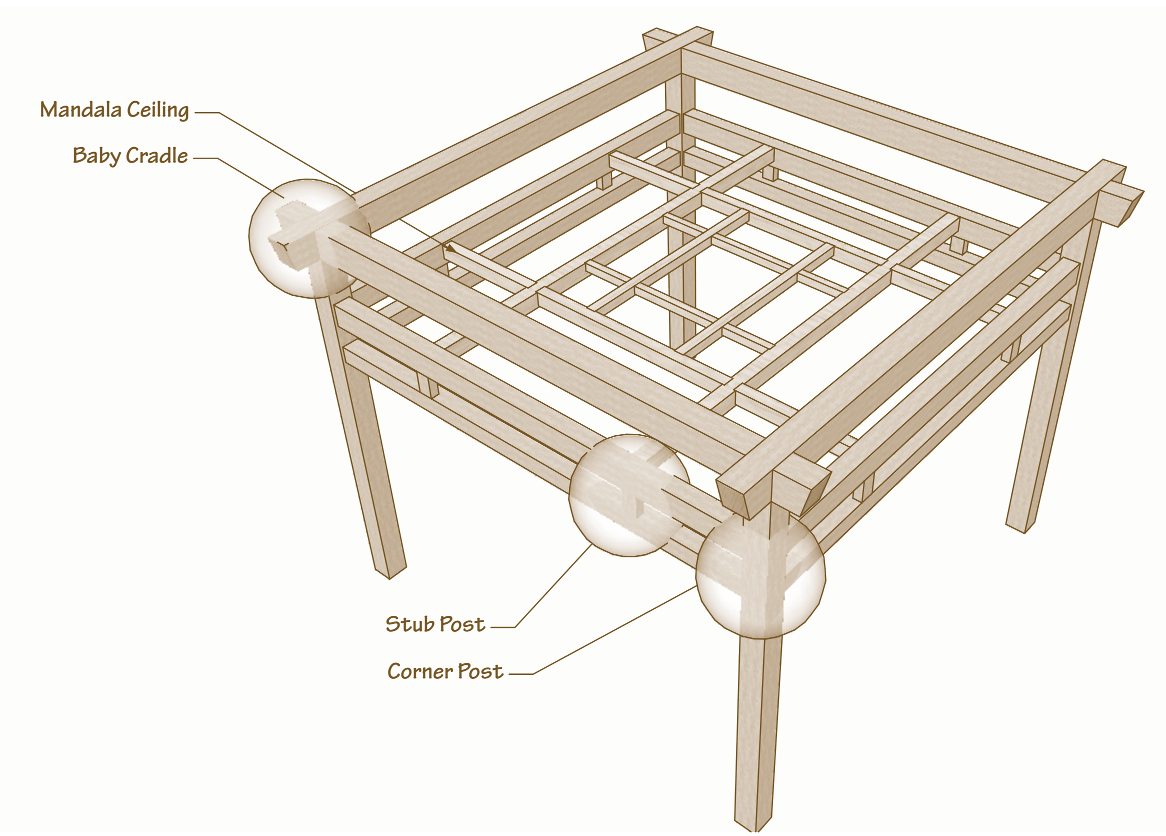


Figure 6.1
The timber-frame core of a single-story EcoNest.

Timber Frame Terms

Beam	horizontal timber
Bent	assembly of timbers perpendicular to the ridge
Bird's mouth	notch on underside of rafter for connecting with longitudinal member
Chamfer	edge treatment to soften square corners
Collar tie	horizontal beam connecting opposing rafters above the wall top plate
Connector	horizontal beam connecting bents together
Corbel	decorative treatment at ends of beams
Elevation (view)	drawings of the construction as viewed from a side
Girt	horizontal beams in bents
Joinery	the work of connecting timbers using woodwork joints
Knee brace	timber that stiffens the posts and beams by connecting them diagonally
Mortise	a rectangular cavity into which a tenon is inserted
Peg (dowel)	wooden pin used to fasten the mortise and tenon joint
Plan (view)	drawings of the construction as viewed from above
Plate	roof support beam providing a base for the rafters
Post	vertical timber
Rafter	beam extending from the eaves to the peak of a roof
Ridge	horizontal line formed by the upper edges of two sloping roof surfaces
Sill	bottom horizontal member of a wall or window
Tenon	a projecting piece of wood made for insertion into a mortise
Truss	a framework of rafters, posts, and struts supporting a roof

Today, we still design and build many full-timber-frame homes, but we also do more economical hybrids in which the perimeter trusses bear some of the load, while a timber-framed core bears the central loads and graces the public space, where it is most visible.

The EcoNest Timber Frame Workshop: Crafting Relationship with Your Home

The art and craft of timber framing are best learned through a rigorous training under the watchful eye of an experienced timber framer. There are many excellent books written on timber-frame building, and some of our favorites are listed in the bibliography section.

The intent of this chapter is to introduce the process of building a core timber frame for one of our Peregrine Series homes; it's a taste of what students learn in the course of the EcoNest timber frame workshop. Some of the students in our workshops have never held a chisel before, while others are already quite experienced and come to hone their skills.

Sharpening the Chisel, Sharpening the Mind

The first day of a timber frame workshop is dedicated to sharpening, fashioning a superior cutting edge on the chisel. In this singular task, an atmosphere of focus is set while each student creates a fundamental resource to cut wood joinery with precision and confidence.

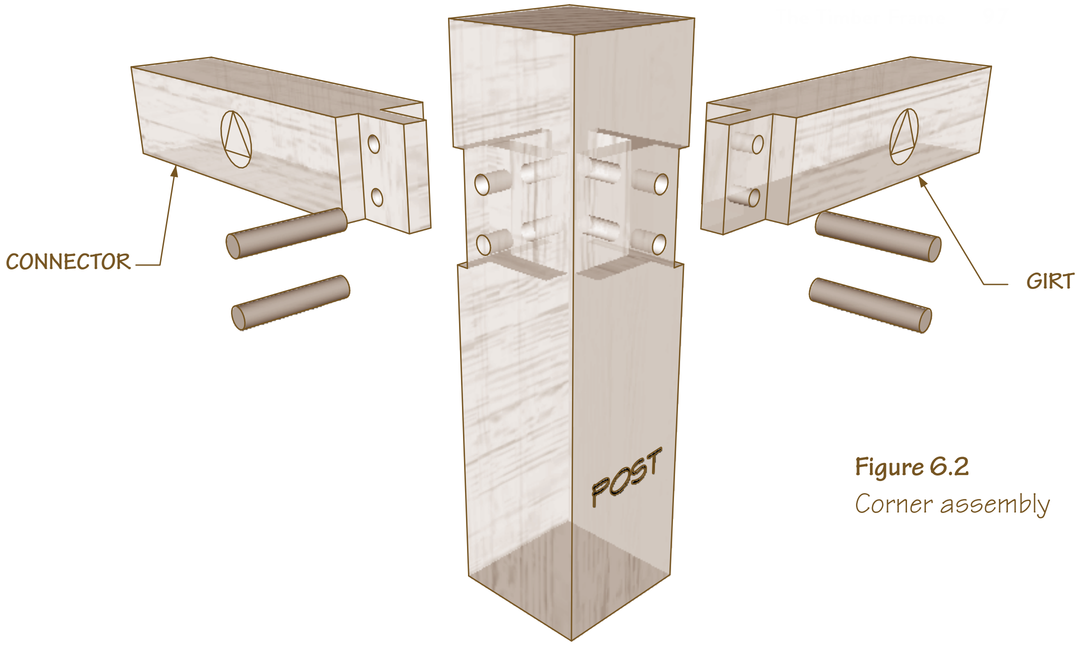
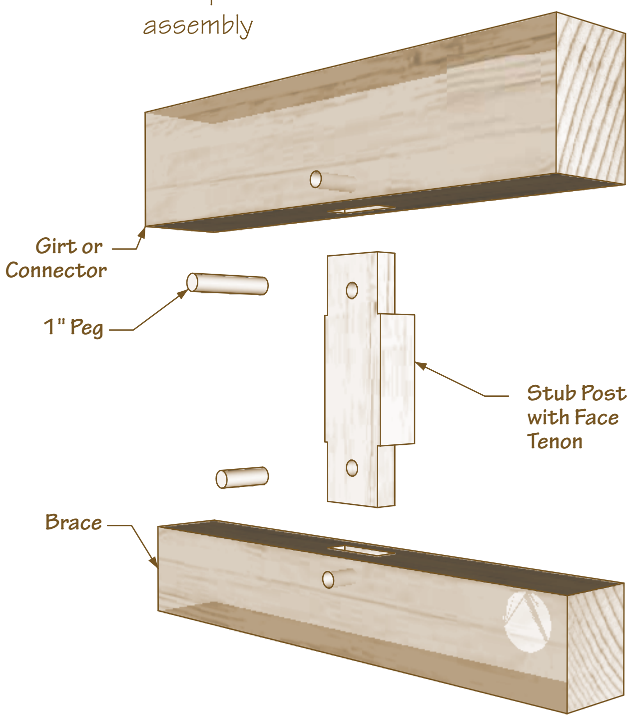


Figure 6.2
Corner assembly

Figure 6.3
Stub post
assembly



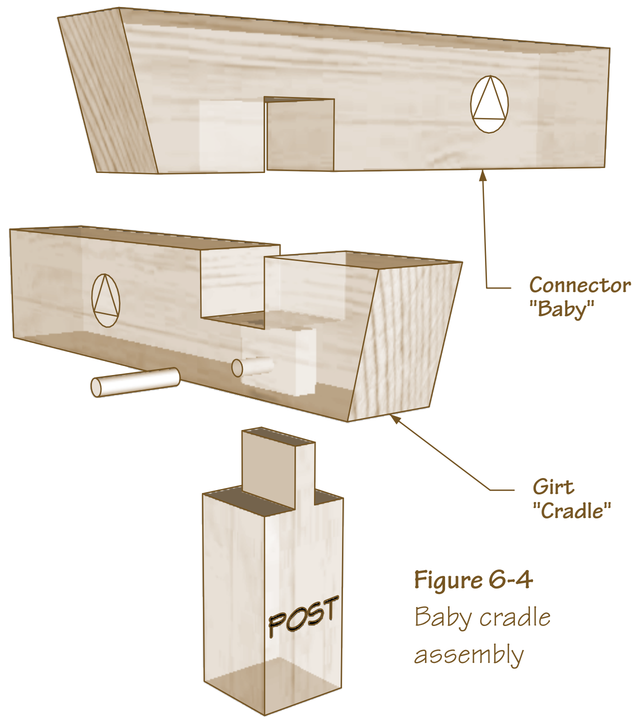


Figure 6-4
Baby cradle
assembly

Their training has begun. Each student will go on to experience the various aspects of this craft, culminating in the raising of the finished frame.

Layout

The timber-frame plans are a set of working drawings presenting the frame members, their relationships to one another, and precise dimensions. Clear plans become the basis for the timber framer to work out the required timbers, joinery, assembly process, and raising sequence.

Layout begins by studying the timbers and orienting them for their best expression in the overall composition of the frame. Special consideration is given to posts, and students learn how to orient them the same way the original tree grew in the forest.

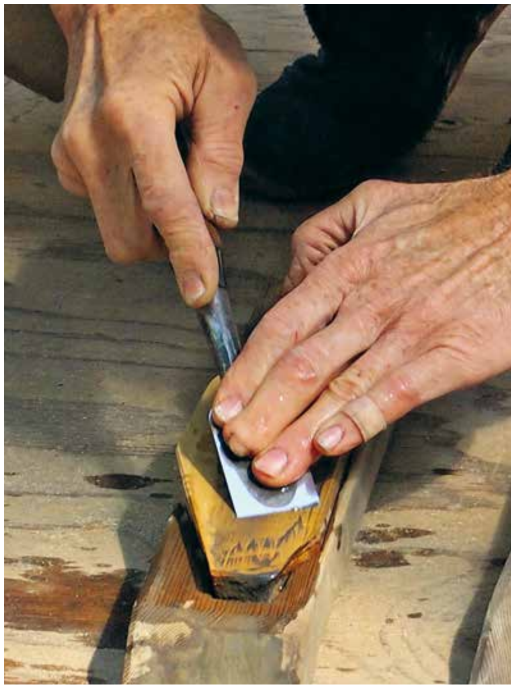
The mortise and tenon joints are then precisely located and drawn on each timber. The layout is carefully inspected by an experienced timber framer and approved before cutting. The old adage "measure twice and cut once" is especially appropriate here because precious timbers are involved.

Cutting the Joinery

Cutting joinery is the systematic procedure of removing wood. Power tools such as mortisers, drills, saws, and routers are used to remove most of the wood. Once roughed out, the

Below: Examining the back of the chisel for flatness. Below right: Sharpening the bevel of the chisel on a Japanese natural water stone.


CREDIT: ZACH COVENTRY


CREDIT: JONATHAN SHAW

CREDIT: ZACH COVENTRY ASSEMBLEY

Laying out a tenon.

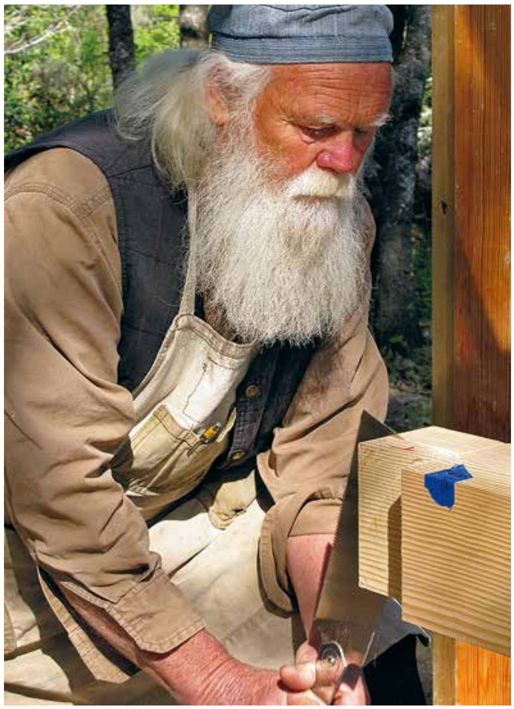
joints are finished with chisels, slicks, and hand planes, carefully respecting the layout lines.

Assembly: Fitting the Pieces of the Puzzle

Once all of the timbers are cut, they are assembled into bents on a level ground surface. Here they are aligned with come-alongs and clamps, fine-tuned to a perfect fit, and finally secured with pegs, wedges, or keys. Bents are built in the reverse order of raising, i.e., the final bent to be raised is the first to be built and will be at the bottom of the stack of bents created in preparation for raising.

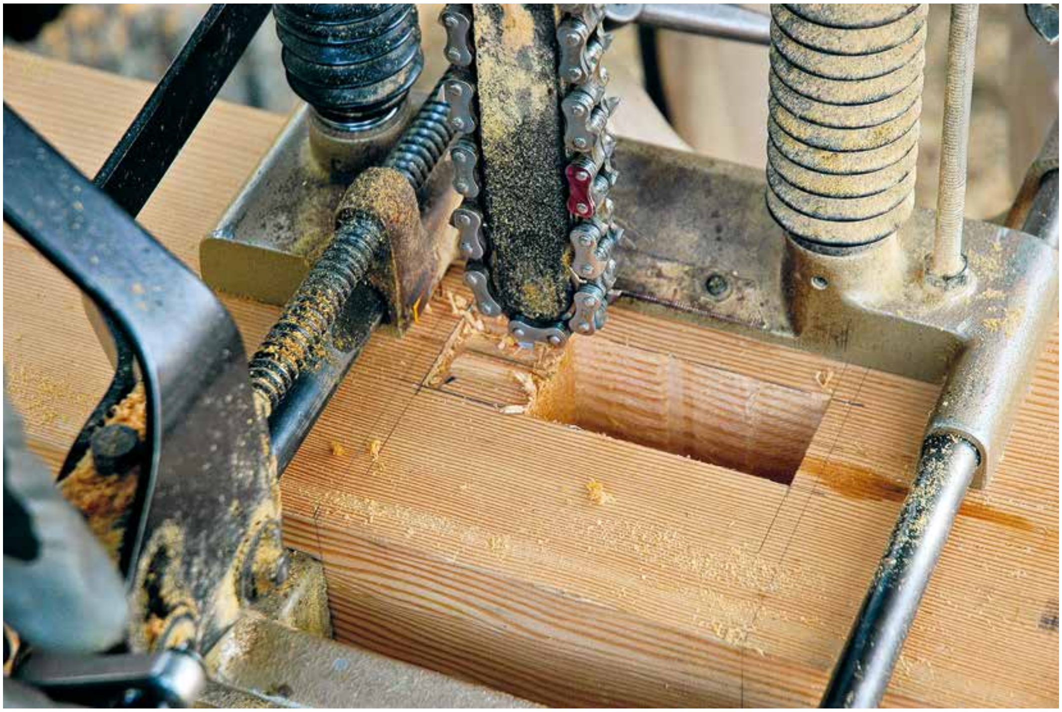
Raising: Joining It All Together

This is the most exciting part of the timber-frame process, where the culmination of



CREDIT: PAULA BAKER-LAPORTE

Sawing a tenon with a Japanese pull saw.



CREDIT: ECONEST CO.

Cutting out a mortise with a chain mortise.

CREDIT: ECONEST CO.

Chisel clean-up of tenon joint.

CREDIT: ROBERT LAPORTE

Students tightening the joinery with clamps and come-alongs.

CREDIT: ZACH COVENTRY

Students assembling wedged through tenon joinery.

CREDIT: JONATHAN SHAW

CREDIT: JON BYRD

hundreds of hours of individual work comes together to create one beautiful entity—the timber-frame heart of the home.

Safely raising tons of wood in the air requires leadership, teamwork, and focus.

The pre-assembled bents are stood up by hand or with the aid of a crane. The first bent is temporarily braced, freeing up the crane to raise the second bent, which is also temporarily braced and spread to receive the connectors that will tie the two bents together. This process is repeated until the entire frame is erected.

With the frame safe and secure, it is racked into a plumb position and the connecting joinery is fine-tuned and secured.

The day culminates with a traditional ridge-top ceremony. A pine bough is secured to the highest point of the building as a symbol of gratitude to nature.

Comparing European and Japanese Timber-Frame Styles

European timber frames are characterized by larger timbers (often hardwood). They employ diagonal braces to stabilize the frame. These are called *knee braces.*

Opposite above:
Hand raising a Taiko beam procured from site.
Opposite below:
Hand raising an EcoNest core.
Right:
A ceremony crowning the timber frame with an evergreen bough.

CREDIT: ROBERT LAPORTE


CREDIT: CATHERINE WANEK

Robert's shop is an integration of European and Japanese timber-frame styles.

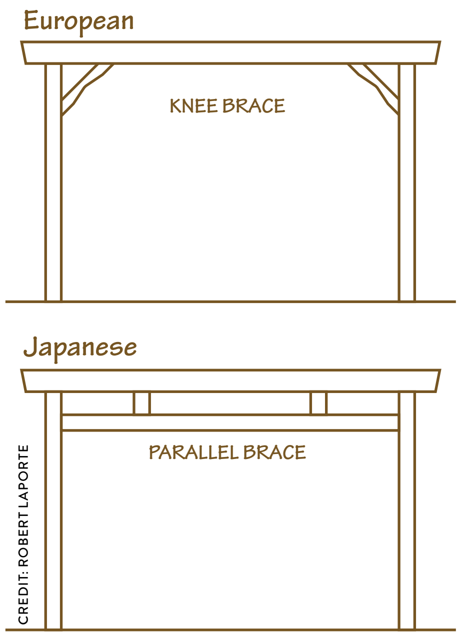

CREDIT: ROBERT LAPORTE

Japanese style timber frame.

In contrast to European timber frames, Asian frames use smaller timbers (often softwood) and a parallel beam system for bracing the frames. This twin-beam arrangement with its short "stub" posts creates "shear diaphragms" that resist racking.

The beauty of both Japanese and European bracing systems is that their flexibility allows them to behave like shock absorbers.

Perimeter timber frames require special attachment considerations when wrapped with LSC. Refer to Chapter 9, the section "Formwork Attachment to Timber Frame."



CREDIT: ROBERT LAPORTE

European timber frame of the Matassoni nest in Colorado.

CREDIT: ROBERT LAPORTE

CREDIT: ROBERT LAPORTE

Chapter 7

Introduction to the EcoNest Light Straw Clay Wall System

History of Light Straw Clay Construction

The history of light straw clay has its roots in wattle-and-daub construction found throughout Europe and Asia. We have been in structures dating back 1,000 years in Japan and 800 years in Germany. The longevity of these buildings attests to the outstanding ability of clay to preserve a building.

In countries where these historic buildings are valued, there is also a flourishing revival of wattle-and-daub practitioners who know how to restore and maintain these buildings

The light version was introduced after World War II, in Europe. The modern examples that Robert studied were infill systems like the wattle-and-daub predecessors, in which the light straw clay mixture was placed between

Ancient Japanese temple with timber frame and plastered bamboo wattle-and-daub infill.

CREDIT: PAULA BAKER-LAPORTE

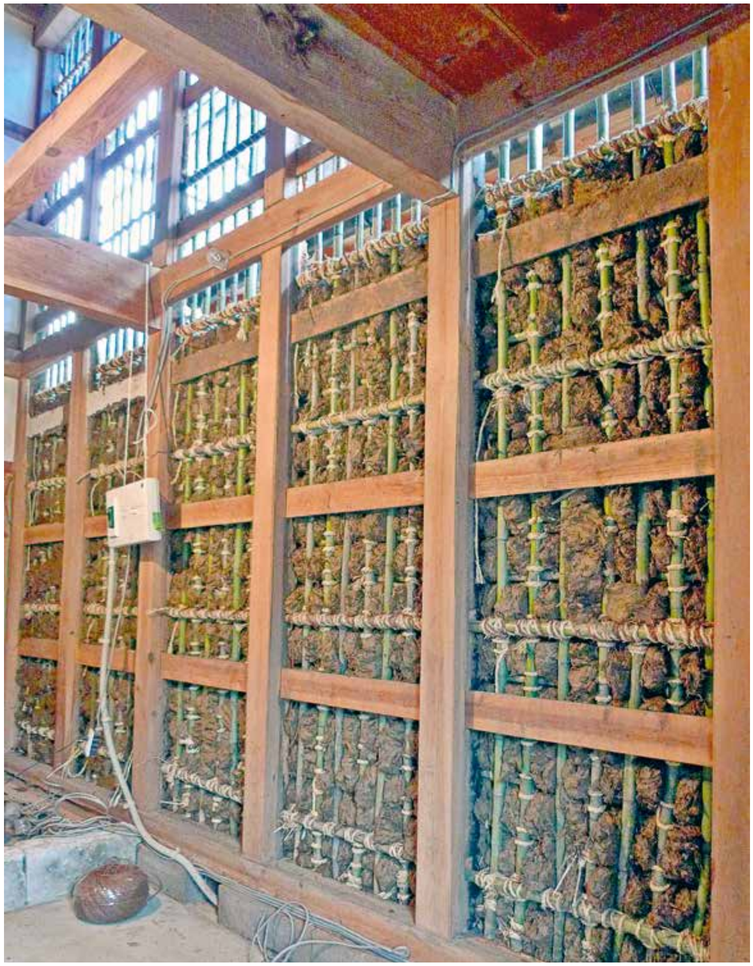
a post and beam framework. In order to meet modern-day energy demands, this "lighter version" doubled the wall thickness and halved the density by introducing more straw, resulting in a radical increase in thermal performance.

In North America, the established practice for timber frames is to wrap them with an insulative material so that a more energy-efficient envelope is created, and the frame is exposed only on the inside. This is most often done with SIPs (structural insulated panels). These are commonly made of foam sandwiched between plywood or pressboard.

Robert combined this more energy-efficient approach with the light straw clay techniques that he learned in Germany. His technique for "outsulating," or wrapping, the timber frames with the natural light straw and clay mixture has been evolving over the past 25 years to a point of efficiency and viability for mainstream builders. The advantages of the LSC wrap are:

Opposite: This abandoned building in Japan reveals its construction. Below: Modern-day wattle-and-daub restoration of historic building in Japan

CREDIT: KYLE HOZHUETER



CREDIT: KYLE HOZHUETER

CREDIT: SPELLER METCALF

CREDIT: SPELLER METCALF

Above: Current wattle-and-daub restoration of historic building in England. Right: Light straw clay infill system as practiced in Germany.

CREDIT: ANGELA WUST ARCHITECT

- Timber-frame structure is completely protected from the elements.
- The LSC is efficient to build because there are no overhead beams to impede loading and compacting.
- Separation of structure and insulation minimizes thermal bridging and air infiltration.
- Heightened aesthetics: the handcrafted timber frame is fully revealed on the inside of the building rather than buried in the wall.

There are five distinct divisions to the EcoNest system of light straw clay building:

1. **Framing:** the matrix of light framework that cages the light straw clay.
2. **Forming:** temporary panels that enclose wall cavities to receive the LSC.
3. **Production:** the process of combining clay soils, water, and straw.
4. **Delivery:** transporting mixed LSC to the walls.
5. **Filling:** the process of compressing the LSC mixture in place.

CREDIT: LAURIE DICKSON

The LSC wall system developed by Robert wraps the frame, protecting it from the elements. The timber frame is completely exposed on the inside.


CREDIT: ECONEST CO.

Chapter 8

Matrix Framework

The matrix is the framework that creates the structure for the LSC wall system. The EcoNest matrix system uses modified Larsen trusses, six each made with a pair of 2 × 4s joined with plywood gussets. When used in conjunction with a load-bearing timber frame, trusses may be placed at 32" intervals. When used as the load-bearing wall, the Larsen trusses must be spaced at a maximum of 24" intervals.

The matrix has the following features:

- Creates straight and stable deep wall trusses, saving on wood use.
- Reduces infiltration and thermal bridging.
- Provides for uninterrupted wall insulation of light straw clay.
- Streamlines door and window installation in thick walls.

- Facilitates the attachment of temporary formwork.
- Supports horizontal stabilizing bars for settlement reduction.
- Defines inside and outside corners.
- Creates wall cavities that are easily loaded and tamped.
- Provides for efficient electrical installation.
- Provides support for cabinetry and shelving attachment.
- Is readily accepted by framers, electricians and plumbers who already have familiarity with conventional framing.

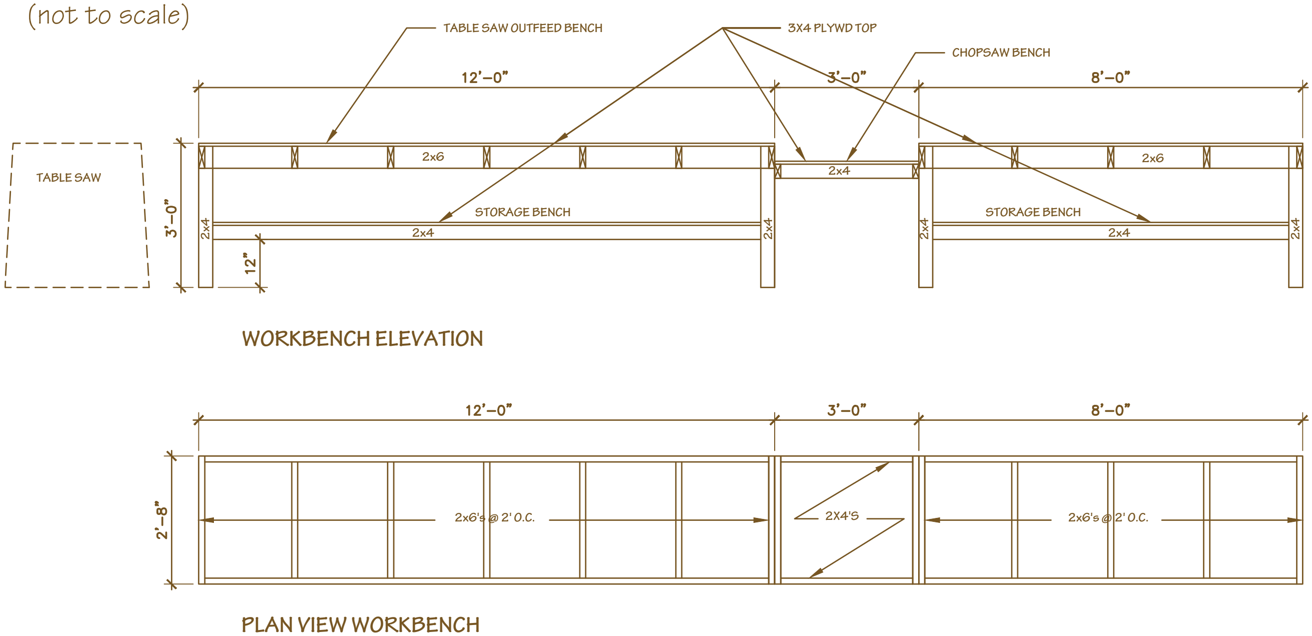
Larsen Truss Fabrication

Efficient, uniform, professional results can be achieved even by novice carpenters by using the following tried and true step-by-step procedures.

Constructing an EcoNest Work Station

Construct an EcoNest work station for matrix production. Whether you are setting up a permanent shop or building a single home, it is well worth your time to create a proper work station for efficient mass production of the many hundreds of framing components (about 1,000 components for an average home). The following plans show our typical work station that we have set up in the permanent

Figure 8.1 EcoNest workbench (not to scale)



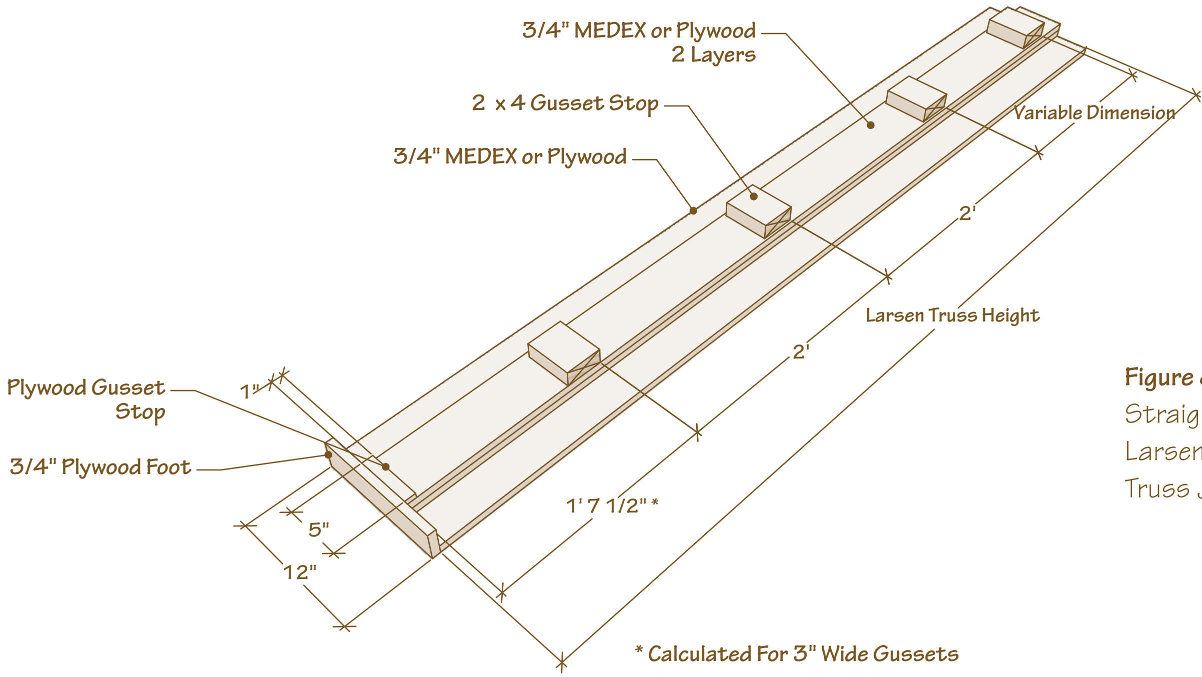


Figure 8.2 Straight Larsen Truss Jig

EcoNest shop; it is also the first thing we build on-site when doing production away from our home base.

Straight Larsen Truss Construction

Straight Larsen trusses are the primary matrix component. To achieve consistency and efficiency, we first build a jig. (A jig is a fabricated template that is used to hold components of the truss in place while assembling them so that each unit will be accurate and uniform with the others.)

Constructing standard Larsen truss jig:

1. Create the base, screwing two layers of ¾" plywood together measuring 12" wide × height of desired truss. We typically make the jigs 96" tall.
2. To this base attach a spine consisting of two layers of ¾" x 5" plywood (or other stable sheetgoods) down the center of the base for its entire length. This serves as a spacer for the two studs.
3. Screw gusset stops to the spine, per diagram, for accurate placement of plywood gussets. Note the bottom gusset stop is placed so that the bottom of the first gusset is located 1" from the bottom of the studs. This allows space for electrical wiring to pass under this gusset. Electricians love

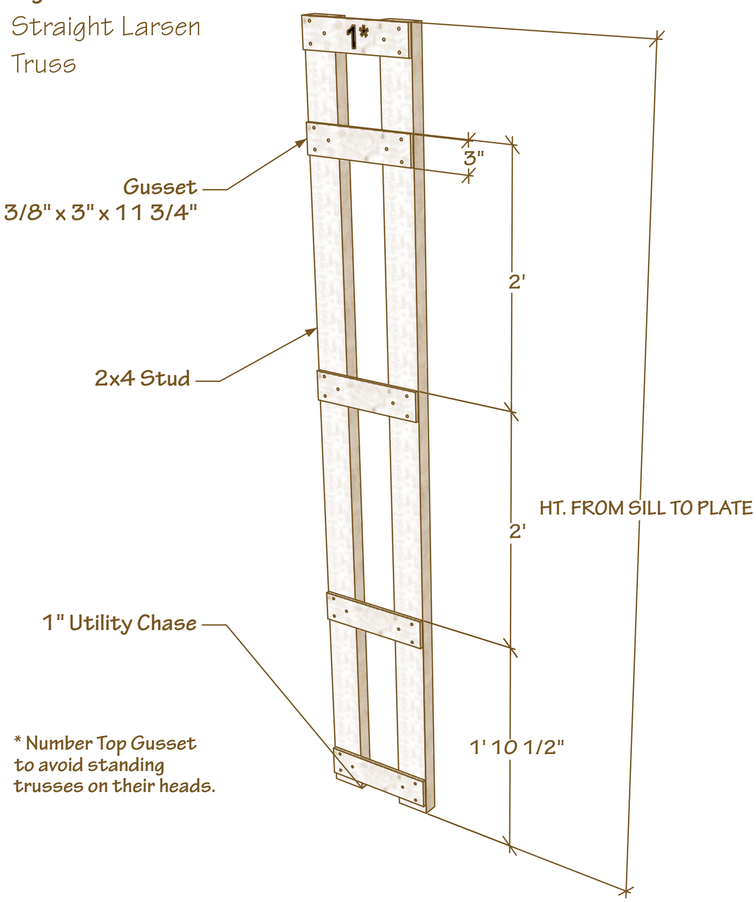
this thoughtful detail, which eliminates the work of drilling passageways for wiring.

4. Screw a plywood foot to the bottom end of the jig, per diagram, for accurate bottom alignment of studs.

Constructing Straight Larsen Trusses

1. Pre-cut all 2 × 4 studs to length and ⅜" plywood gussets to a size of 3" tall x 11⅞" wide.
2. Set Larsen jig on work table to a comfortable working height, typically 32"–36" above floor/ground.
3. For maximum efficiency, a pneumatic staple gun is used for fastening the gussets to studs.
4. Load jig with two studs aligned with bottom foot.
5. Fasten the gussets with three staples/ fasteners per connection.
6. Label the top gusset to ensure that Larsen trusses are installed right side up.

Figure 8.3
Straight Larsen Truss



Student fabricating a Larsen truss in the jig.

CREDIT: JACKSON PORETTA

Constructing Corner Larsen Truss Jig

Corner trusses are stouter, consisting of an inside and an outside 4 × 4 corner connected with paired 2 × 4 gussets. Although they are more complex, the following jig greatly simplifies their construction (refer to pg. 118).

1. Frame a base platform of 2 × 4s with ¾" plywood screwed to the top. The platform will measure 24" wide x height of truss.
2. Cut three cradle pieces from 4 × 4s and notch per illustration. These will hold the 4 × 4s of each corner truss diagonally in place during fabrication.
3. Screw a cradle component to the platform at top, center, and bottom locations, per illustration.
4. Screw a 2 × 4 gusset stop, centered on top of each cradle.
5. Attach 4 × 4 × 7 gusset stop bases to platform per diagram, and then attach 2 × 4s to top of gusset bases.
6. Note the bottom gusset stop is placed so that the bottom of the first gusset is located 1" from the bottom of the studs to provide for an electrical raceway and aligning the resulting corner gussets with those of the straight trusses.
7. Screw a plywood foot to the bottom end of the jig, per diagram, for accurate bottom alignment of the truss.

Constructing Corner Larsen Truss

Each corner truss will consist of two 4 × 4s connected with double 2 × 4 gussets @ 24" o.c. (on center) vertically.

1. Pre-cut all 4 × 4 corner posts to length.
2. Rabbet all inside corners per diagram on a table saw or a skill saw with a fence. This rabbet detail facilitates attachment of formwork.

Corner Larsen truss jig.

CREDIT: ECONEST CO.

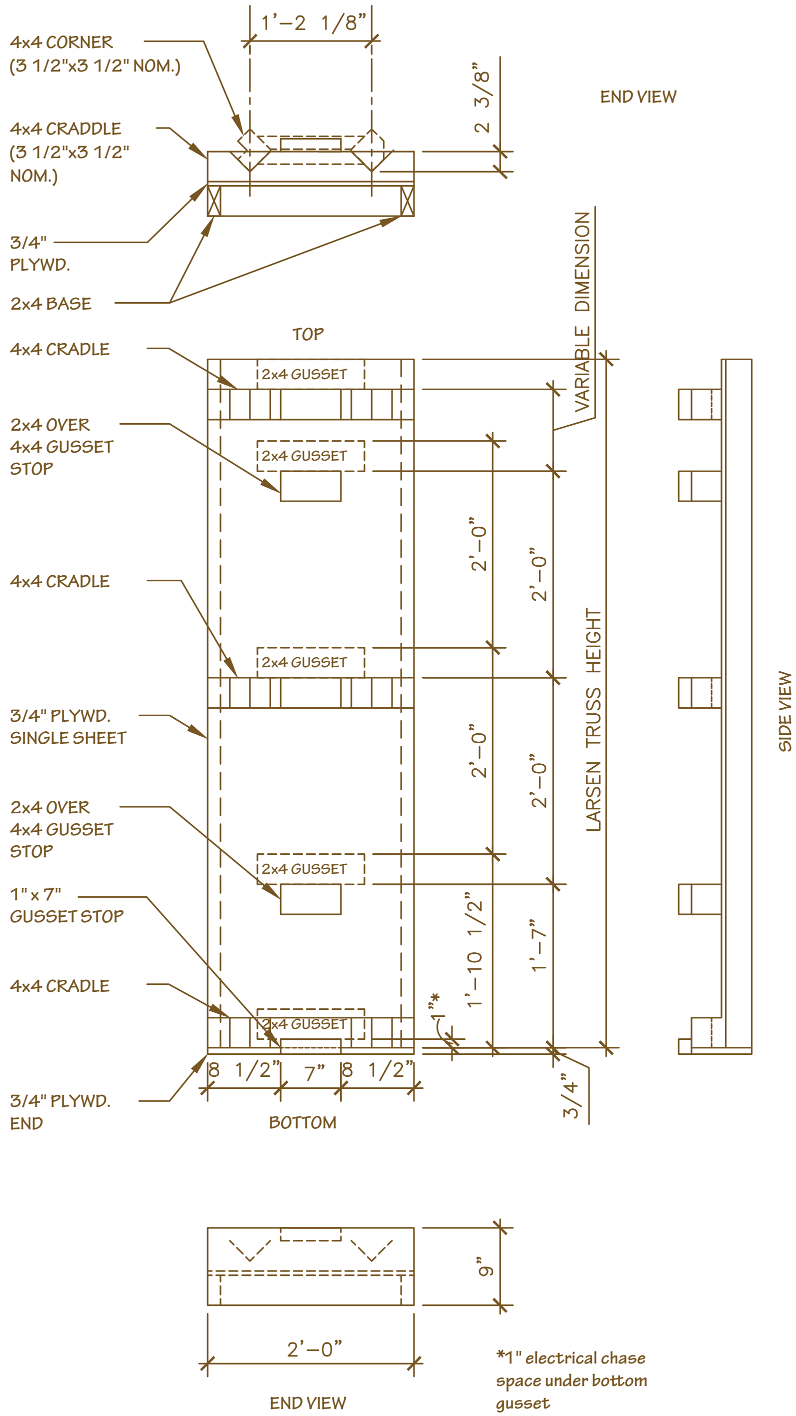


Figure 8.4
Corner Larsen truss jig

3. If the exterior is to be finished with plaster with rounded corners, miter outside corners for desired radius. Typically we do a 1 × 1" miter.

4. Pre-cut all 2 × 4 × 12¾ (longest dimension) gussets with 45-degree mitered ends, per illustration.

TIP: The 12¾" length deliberately creates a gap between the pair of gussets and ensures a tight fit to the 4 × 4s despite any slight lumber distortion.

5. Set jig on work table to a comfortable working height.

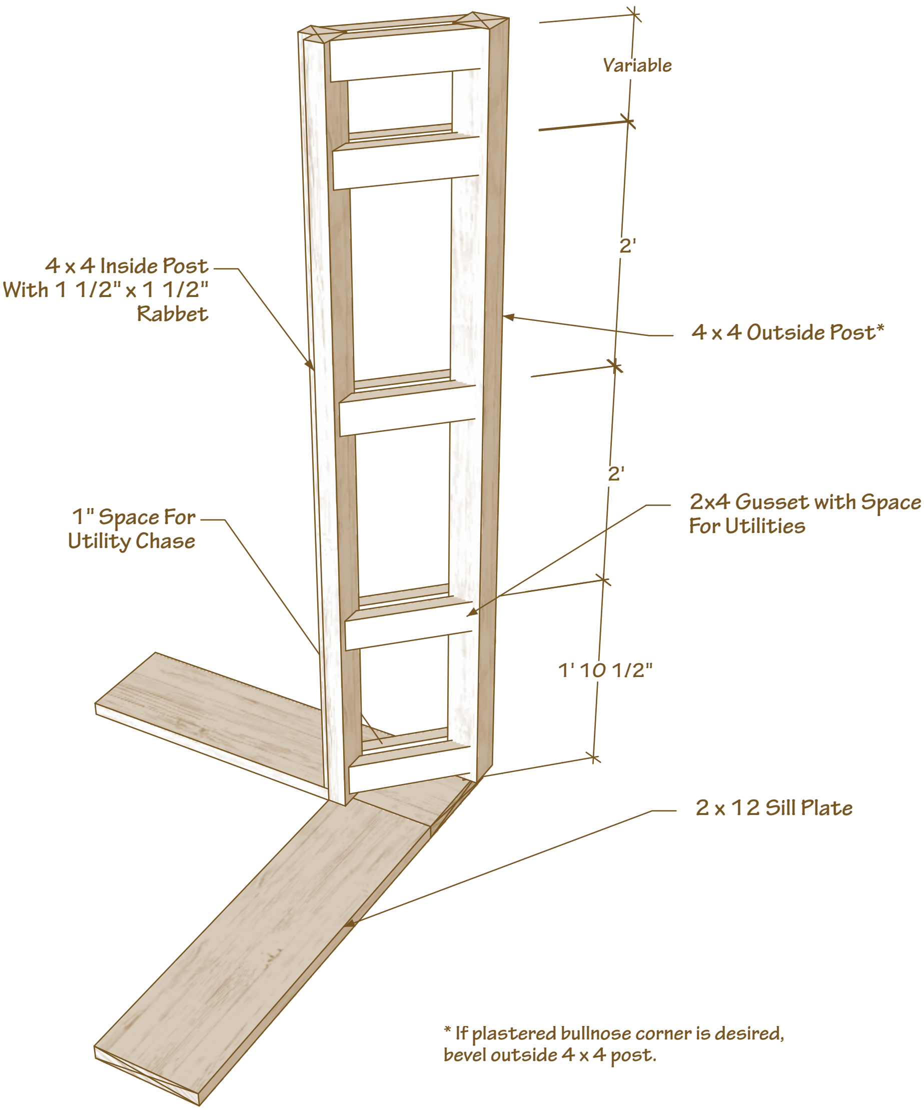


Figure 8.5
Plan view of corner Larsen truss

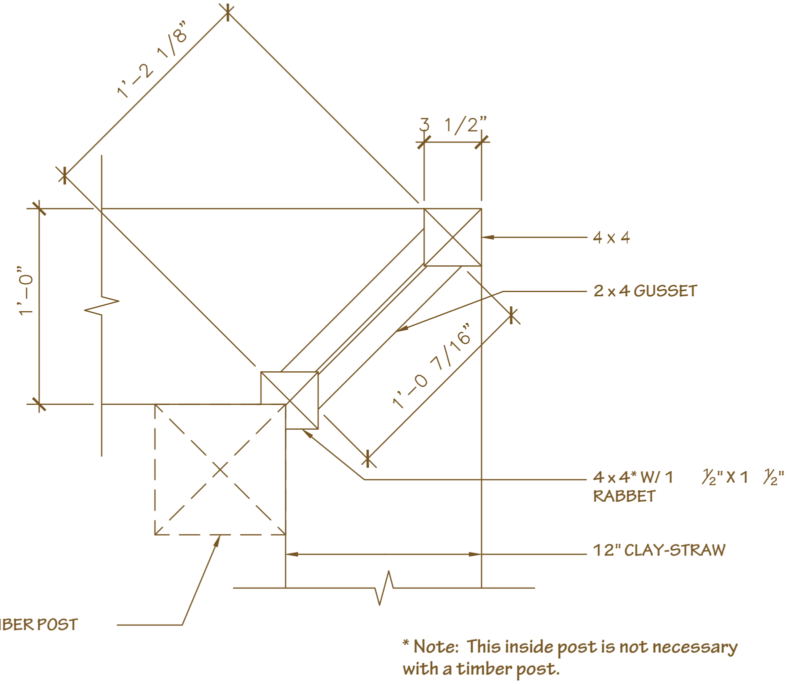


Figure 8.6
Corner Larsen,
plan view

Corner Larsen
truss in jig.

CREDIT: ZACH COVENTRY

6. For maximum efficiency, a pneumatic nail gun is used with 3" nails for fastening the gussets to studs.
7. Load jig with two posts aligned with bottom foot.
8. Fasten the gussets with two fasteners per connection.
9. Label the top gusset to ensure that trusses are installed right side up.

Door and Window Openings

As a part of the matrix, door and window jambs, sills, and headers are all pre-fabricated according to the rough opening sizes provided by the window/door manufacturers. A sample worksheet has been provided in Appendix B to help you accurately calculate all the necessary components.

Constructing a Window Unit

Each window unit will consist of the following components: header box, two jambs, and two sills. To determine lengths for each component, use the worksheet in Appendix B.

Constructing the Header Box

The header box is an insulated box beam that consists of two headers with plywood fastened to the top and bottom ends to create a 12"-wide box. Depth will vary depending on size of headers as determined by structural load. To allow access for future insulation, the bottom of the box is left open and stabilized with 4 × 12 plywood ties at either end of the box. In the past, we would insulate this box with a dry, lightweight straw/clay mixture but now find it more practical and energy efficient to insulate with batts of mineral wool, cotton, or wool.

Constructing the Jambs

Each jamb consists of two jack studs, two king studs (eight per window), and plywood.

1. Calculate length of king and jack studs as per Appendix B and cut to length.
2. Calculate and cut two pieces of ¾" plywood per drawing in Appendix B.
3. Using the straight Larsen jig, align and nail the king and jack studs together.
4. Align plywood to the top of the jack studs and fasten, creating a 12"-wide assembly.
5. Repeat steps 1–4 to create second jamb assembly.

TIP: There are two ways to finish a window recess: either with wood casing or plaster. If you are plastering your window jambs and want rounded corners, cut the plywood 11¼" wide and set it back from the interior edge of the jack stud to facilitate radiused lath attachment. This will create a left and a right jamb.

Preparing Mitered Sills

Unlike conventional wall framing, where sills are oriented horizontally, sills in LSC walls are oriented vertically, allowing for the filling and tamping of LSC. The bottom edge of the sill is mitered to facilitate loading and tamping under the sill. This detail eliminates voids in the LSC.

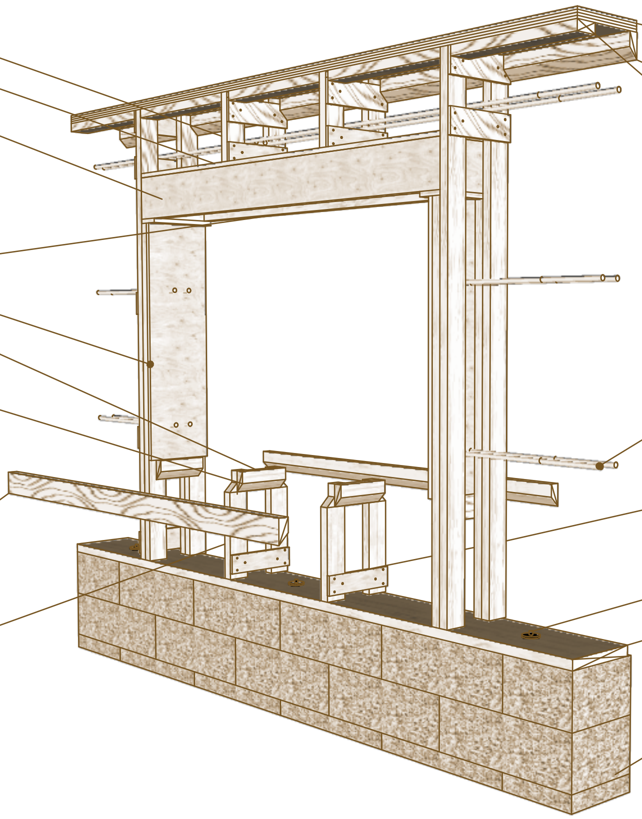
This mitered detail is standard for all blocking placed horizontally between Larsen trusses.

TIP: Two mitered sills can be created from a single 2 × 6 ripped lengthwise at 45 degrees on a table saw.

Assembling the Window Unit

1. On a flat surface, clamp and screw the header box and inner sill between the two jambs.

Figure 8.7
Window Framing exploded view



2. Flip unit over and re-clamp header and outer sill and fasten. We prefer to use 3" screws to draw joints together and create a tight assembly.

Building Cripple Larsen Trusses

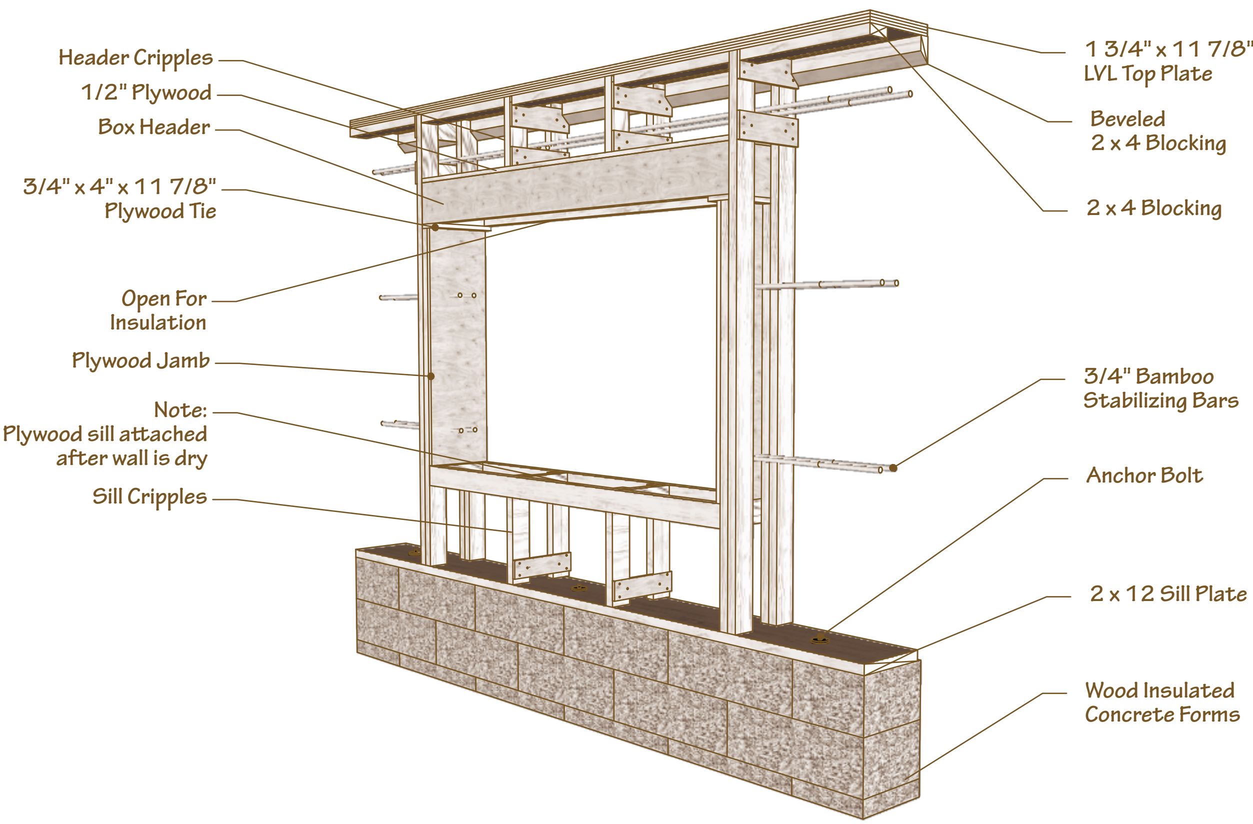
Cripples are short Larsen trusses that extend from the top of the window header box to the top plate and from the window sill to the bottom plate.

These are also fabricated in the straight Larsen jig.

1. Calculate height of sill and header cripples per Appendix B.
2. Sill cripples require notching to seat the window sill.

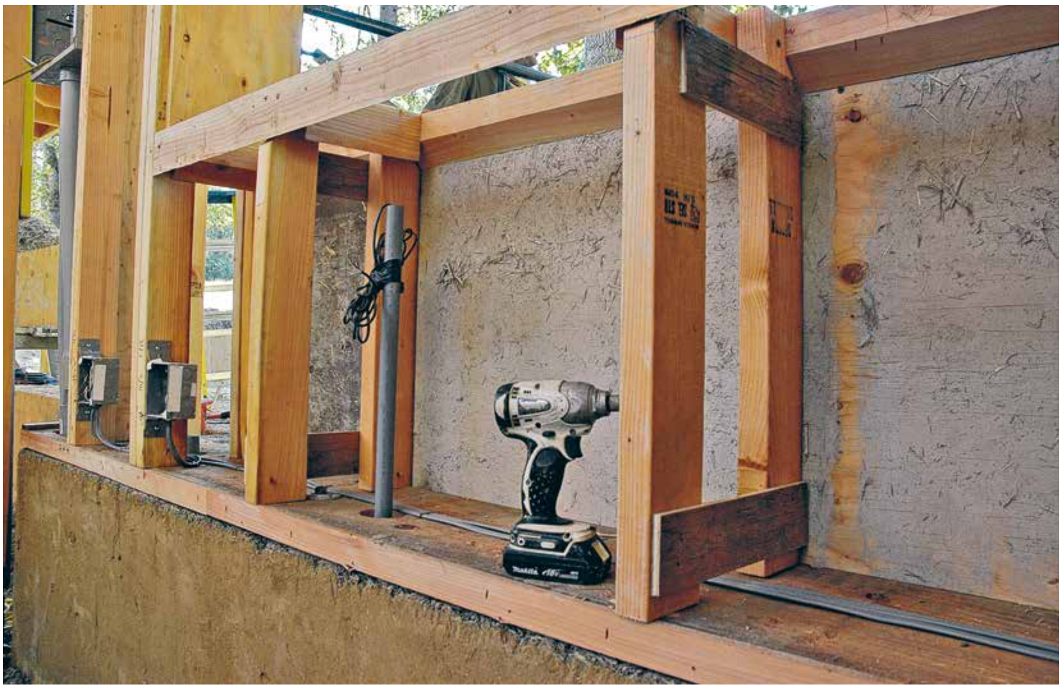
TIP: The notches can be cut on several sill cripples at once by clamping them together.

Figure 8.8
Window Framing



Students installing a window buck.

CREDIT: ECONEST CO.



Cripple Larsen truss under window.

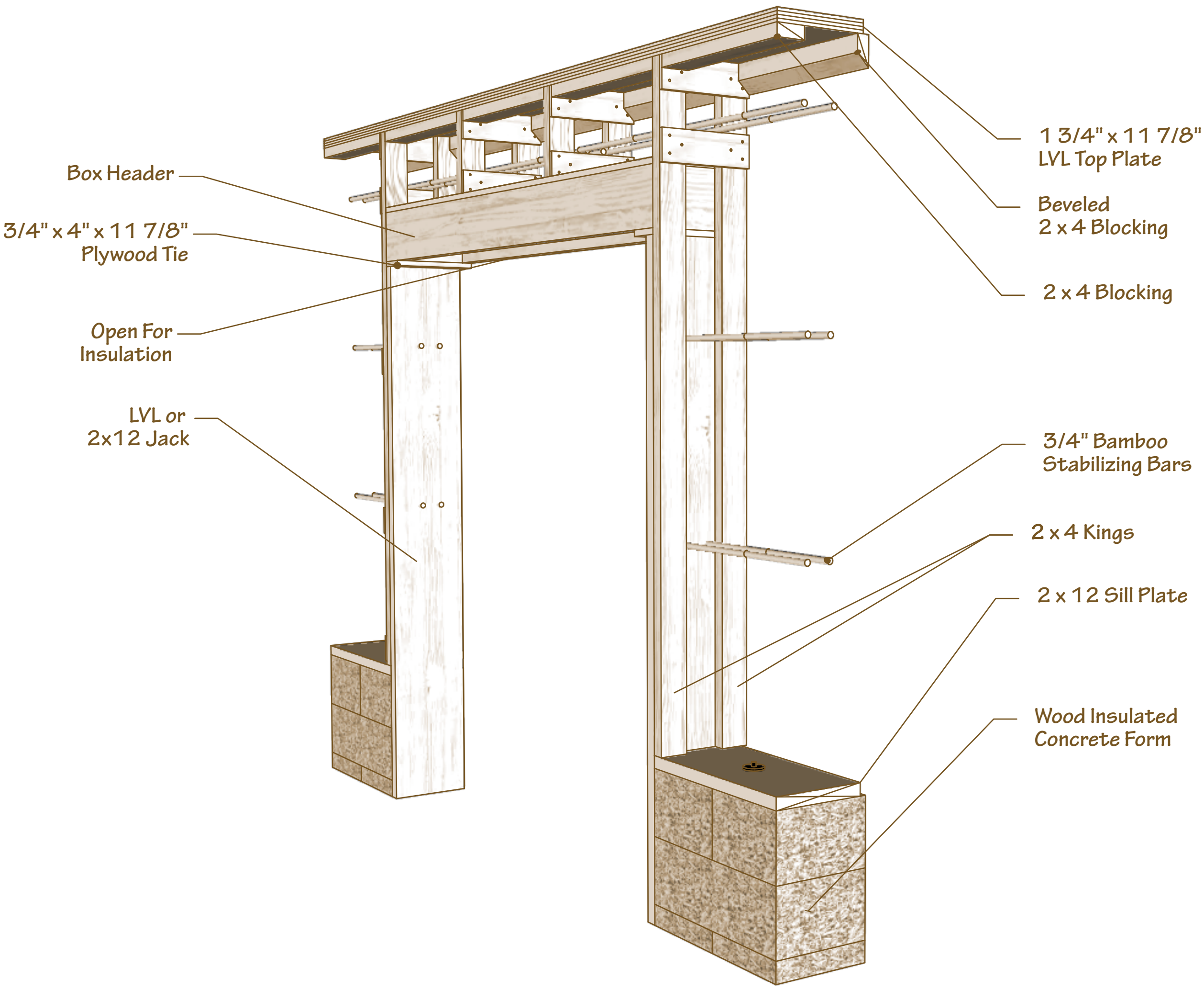
CREDIT: ZACH COVENTRY

Building a Door Unit

Door units are built in a similar fashion to windows, but without the sill construction. A 2 × 12 or 11⅞"-wide LVL (Laminated Veneer Lumber) is the jack that supports the header box. Door jacks sit on the sub-floor while the king studs bear on the sill topping the stem wall, per illustration.

Header box construction is the same as for a window previously described. 2 × 4 king studs are screwed or nailed to the jack and the assembly is fabricated in the same fashion as a window, clamping the header box and jambs together to facilitate controlled assembly.

Figure 8.9
Door framing



TIP: Stabilizing bar considerations: Our horizontal stabilizing bar of choice is ¾" bamboo. If bamboo is not available, 2 × 2s can be substituted. When using bamboo, pre-drill 1" holes in door and window jambs, making certain that the holes are aligned with the top of the gussets in the Larsen trusses.

Summary for Building Window and Door Framing Units

The sequence for building a door or window unit is as follows:

1. Complete the Larsen worksheet calculating all required dimensions for door and window components. (See Larsen Worksheet in Appendix B.)
2. Cut, assemble, and label header units.
3. Cut, assemble, and label jamb units.
4. Mill and label window sills.
5. Assemble header, jamb, and sills.
6. Cut, fabricate, and install cripple Larsens (both sill and header, where applicable).

Matrix Assembly

Non-Load-Bearing Walls

Where a full timber frame is in place, along the perimeter of the building the Larsen truss wall system is non-loadbearing. The IRC (International Residential Code, see Appendix C) allows Larsen trusses to be spaced at 32" o.c. maximum.

Having the timber structure in place expedites the installation of the matrix. Larsen trusses and window and door units are directly attached to a stable timber frame, which has been previously erected.

When erecting the various matrix components, lightweight clamps are useful for securing them to the structure, leaving both hands free for adjusting and attachment work.

TIP: To protect the timber frame from damage during construction, we wrap the posts with temporary boards or strips of plywood. When clamping components to the timber frame, a protective piece of plywood is inserted between the jaw of the clamp and the timber to preventing unsightly denting in the timbers, which will be exposed in the completed building.

Load-Bearing Walls

When there is no perimeter timber structure to secure and align the numerous wall components of the matrix, a temporary "strongback" is set up. The strongback serves as a beam to which all matrix components are temporarily attached until the straw clay is placed in the wall and the final top plate is secured. It creates temporary structural stability without overhead obstruction that would otherwise hinder loading and compacting the LSC.

When strongbacks are required, the matrix framing procedure is as follows:

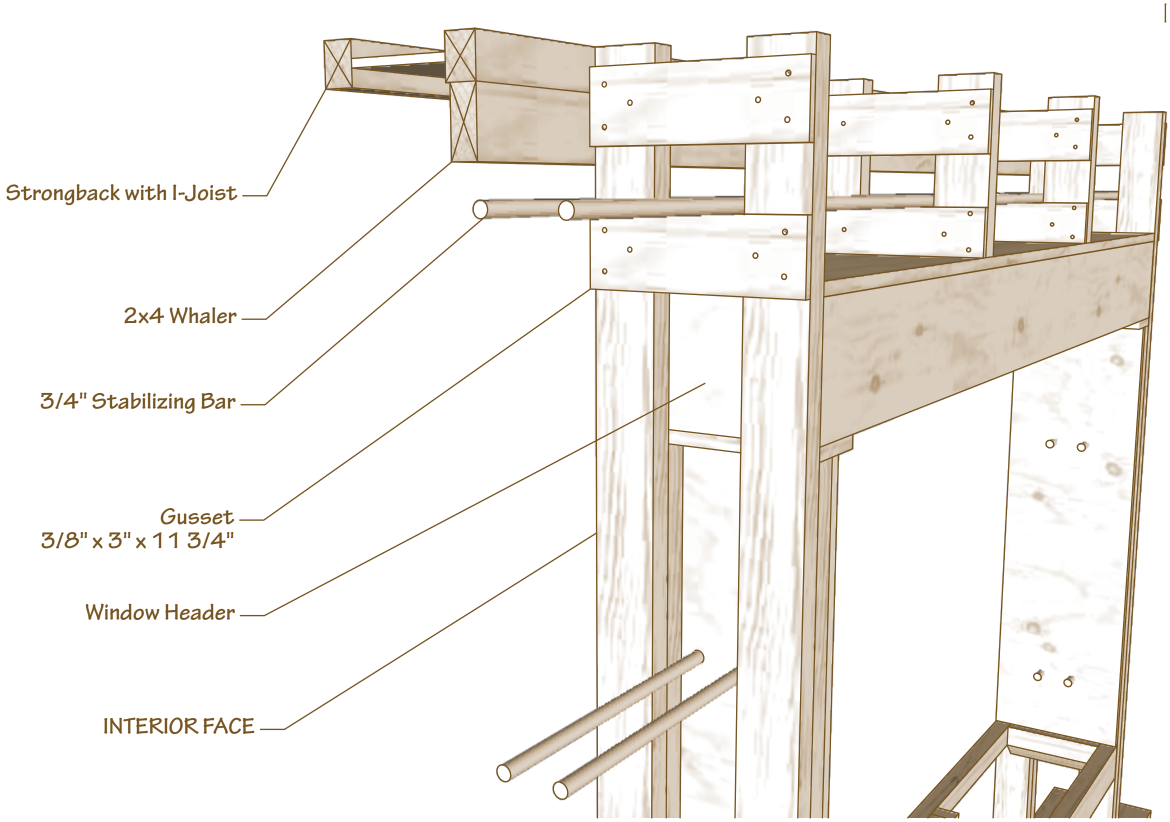
1. Fabricate a strongback for each wall per illustration. Although 2x lumber could be

used for this purpose, we prefer to use manufactured wood I-beams, which create a lightweight, long, strong, stable, and re-useable "straight edge." Wood I-beams are available in lengths of up to 60'. A 2 × 4 "whaler" (temporary nailer) is screwed to one flange of the I-beam to create an L-shaped strongback. To ring the interior with a level horizontal plane, the inside corners of each strongback must have a 45-degree miter.

2. Stand corner Larsen trusses (CLT) in place and nail or screw to sills. Plumb CLTs and temporarily brace with diagonal 2 × 4s fastened to outer sill plates and upper outside corner of the CLT. See photo.

TIP: Tilt CLTs ¼" inward to compensate for the wall's tendency to drift outward under the pressure of compacted straw/clay.

Figure 8.10 Strongback Installation



3. Stand door and window units in place. Attach to the sill and temporarily brace with diagonal 2 × 4s, running the bracing perpendicular to the building outward to ground stakes.
4. Install the strongbacks: First screw the strongback flush to the top of the inside corners of a wall with 3" deck screws through the whaler. The strongback is usually placed on the interior face of the wall so as not to interfere with exterior loading and tamping the clay straw. Occasionally a site will dictate that it is more practical to fill a wall from the inside, in which case the strongback is attached to the outside.
5. Next screw the strongbacks to the top of the standing door and window units.
6. Now that the strongback is stabilized, set, plumb and screw the straight Larsen trusses to the whaler of the strongback.
7. Once all components in a wall have been temporarily secured to the strongback, we now install beveled 2 × 4 blocking at the top interior Larsen truss to strengthen the future connection between the top plate and the wall. The blocking is installed vertically to maximize the opening for filling the cavity and beveled so that the LSC flows to the face of the wall, eliminating voids.

Erected and braced matrix. Note the strong back running to the inside of the top plate on this load-bearing structure.

CREDIT: ECONEST CO.

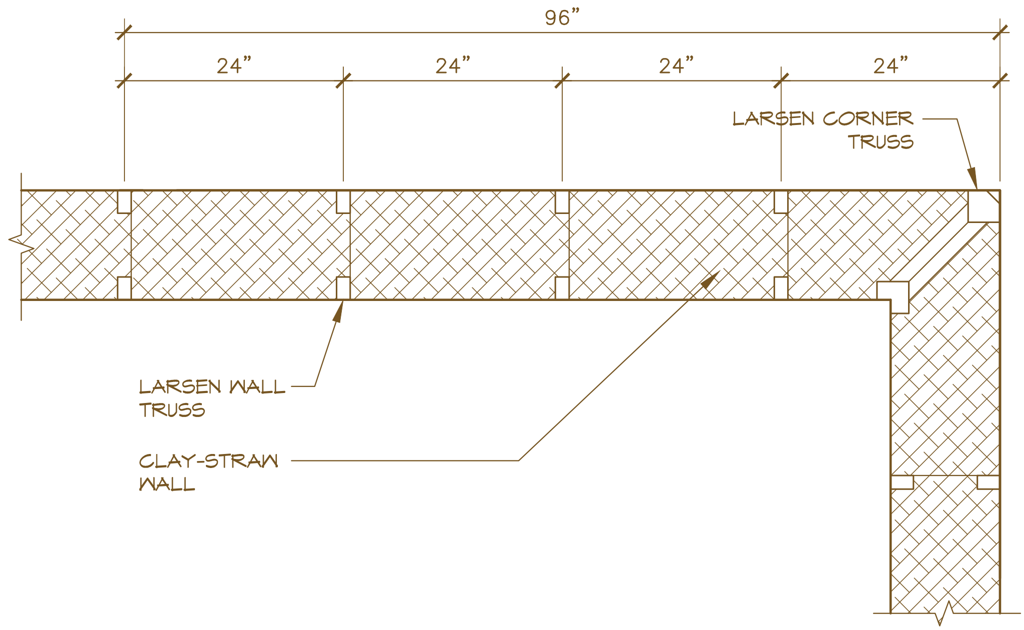


Figure 8.11 Larsen truss wall layout (load bearing clay-fiber walls)

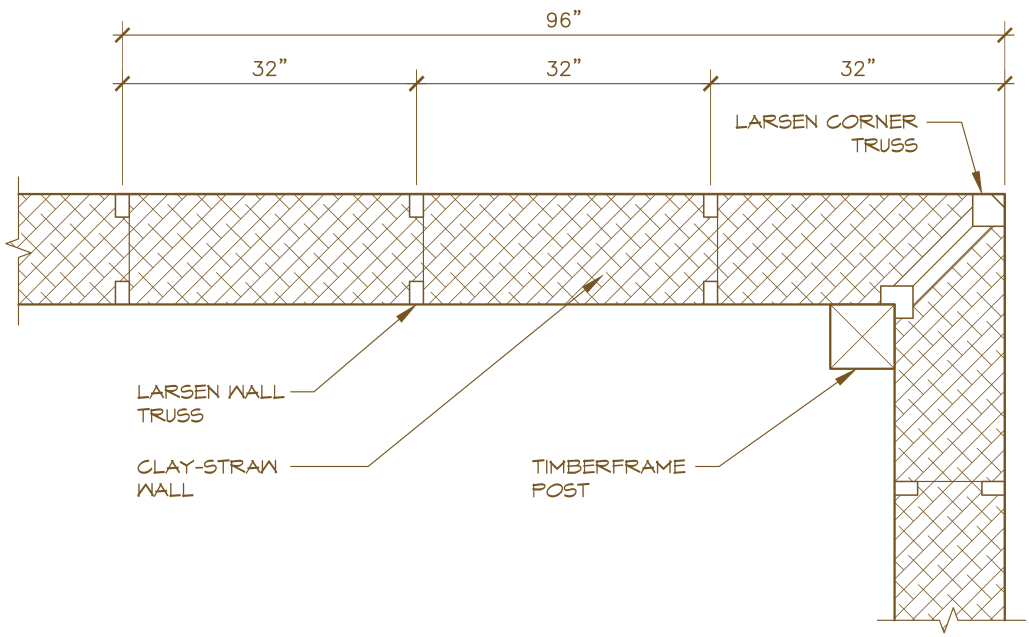


Figure 8.12 Larsen truss wall layout for timberframe (non-load bearing clay-fiber walls)

8. Temporary bracing can be removed once the interior formwork is in place.
9. When the straw clay has been completed and a top plate is installed, capping the walls and completing the matrix, the strongback can be removed.

Planning For Interior Attachments

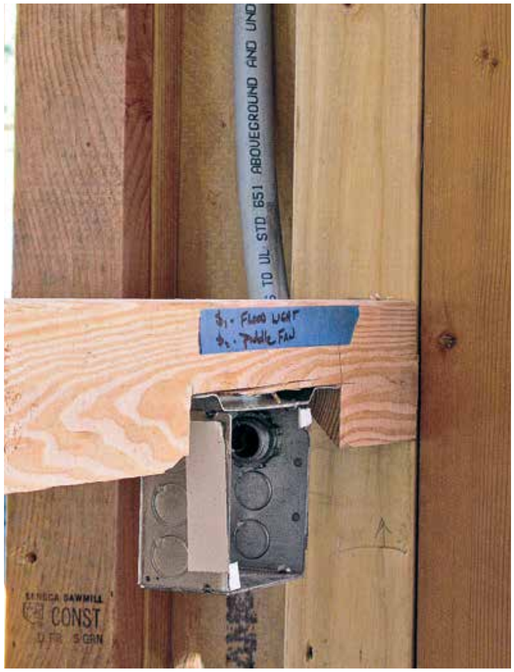
Once the matrix is standing, additional studs are added as needed for attachment of interior walls, cabinetry, and hardware. It is important to provide the additional support without restricting the wall compaction process. 2 × 4 studs are added to the inside face of the wall as needed. Cabinetry will require support every 16", with additional support at each end.

The perimeter wall will require additional framing where interior walls attach if there is not a Larsen truss at these locations. Locate all interior partitions and install a single 2 × 4 nailer in the matrix as required. Review plans carefully with special attention to kitchens, bathrooms, dens, and closets to determine all locations where additional framing may be required at present or in the future.

Incorporating Mechanical and Electrical Systems

Electrical Installation

Electrical rough-in is best performed upon completion of matrix and before the formwork is installed. This is also the time to install



CREDIT: ECONEST CO.

Electrical conduit in place prior to filling for future wiring.

conduit for situations that will require additional wiring after the LSC is in place. In the event a wiring change is required after the walls are completed, it is possible to channel the LSC to run additional wiring.

As previously mentioned, the bottom gusset on the Larsen truss is elevated 1", leaving a pathway for ease of electrical wiring prior to loading the walls with LSC. All wiring should be attached to the matrix, avoiding situations where wires are vulnerable during the loading and tamping of the light straw clay.

In a situation where an outlet or fixture must be located such that it is not in contact with the matrix, additional horizontal blocking must be added. Bottom of blocking should be beveled to prevent voids in the LSC. Refer to illustrations.

There are three types of wire generally accepted by code officials for burial in the LSC walls. These are UF, MC, and various types of conduit systems. UF (underground feeder) will be the most economical. We often use MC (metal clad) cable in cases where electromagnetic radiation is of concern (the metal cladding will block AC electric fields). We advise checking in with your electrical inspector and electrician for acceptable practice in your location.

Electrical Panel Installation

Whenever the main electrical panel is installed in a LSC wall, we create a custom bay the width of the electrical panel, typically 15" for a 14½" wide panel and the depth of the outer 2 × 4s of the Larsen truss. This bay is dammed off from sill to plate with a sheet of plywood, creating a 4"-deep raceway for ease of attachment of wiring and for recessing the electrical panel flush with the finished wall. Once wired and before sheathing, any space in the chase is insulated. The remaining 8" between the plywood and interior face of the Larsen truss is insulated with LSC or other appropriate insulation.

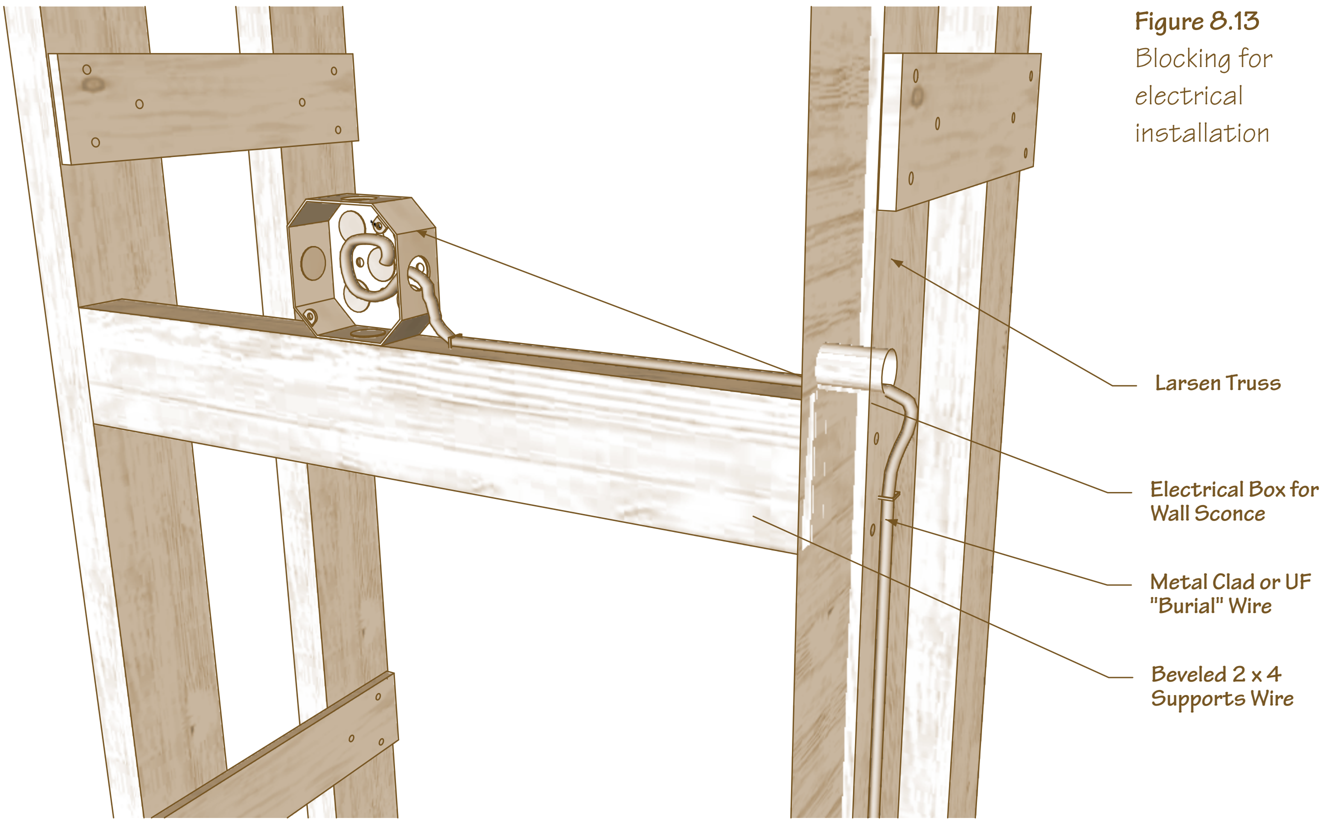


Figure 8.13 Blocking for electrical installation

Electrical conduit in-place prior to filling for future wiring.

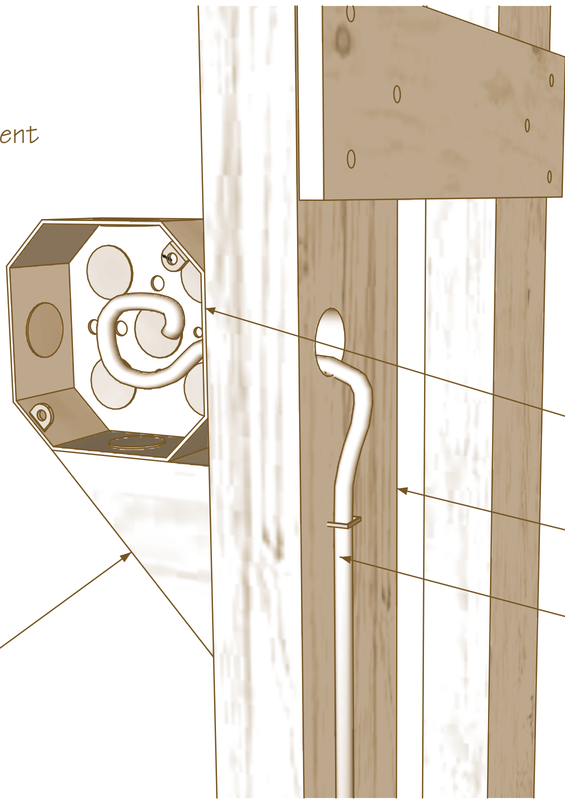


Figure 8.14
Outlet attachment to Larsen Truss

TIP: We install an empty conduit between the attic and the electrical panel to accommodate future electrical changes.

Plumbing

For ease of access and cold weather protection, plumbing supply lines are placed in interior partition walls wherever possible.

When supply lines are necessary on an exterior wall, a chase, similar in construction to the electrical panel chase previously described, is created using the inner stud space of the Larsen truss. The remaining 8" of LSC protects the lines from freezing. The supply lines in the chase behind the sink cabinet are left uninsulated so that they are tempered by the

CREDIT: ECONEST CO.

Special matrix framing in the area behind the kitchen sink has a 2" space on the inside dammed off for running piping. LSC will fill the 10" behind it.

interior climate. Propane or natural gas lines also receive a designated accessible raceway on the warm side of the LSC wall.

TIP: To facilitate pre-workshop plumbing, construct and erect the matrix for the kitchen before the workshop. The kitchen sink vent should be installed prior to the workshop as well. If the bathroom requires venting in an exterior straw clay wall, erect the necessary matrix components to facilitate this venting.

Venting

Because windows are often located in front of sinks, the vent pipes are easily diverted into the raceway created by the double king and jack studs. The top and bottom plywood of the header box will require a ½-round notch.

CREDIT: ROBERT LAPORTE

Vent stack tucked into window buck. Electrical panel chase shown beside it.

CREDIT: ECONEST CO.

Chapter 9

Formwork

Temporary formwork is used to contain the LSC during the filling and tamping process. Three-quarter-inch plywood is ideal because it is light enough to be installed by one person, hefty enough to withstand the forces of compaction, and durable enough to be re-used.

All formwork is attached with 2" deck screws. Torque drive or square drive screws work best. Avoid drywall screws, which break easily and are then difficult to extract.

We use two kinds of formwork: *full forms* and *slip forms.* Full forms are used on the interior and remain in place while the wall is being filled, whereas slip forms are moved up the wall incrementally as it is filled.

Ideally, all formwork is removed as soon as the wall is completed, allowing the walls to begin the drying process. Formwork should never be left on more than 48 hours after it is filled because superficial mold can begin to form on the surface of the LSC due to insufficient air flow.

Interior Formwork: Full Forms

The ¾" plywood used for interior formwork is recycled for roof sheathing. It is therefore practical to use full sheets of plywood and avoiding cutting as much as possible. When cutting plywood is unavoidable, reduce it in 16" or 24" modules, which will make it more useful for other purposes later. To minimize plywood cutting, allow formwork to run past door and window openings.

For attachment purposes, it is practical to add the occasional 2 × 4 stud on the inside wall to create an 8' module, minimizing plywood cuts and waste without impeding access to the filling process.

Forms should be screwed 8" o.c.

TIP: Double checking that no screws are missed is well worth the time because bulging walls or form blow-outs are time-consuming mistakes, best to avoid.

Full plywood forms installed on interior, and first tier of slip forms installed on exterior.

CREDIT: ROBERT LAPORTE

Formwork Attachment to Timber Frame

The simplest method of installing full formwork to a timber frame without leaving visible blemishes is to first install permanent screwing "flanges" to the backside of the timbers on the exterior walls.

Flanges are ripped strips of 2" wide ¾" plywood (chosen because of its resistance to splitting when screwed). The flanges are carefully fastened to the timber, leaving 1" exposed for screwing the formwork. The interior full form is then screwed to the flange with 1¼"-long deck screws. Avoid longer screws, which would penetrate the flange and cause a potential safety risk to people working inside the wall.

Japanese braces are easy to fit plywood forms to without any offsetting because of their rectangular shape. European timber frames have diagonal bracing called *knee braces.* We offset knee braces 1" to the inside. This offset will allow the ¾" interior form plywood to slide behind the brace, eliminating the need to custom cut plywood formwork (which would probably become waste because of its curved and triangular nature). To prevent the interior plywood form from becoming jammed against the brace, set removable wedges between the back of the brace and the plywood.

CREDIT: ZACH COVENTRY

Student installing 2"-plywood strip flanges to back side of timber frame in preparation for attachment of full interior forms.

CREDIT: ROBERT LAPORTE

Exterior Formwork: Slip Forms

Re-useable slip forms are made by screwing a 2 × 4 whaler to ¾" plywood using 2" deck screws at 8" o.c. Full slip forms measure 2 × 8', as per diagram. Half slip forms 4' long, and quarter slip forms 2' long are handy for shorter wall sections. For a typical 1,000–2,000 sq. ft. home, we recommend having a minimum of 12 full slip forms pre-made.

TIP: Offset the whaler ½" from the edge of the plywood. This creates a lip which serves as a keyway for the insertion of the next slip form, allowing for easy "one person" formwork installation and seamless walls.

Slip Form Attachment

The bottom of the lowest slip form, Tier One, is installed level with the bottom of the sill and screwed 8" o.c. horizontally to the sill and vertically to each Larsen truss. Subsequent slip forms only require three screws per truss because of the tongue-and-groove design.

As previously noted, the Larsen truss layout on the exterior will be at 24" or 32" centers, providing attachment for 8' long slip forms.

Plywood flanges installed to back side of post.

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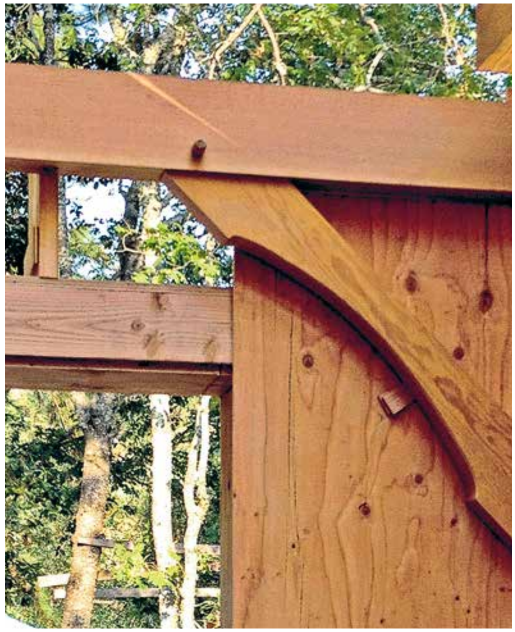

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Knee brace spaced 1" from wall allowing ¾" plywood form to slide in behind it. Wedge allows for easy removal of formwork.

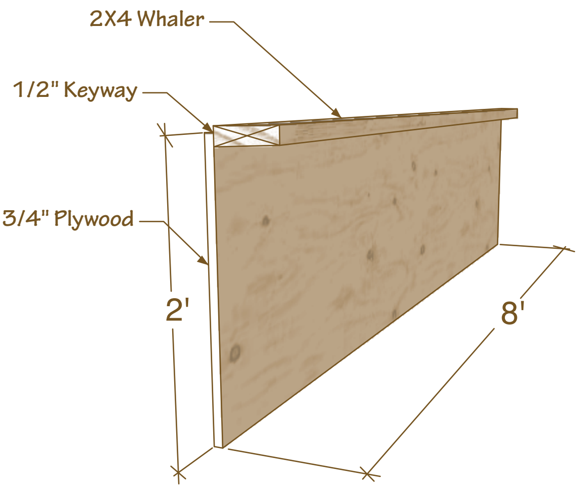

Figure 9.1
Standard slip form

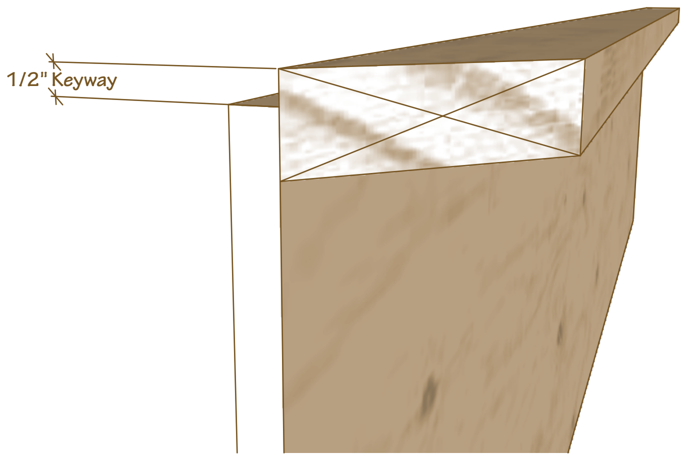

Figure 9.2
Slip formkeyway detail


Co-Creating Living
VERSA-LAM
Boise
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Chapter 10

Wall Production

Definitions

For the purposes of this book, the following terms will be used as they are defined in the Light Straw Clay Appendix of the International Residential Code (IRC)(2015):

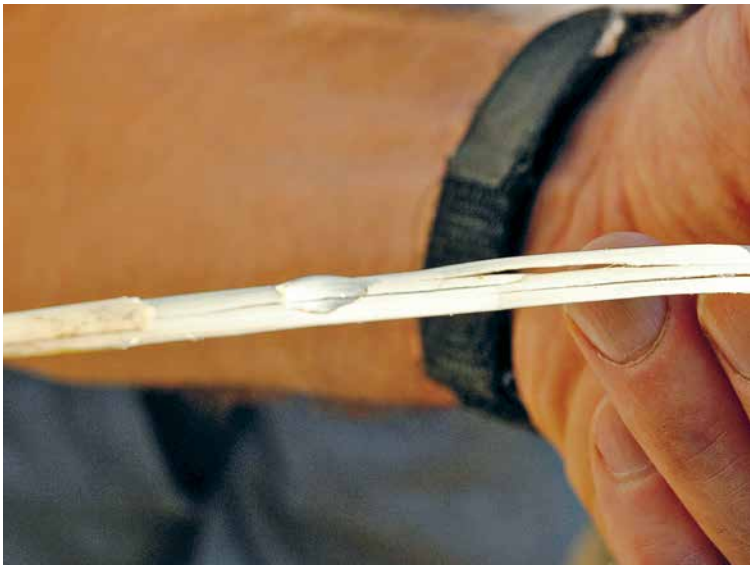
- **Clay:** Inorganic soil with particle sizes less than 0.00008 in. (0.002 mm) having the characteristics of high to very high dry strength and medium to high plasticity.
- **Clay slip:** A suspension of clay soil in water.
- **Clay soil:** Inorganic soil containing 50 percent or more clay by volume.
- **Infill:** Light straw clay that is placed between the structural members of a building.

- **Light straw clay (LSC):** A mixture of straw and clay compacted to form insulation and plaster substrate between or around structural and non-structural members in a wall.
- **Non-bearing:** Not bearing the weight of the building other than the weight of the light straw clay itself and its finish.
- **Straw:** The dry stems of cereal grains after the seed heads have been removed.
- **Void:** Any space in a light straw clay wall in which a 2-inch (51 mm) sphere can be inserted.

About Straw

In Light Straw Clay (LSC) building (not to be confused with *straw bale* building), the straw is one component of the wall system. Straw bales are taken apart and the loose straw is mixed with clay to create a monolithic wall. In a LSC system, the straw provides bulk, insulation, and tensile strength. Straw fiber has significant tensile strength, as can be verified by anyone who has ever tried to break a strand of straw by pulling its ends apart! The hollow structure of straw traps air, providing excellent natural insulation. As a waste product of grain production, straw is often burned in conventional agricultural practice, creating harmful pollution and releasing carbon into the atmosphere. Using it for construction takes it out of the waste stream. Straw has been combined with clay for construction since the dawn of building history, and history has proven the longevity of this combination of materials. The technique described in this book is referred to as *Light Straw Clay* because much more straw is used in this modern system than in historic building techniques. These more insulated walls meet more stringent energy demands and comfort levels.

The waxy surface of barley straw repels water.



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Choosing the Straw

Several types of straw are acceptable for LSC wall building. Choosing from what is available locally is most ecological, avoiding the environmental costs of transportation. Seek out a local supplier who has stored the straw out of the weather and, whenever possible, source straw that is free of pesticides. It is helpful to open and inspect a few bales from any source prior to purchasing the bulk order. Look for straw that is dry, has maintained its shine and shows no visible signs of mold or insect infestation in the heart of the bale.

The most efficient straw for building is barley, followed by wheat. Because of their high water repellency and bulkiness, they compress less, so it takes less straw to build up the walls; there is less shrinkage, and the walls have a higher insulating value.

LSC walls have also been successfully built with rice and oat straw, but these walls tend to compress more, requiring more straw and taking a little longer to build.

Two- and three-string bales ranging in weight from 35–70 lbs. are practical to handle and readily available.

How Much Straw?

We average 7 pounds of barley straw/cubic foot of wall area. For our typical EcoNest construction methods, a 1,500 sq. ft. residence will require approx. 7,500 lbs. of straw depending on the wall density. We typically order 10–15 percent extra straw to make sure we don't run out in a workshop and to account for any spoilage that is encountered in the odd bale. Leftover straw can usually be recycled into a garden operation or be re-sold.

Preparing the Straw

Straw bales must be taken apart, and the straw needs to be loosened so that it is delivered to the tumbler as individual strands without any clumps. Because this job does not take a high

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Bales of barley straw being delivered to the site.

skill level, it can be assigned to the young, the elderly or anyone who is not otherwise occupied. Utility knives are required to cut the bale binding strings. Create a designated place to store the utility knives, because they are easily lost under the mounds of straw (and train your helpers to return them after use). Handling unmixed straw is dusty, so dust masks are required. Once the material is wet, it is no longer dusty and protective gear is unnecessary.

On open, windy sites, some enclosure is required to contain the loose straw and prevent it from blowing away. Bales can be stacked in a way that creates a natural wind break near the tumbler. Additional wind barriers can be constructed with plywood and/or tarps if needed.

TIP: Provide a garbage can for collecting the discarded strings that bind the bales because the strings become an annoying trip hazard if not properly disposed of.

Other Fibers for Building

Where wood products are abundant and straw is scarce, woodchips may be substituted for straw. We readily combine up to 50 percent wood chips with straw without modifying the matrix.

When we elect to use wood chip as the primary fiber, we still add 10 percent straw to increase tensile strength to this "granular-like" wall. In a wood chip application, we space the Larsen trusses closer—at 16" centers—and install permanent wooden lath to create a well-ventilated cage. We use wood lath measuring ⁵⁄₁₆" x 1½" and spaced 1½".

Hemp fiber is a viable alternative in Canada, where it is legal. Because the fibers are longer than straw and very strong, they do not work as well with the tumbler/mixer that we typically use for light straw clay production (the fiber can get tangled in the tines). If you can influence the hemp fiber length at the baling operation, a fiber length of 3"–6" would be ideal.

About Clay

In a light straw clay wall system, clay serves as the "glue" that binds the straw together to form a monolithic wall. The clay component in the wall provides the mass. Clay has outstanding material characteristics that make it, in our opinion, the "Cadillac" (or Prius) of building materials.

Clay, by its very nature, addresses the two major natural threats to the longevity of any wall: fire and water. Clay does not burn. Ceramics are made of vitrified clay. It is well known that clay fired to more than 2,000°F becomes even stronger. Although straw is a flammable material, once it is coated in clay it is non-combustible. This is easily demonstrated by firing a plumber's torch onto a LSC wall.

Clay is highly *hygroscopic*, which means it has the ability to absorb several times its own weight in water without losing integrity and then to release that water as atmospheric conditions change. (Anyone who works with clay knows this because it dries out skin.) Similarly, in a LSC wall, clay will draw moisture away from vulnerable cellulose elements like straw and wood, thus protecting them from moisture damage and decay. This thirst explains why historical clay-based wall construction throughout Europe and Asia has so gracefully passed the test of time without petrochemical-based vapor barriers or chemical preservatives and fire retardants.

Clay Testing

How do you know if your clay soil is suitable for construction? There are a variety of ways to test the clay soils, from simple site tests to more sophisticated laboratory analysis.

While simple field tests suffice for the normal density ranges that we work in, more sophisticated lab testing becomes necessary when the goal is to achieve very lightweight walls of less than 30 pcf (pounds per cubic foot).

Sedimentation Test

This field test is a preliminary step to help determine the ratios of sand, silt and clay in a soil sample.

1. Fill a quart jar ⅓ with water, and ⅓ with clay soil sample.
2. Cap, and shake the jar vigorously until the solids are in suspension.
3. Allow the mix to settle overnight.

The solids will form distinct layers of clay, silt, sand, and possibly small stones.

The top (clay) layer should occupy at least 50 percent of the volume of the solids in soils suitable for LSC construction.

How do you know you have a clay layer and not suspended silt? Clay is smooth, slippery, and somewhat sticky when it is wet. It consists of very fine particles, and when moist it can be easily molded, shaped, or formed.

The Ribbon Test

The ribbon test indicates *plasticity*, which roughly translates into stickiness, or the binding capacity, of the clay:

1. Take a tablespoon of the dry, granulated soil and wet it just enough so that it becomes malleable.

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A ball of clay soil ready to test.

2. First roll the sample into a pencil-sized cylinder. If it falls apart, reject the soil.

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3. If the pencil-shaped sample can be bent to 90 degrees without breaking, a higher clay content is present. This is the threshold of acceptability for a denser wall.

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4. If the sample can be molded into a ring without breaking, this indicates sticky clay of good quality that can work with a range of densities, as desired.

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Batch Testing

A simple and effective test that we recommend before committing to a clay soil source is as follows:

- Make a quart of slip with the sample clay soil.
- Thoroughly coat a small batch of straw with it.
- Using two hands, compress the fresh clay/straw tightly into a 2" diameter by 12" long cylinder. Hold the end of the "cigar" in one hand and shake it around to see how well it holds its shape. If it holds its shape, then your clay passes the test with flying colors. If it falls apart…don't despair!
- Now, allow the same mixture to sit overnight, covering it so that it doesn't dry out. The straw and clay mixture becomes stickier when the moistened clay has time to "season."
- Using two hands, compress the "seasoned" clay/straw tightly into a 2" diameter by 12" long cigar. Hold the end of the cigar in one hand and shake it around to see how well it holds its shape. If it holds its shape well and resists falling apart, the clay and straw are binding together well—your soil has passed the batch test!

Laboratory Testing

The particle size distribution (PSD) test is a scientific procedure that determines the percentage of clay, sand, and silt in any given soil sample.

This test is available through private labs, USDA-soil departments, and Grange Co-ops, if you have one in your area. It costs about $50.

Sourcing Clay

If there are birds in your neighborhood, such as swallows or robins, who build with fiber and mud, this is a strong indication that suitable clay soils for construction exist in your locality.

We have now built in 17 US states, 5 Canadian provinces, Central America, South America, and throughout Scandinavia, and we have found suitable clay soils for building purposes to be abundantly available. This forgiving building system is adaptable to a wide variety of clay soils.

Clay Harvesting

If you have a site with good-quality clay that lies on the surface, a winter with freeze/thaw cycles, and dry spring weather—and you have time to plan ahead—then you can let the climate do your work for you!

1. In summer or fall, remove the topsoil, exposing the clay-rich layer to the sun so that it bakes into hard plate-like pieces.

2. During the winter, freezing temperatures will expand and fracture the clay plates. This freeze-thaw/wet-dry cycle renders the clay into a friable state.

3. The fine powdered clay on the surface can be collected in the dry spring and must be kept dry until used for slip. This fine powder is ideal for slip making.

In wetter areas or seasons, clay will come out of the ground in big, heavy clods, which are not efficient for slip making. Ideally, the clay soil should be in a dry powdered or pulverized form. Most landscape companies have a soil shredder that can granulate chunky clay into an acceptable pea-size for use in wall building.

Occasionally we have encountered a situation where high-clay-content soils are wet and cannot be efficiently dried out and processed prior to production. In those cases, we constructed an on-site soaking pond. Here's how to do it:

- Make a 50–100 sq. ft. soaking pond 12"–16" deep (an EPDM pond liner works well).
- Soak your chunky clay for 24 hours or more. This soaking will soften the clay, making it easier to liquefy.
- Make your slip right in your pond, after the soaking period, by blending it with a power drill and paddle.

Purchasing Clay

It is not always cost effective or time efficient to harvest your own clay, especially for larger buildings. Over the years we have found a variety of sources for purchasing suitable clays.

Here are some sources that you can investigate in your locality. Be sure to test a sample from your clay source to determine that the product has sufficient clay content.

Building Supply Outlets: Pre-packaged mortar clay, also called fire clay, is the most expensive to purchase but can be a labor-saving, cost-effective solution in the long run because its high clay content and powdered form create a high-quality slip that is easy to mix and can be used in all density ranges. Mortar clay is commonly available in bulk or 50-pound sacks. H.C. Muddox is a common brand. Mortar clay is always available, so you can fall back on it if local sources below are not available.

Ceramics Outlets: Powdered clay is commercially available from ceramic suppliers. Most Kaolin clays, including "Tile #6," work very well.

Sand and Gravel Companies: Companies that sell washed sand may have ponds of discarded clay and silt that they are willing to sell for the cost of loading and trucking. Transporting heavy slip-like material requires a dump truck with a sealed tailgate. The same companies often have inventories of dry, clay-rich soils that they can screen for you for a modest fee.

Local Landscape Suppliers: Landscape suppliers often stock bulk clay soils. Ask for screened product that will render granulated clay, otherwise you will need to process the clay soil onsite by shoveling it through a screen.

Brick Factories: We were surprised to learn that our local brick factory filtered airborne clay dust out of the air. What was a waste

Below: Locally sourced dry clay. Below right: Bagged clay by H.C. Muddox being delivered to the site.

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CREDIT: ECONEST CO.

product for them became an excellent resource for us!

Their bulk super sacks of finely powdered clay soils were available for the taking. They were happy to give them to us. These super sacs require a forklift for handling and are more suited to larger-scale production.

How Much Clay Will You Need?

The amount of clay you will require depends on whether you source purified dried clay (such as mortar clay) or locally excavated clay.

The percentage of clay in various clay soils will range, and therefore so will the quantity of clay soil required. As a rule of thumb, a high-clay-content source such as mortar clay or distilled clay will average approximately 15 lbs. of clay per cubic foot of wall.

For a 1,500 sq. ft. EcoNest we use approximately 18,000 lbs. of mortar clay. To do the same building with a good local source of clay soil, we would order two 10-yard dump trucks of screened product. If screened product is unavailable, you will need to screen or shred your clay soil on site. A soil shredder will process chunky material into pellet-sized material and remove any rock. Refer to "Products and Suppliers" in the Resources Appendix for shredders.

The clay soil quantity required using local clay soils is less predictable, but because it is relatively inexpensive we recommend over-estimating your needs.

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Super sacks of clay dust from Kinney brick factory in Albuquerque.

About Slip

Slip is a solution of clay particles suspended in water. Slip will "fatten" (become stickier) over time as the water infiltrates the microscopic clay structure. For ease and speed of tamping, we prefer to mix the clay and straw in advance and let the mixture sit—ideally overnight—prior to loading the forms.

The goal in mixing the clay and straw is to thoroughly coat each blade of straw with clay slip. The "stickiness" of the slip is a product of the percentage of clay in the clay soils used to make the slip. The higher the clay content, the stickier the slip, and the less slip required to create a wall. The densities used in successful light straw clay walls have ranged from as dense as 50 pcf to as light as 15 pcf. (Refer to "Wall Density Variations" in Chapter 12.)

Clay Slip Formulas

Well-mixed slip will remain in suspension (with only a thin skin of clear water forming at the top) for several weeks. We commonly use three different densities of slip for the various applications in LSC construction.

#1 Thin: Mix of clay slip is the viscosity of light cream and requires high-clay-content soils. A suitable thickness for the #1 mixture has been reached when the fingerprint does not show through upon dipping the finger in the mix. When poured on a clean, flat surface such as glass, this blend of slip will run freely, and completely flatten out.
Application: Walls requiring higher insulation-to-mass ratio, such as north walls or cold-climate walls.

#2 Medium: Mix of clay slip is the viscosity of thick cream. When poured on a clean, flat surface such as glass, this blend of slip will flatten out slowly, but maintain some of the irregular form of a semi-solid.
Application: Universal—can be used for all walls.

Slip masking finger prints.

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#3 Thick: Mix of clay slip is the viscosity of a thick smoothie. When poured on a clean, flat surface such as glass, this blend of slip will flatten somewhat, but keep a distinct thick edge at the perimeter. Mix #3 does not run easily, and it holds the rounded shape of a semi-solid material. It is more solid than liquid. Turning the flat substrate on its side, this mix will run off slowly.
Application: Suitable for making chinking compound. Chinking compound is a very dense, moldable mixture, heavy in clay; it is used to fill in any shrinkage gaps prior to plastering the LSC wall.

TIP: Mix #3 can be harvested from the inside of the tumbler periodically when the tumbler is being cleaned out.

Equipment

The key to making slip efficiently is good mixing equipment and clay soils that are sufficiently broken down into granules or powder. Soil shredders can be used to pelletize chunks of clay.

Turbulence is required to disperse and suspend the clay particles in water.

The equipment you need will depend on the size of your project.

Small Projects: Small projects that do not warrant the investment in specialized equipment can be done with standard tools and accessories. Heavy-duty electric drills equipped with mixing paddles can be used. For example, we have found that Makita's right-angle drill or the Milwaukee "Hole Hawg" deliver the necessary power and torque for continual mixing. These are good multi-use drills, and we suggest they be on hand for larger projects as well (as backup) so that production can continue in the case of an equipment failure.

For major projects such as the walls of a home, where thousands of gallons of slip are required, we recommend using either a mortar mixer or a commercial slip mixer called the *Slip-o-matic*.

If you plan to do repeated LSC production, it is well worth it to invest in a commercial electric slip mixer for silence, dependability, and efficiency. Slip-o-matics are available in a variety of sizes ranging from 100- to 600-gallon capacity, and they can be purchased from **Lehman Manufacturing Co.** We use a mid-size 225-gallon model, which will make 200 gallons of slip in 30 minutes. These machines are designed for the ceramic industry and are made for blending powdered high-clay content material. The drive shaft bearings will wear out prematurely with high-silt-content soils. If you are working with

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Top: Soil shredding at Ionia in Alaska.
Bottom: Slip mixing with drill and paddle.

chunky or high-silt-content soils, a mortar mixer would be better suited.

Mortar mixers can effectively break down larger chunks. Unlike cement mixers, in which the drum rotates and the paddles are fixed, mortar mixers have a fixed drum with a rotating horizontal shaft. The shaft is equipped with paddles that press the mixture against the walls of the drum, pulverizing the malleable solids. They are readily available through equipment rental agencies. These gas-powered work horses have the disadvantage of giving off fumes and noise, creating a less-than-ideal work environment.

TIP: To prevent costly repairs, screen out rock through a ½" × ½" hardware cloth. Unlike cement mixers, neither of these machines is designed for mixing gravel.

Slip Production

Set up the slip-making operation near to where the slip and straw will be combined. Dry clay is dusty, and the naturally occurring silicone in it is considered a health risk if continually inhaled. A protective face mask should be worn when working with dry, powdered clay.

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Making 200 gallons of slip in a Slip-O-Matic.

Small Projects: Heavy-duty drill with paddle

Mix the slip as follows:

1. Fill a *heavy-duty* 30 to 50 gallon plastic container (we like the Brute Rubbermaid garbage can) one-third full with water.
2. With a heavy-duty drill outfitted with a mixing paddle, blend in powdery or granular clay until the solution reaches a heavy, cream-like consistency.
3. The amount of clay will vary depending on purity, but the formulation is ready when it masks or hides your fingerprints.

Larger Projects: Slip-o-Matic

With major projects like a house, it is ideal to gravity feed the slip via pipeline to the tumbler/mixing station. This is accomplished by either setting up the slip production uphill from the mixing operation for gravity feed or by pumping the slip into an elevated reservoir.

1. First determine the clay-to-water formula for your slip. To do this, fill the slip mixer tank one third full with water.
2. Turn on the Slip-o-matic and add measured dry clay incrementally until the desired slip consistency is achieved.
3. Once you determine your precise water-to-clay ratio, you may increase the recipe to fill the tank. (Initially filling the tank a third full was to ensure achieving a slip before running out of space in the tank.)

Larger Projects: Mortar Mixer

For a one-time project, a gas-powered portable 6-cubic-foot mortar mixer is an easily rented and viable option. This is also a better option where chunky clay soils or siltier clay soils are being used.

1. Fill the drum one third full of water.
2. Add prescreened clay soil into the mixer.
3. Process until the desired slip is achieved.

Slip Delivery

Bucket Method (Low-Tech):

1. Set up a slip reservoir near to the straw and clay mixing station (tumbler or pitchfork station). An elongated stock tank works well for scooping slip with buckets. Recommended tank size is 70–200 gallons.
2. Transfer slip from slip production site into the reservoir with buckets or a pump. Slip can be made in the reservoir tank as well, but since it needs to be right next to the input end of the tumbler, it is challenging to keep straw out of the tank, so it requires frequent cleaning.
3. As each armful of loose straw is placed into the tumbler, immediately follow with slip. With a 2- to 5-gallon bucket, toss approx. 2 gallons of slip onto the tumbling straw.
4. If necessary, follow with a chaser of slip to achieve the desired mixture.

Automatic slip delivery method:
For highest productivity and greatest control, gravity feed the slip into the tumbler as follows:

Set up a 2"- to 4"-diameter pipeline from an elevated storage tank. The volume of slip at the tumbler is controlled by a valve. Having a shut-off valve at the reservoir is handy in case the pipeline requires servicing and you have a few hundred gallons of slip you don't wish to move or use.

Storage tanks are available at farm and feed suppliers. Piping and valves are available from hardware, plumbing and building material suppliers. Suitable pumps for transferring slip such as a trash pump, mud pump, or diaphragm pump, can be purchased through industrial equipment suppliers or are available through rental shops. You will require both a suction and a discharge hose for the pump.

On out-of-town projects, we have used the Slip-o-matic itself as the reservoir and set it up uphill of the tumbler. When a building site has insufficient slope, the slip can be pumped from the slip-maker into an elevated reservoir.

Mixing the Clay and Straw

Creating good LSC walls mixture is not rocket science. It is simple, friendly, and forgiving. There is never a batch of clay/straw that cannot be used or easily modified, if necessary.

Hand Mixing LSC

Hand-mixing of straw clay is practical when either the project is small or the workforce is large because this method is labor intensive. Our first 30 buildings, prior to the invention of the von Bachmayr tumbler, were mixed by hand.

For hand-mixing the straw and clay:

- Prepare an 8 × 8 plywood working platform elevated approx. 12"–16" off the ground. Straw bales work well to support

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Right: The feed end of the tumbler. Slip is delivered via gravity fed pipeline while armloads of straw are tossed in. Far right: Mixing straw clay with pitchforks on raised plywood platform.

the plywood. This is a suitable size platform for two to four people forking the straw. For larger crews, an 8' × 12' platform works well. Elevating the platform is more ergonomic, reducing back strain and body fatigue.

- Set this portable station in proximity to the wall being constructed and move as necessary.
- Dismantle ½ bale of straw on the platform.
- Next, take a bucket of slip and broadcast it uniformly over the straw.
- Several people working with pitchforks should now toss the straw using a bouncing motion (like tossing a salad).

The desired goal is to have a light, even coating of clay on the surface of each blade of straw.

TIP: Don't saturate the straw with wet clay; a light coating will do the job.

Mechanical Mixing with the von Bachmayr Tumbler

For all but the smallest jobs, buying, making, or renting a von Bachmayr tumbler is essential for an efficient straw clay mixing operation. The tumbler will deliver a constant supply of LSC with as few as two people operating it, saving on manpower and avoiding production bottlenecks. A variety of tumblers have been


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Left: Clay-coated straw propelled by the tumbler's slope is discharged from the end of the tumbler.
Below: Spiral arrangement of 8" spike tines inside a clean VB tumbler.


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fabricated by individual builders—all are patterned after the original design by Alfred von Bachmayr and Joe McGrath. This simple but ingenious piece of equipment is created out of corrugated plastic drain pipe mounted on a motorized set of wheels. The whole assembly is then set at a slight incline so material tumbles forward and downward. Three rows of tines inside the cylinder toss the slip and straw as the material works its way from the feed end to the tail end.

VB Tumbler Facts:

- 3' diameter × 10' long tube
- Powered by an 18-amp, 110-volt, single-phase electric motor
- Drive system: center pivot irrigation gearbox
- 17 rpm
- Trailer-mounted
- Rate of mix governed by slope of tumbler
- Average mixing speed = two minutes

Step-by-Step Light Straw Clay Production with Tumbler

The well-coordinated LSC production site, like an orchestra, has several different sections that need to work seamlessly together for a successful creation.

1. **Setting up the Site:** The production site requires the careful planning and arrangement of straw storage, clay storage, water supply, power supply, slip production and straw/clay production so that there is safe and efficient access between the various components of supply and production.

   Straw storage requires space for 100 bales, a safe work environment for workers to take the bales apart, and an easy delivery path of loose straw to the tumbler.

   Slip production requires easy access to electricity, clay soils, water, and a clear path of delivery to the tumbler.

   The tumbler is at the heart of the operation, requiring electricity and an ergonomic set-up with easy access to prepared slip and loose straw at one end and a delivery system of mixed LSC material at the other end.

2a. **Mixing the Slip and Straw Together:** Our LSC mixing process is a two-person operation. The pilot is the person feeding the straw and slip (or dry clay and water) into the front end of the tumbler. The co-pilot handles the delivery end of the tumbler. Because slips will vary in clay content and stickiness and because the desired densities for LSC will vary depending on wall orientation, several different recipes will be required for each construction. It is the co-pilot's job to provide constant quality control making sure that straw is sufficiently coated and that the mixture is neither too dry nor too wet and to give feedback to the pilot—"too wet," "more clay," or "just right."

With a little practice, a uniform mixture is achieved.

Any straw that is not coated with slip is easily tossed back into the tumbler for additional mixing.

TIP: Have a small supply of powdered clay soil handy to the output end of the tumbler. If a batch comes out too wet, you can "save" it by sprinkling some powdered clay soil into it until the desired consistency is reached. This material would then be used in the heavier south wall.

2b. **Dry-Clay Method with Tumbler:** The tumbler can mix granulated clay, straw, and water in one operation. Loading buckets of clay, water, and armfuls of loose straw into the tumbler in rapid succession will produce mixed wall material. However, this method requires far more energy and manpower than feeding pre-mixed slip and straw into the tumbler and will result in a heavier mixture. This dry-clay method successfully delivered many homes prior to the slip-feeding innovations—as did the hand-mixing in the era prior to the tumbler's invention.

CREDIT: ECONEST CO.

Well orchestrated production set-up showing Slip-O-Matic producing slip, which is pumped up to 1,000-gallon reservoir elevated 7' above ground, gravity fed into VB tumbler. A two-man operation.

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Hoppers in formation at discharge end of tumbler.

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LSC curing in covered hoppers.

3. **Loading the Hoppers:** The delivery end requires a clear pathway for a forklift to easily move in and out. A fleet of specially designed hoppers are set up at the output end of the tumbler. (Refer to Chapter 11 for the construction of these hoppers.)

   The mixed material falls from the tumbler onto a 4 × 8 sheet of plywood surrounded by a semi-circle of several hoppers. When space allows, we set up six hoppers.

   The mixed straw clay is pitch-forked into the surrounding hoppers. This process continues until all hoppers are filled.

   A forklift moves the filled hoppers to a curing area from which they can be easily transported to the wall-stuffing sites around the building.

   It is also possible to save a step by loading each hopper directly from the tumbler, but this requires the constant attention of the forklift operator or the co-pilot, so this may not always be the most efficient method.

   On smaller jobs that do not warrant the construction of hoppers or presence of a forklift, the mixed material can be transported using wheelbarrows.

4. **Curing the Light Straw Clay Mixture:** Ideally, we prepare ten or more hoppers ahead of time and begin loading hoppers well in advance in order to set aside enough to get well ahead of the demand from the wall-loading activity. Although the LSC can be used immediately, letting the mixture sit or “cure” gives the clay more time to activate. The mixture becomes “stickier” and packs more quickly with less effort. For best results, allow the mixture to sit overnight; even several hours makes a huge difference. For maximum “activation,” cover the loaded hoppers with tarps while the LSC cures. Tarping prevents rain from diluting the mixture and sun from drying it out too quickly.


130
Bobcat

CREDIT: ZACH COVENTRY

Chapter 11

Delivery

The safe and efficient delivery of many tons of material from the mixing station to the wall-building site is one of the keys to successful productivity. While some projects are straightforward, others will require a well-thought-out strategy.

A well-orchestrated project will result in reliable, on-time, and safe delivery of cured straw clay mixture to the wall-building site so that an uninterrupted work flow can be maintained.

Equipment for Transporting LSC

For transferring hoppers filled with the LSC mixture, use the services of an experienced equipment operator. We usually have a

Skidsteer setting hopper on platform.

designated operator on the team who has had the proper training. Depending upon the site conditions, scope of work, and equipment availability, we use one of the following:

- A four-wheel-drive skid-steer loader equipped with forks is the most versatile machine for level sites. Capable of turning on a dime, skid-steer loaders are extremely maneuverable and valuable for applications that require a compact, agile loader. The 9' reach is sufficient for most projects.
- Compact track loaders are similar to skid-steer loaders but are equipped with tracks suitable for rougher terrain with tight access.
- Tractor-type four wheel drive forklifts are larger than skid-steers and capable of higher lifts to 20+ feet.
- A reachlift with forks mounted to a telescoping boom can place hoppers 30' away for more demanding sites. These are much larger machines than compact skid-steers and require more room to maneuver.
- For extremely challenging sites, we recommend a site crane or mobile crane for material delivery.

The EcoNest Hopper

Another key for efficiently moving tons of LSC material is the EcoNest Hopper. The hopper has been developed to simplify the delivery process. Each hopper can accommodate 500 pounds of wet material and is designed to be easily and safely transported from the straw clay production area to a wall building site with a skid steer or forklift. Two

CREDIT: ROBERT LAPORTE

Forklift setting hopper on platform.

keyways (portals/openings) in the rear bottom of the hopper are designed for safely lifting and moving the heavy hoppers with forked equipment.

The sloped sides of the hopper are easily accessed by those feeding the material into the walls. Their lightweight construction makes them safely movable when empty without lifting equipment. On very small projects, wheelbarrows can be substituted for hoppers.

Making Hoppers

The hopper is designed to be easily and efficiently site-built with ¾" plywood and deck screws. We recommend making at least ten hoppers for a house-sized project so that they can be available for loading, curing, and being moved to the wall-building sites without any break in the flow of production.

1. Using the hopper drawings as shown, pre-cut all the 2 × 6 floor frame components and the plywood sides, backs, and bottoms for each hopper.

2. Prefabricate the 16" × 48" central floor frame with 2" × 6" boards.

TIP: This 6" tall floor frame creates a generous "gate" for the forks to enter. This feature will be appreciated when loading hoppers onto the scaffold on uneven ground where one fork is a different height than the other fork.

3. Screw the 4' × 4' plywood floor to the central floor frame and both outside 2 × 6s as shown.

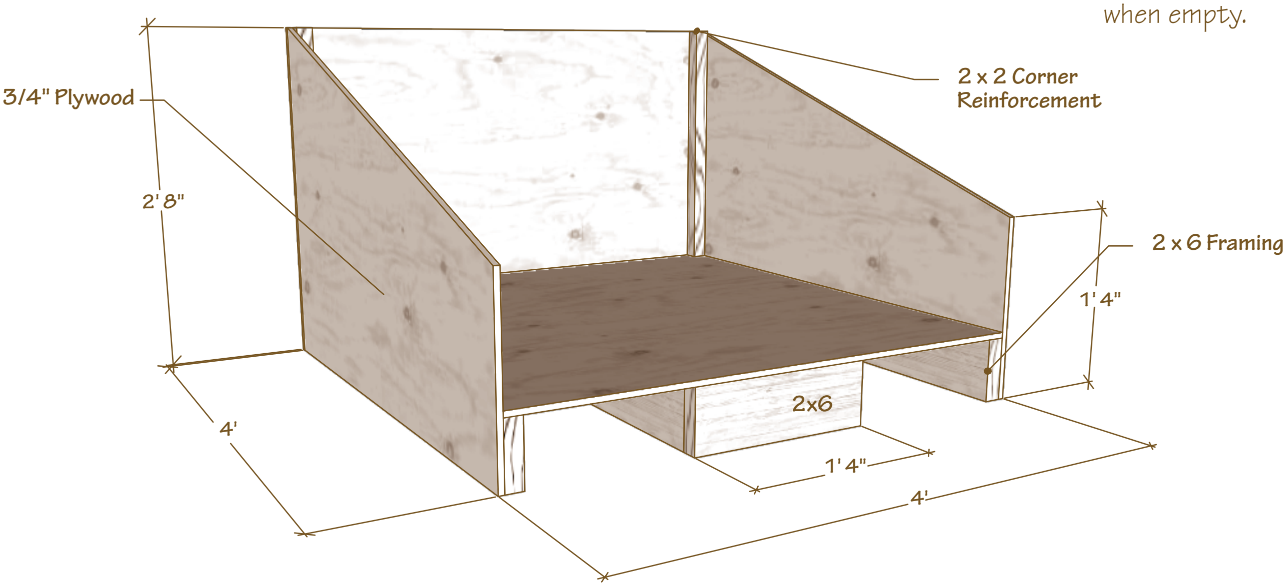
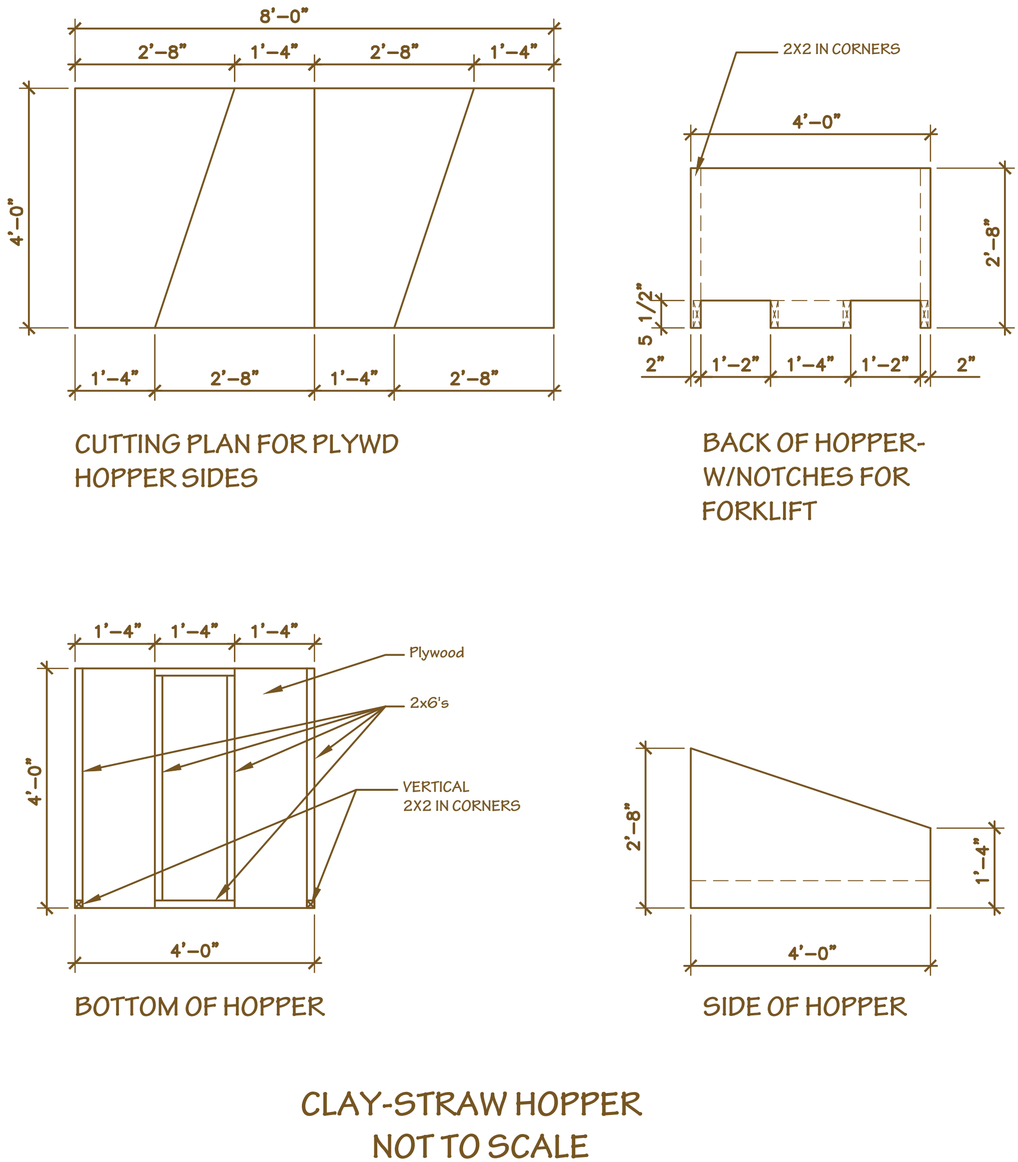


Figure 11.1 The EcoNest hopper is designed to move 500 lbs. of LSC with a forklift and is light enough to be moved by hand when empty.

Figure 11.2 Hopper cut sheet uses 4' x 8' plywood with no waste.



4. Screw the back to the floor assembly.
5. Screw the sides to the floor assembly
6. Reinforce the inside corners with a 2 × 2 screwed to the back and sides as shown.

Loading Hoppers

We prefer to arrange multiple hoppers in a semi-circle surrounding a 4 × 8 plywood receiving platform at the tumbler's discharge. Although this requires manually moving the LSC materials into the hoppers, this technique has several advantages over stationing the hopper directly under the discharge end. (For smaller jobs, a "fleet" of wheelbarrows can be employed in the same manner.) These advantages include:

- A variety of densities can be batched simultaneously, sorting light, medium, and dense mixtures.
- Delivery is not bottlenecked waiting for a single hopper to be filled or for lifting equipment to arrive. It is more efficient to fill and then move several hoppers one after the other.

Hoppers ready for action.

CREDIT: ZACH COVENTRY

- This multiple hopper process makes it easy to remix any straw that is either too dry or too wet—by tossing the too-wet material into a drier hopper or batching too-dry material into a wetter hopper.

Scaffolding

For several years, we simply pitch-forked material up to people working in the forms. More muscle was progressively required as the forms got higher and more material missed its mark, falling to the ground. One day, after working on a particularly difficult site to access, we gained a new appreciation for the force of gravity and how we could use it to our advantage, The EcoNest delivery system evolved as a result. Here is the story:

The project was our own home and the building pad was cut into a steep hillside. The cut was as tall as the roof overhang. Access around the building for setting up scaffolding and delivering LSC was severely limited by this

Six full hoppers… 3,000 pounds of LSC ready to fill.

CREDIT: ZACH COVENTRY

hillside. How to deliver 20 tons of LSC? We decided on a radical idea using the low-slope roof itself as the scaffold.

Once the roof was framed, the top edge of the cut and the eave were roughly the same height. A 4' gap between them was easily bridged with a ramp, wide enough for a wheelbarrow. We sheathed the entire roof, and the plywood directly above the perimeter walls was screwed down so it could be easily removed when a section of wall was filled with straw clay. All of the LSC was delivered onto the roof with wheelbarrows, and all the LSC walls were completed in a record time of three days because it was very easy to drop the LSC down into the cavities as it was being compressed. Sir Isaac Newton became our ally and inspiration for delivery set-up.

The scaffolding system that we subsequently developed came out of this experience. Although it takes time to set up, it creates the most efficient way to load formwork—saving time, money, and effort while increasing safety, productivity, and job satisfaction.

Scaffolding, also known as staging, sets the "stage" for working safely and productively above the ground. Although this stage is only temporary, it requires a good, solid foundation and attention to detail.

At times, the scaffolding will support a half dozen people and several thousand pounds of LSC in hoppers. In addition, the scaffold can be easily rocked when a forklift is setting a heavy hopper. So stability is important! Properly support the feet of the scaffolding frames so the frames are all level and plumb.

To prevent the scaffolding from sinking into the ground, provide generous mud sills under each scaffold leg. Mud sills measuring a

Roof sheathing removed to facilitate tamping in wall below.

CREDIT: ZACH COVENTRY

minimum of 8" × 8" are made from ¾" plywood because it resists splitting under the extreme pressure of a heavily loaded scaffold. To level the scaffold on uneven ground, the plywood mudsills are combined with lumber, timber cut-offs, or cement blocks. Alternatively, a real time saver is to use specially designed screw jacks with metal mudsill plates that quickly adjust and level scaffolding on uneven ground. These can be rented or purchased where you source your scaffolding

Scaffolding comes in all shapes and sizes but the type best suited for straw clay building is the standard 5' × 5' scaffold with two ladder rungs. These ladder rungs provide variable height support for the walk boards, which move up to the top of each new slip form as it is added.

A basic scaffold section consists of two 5' × 5' frames stabilized with two scissor braces, creating a 5' wide × 7' long module. This 7' module is expanded by adding frames and braces that support walk boards and platforms. Aluminum walk boards have a traction groove

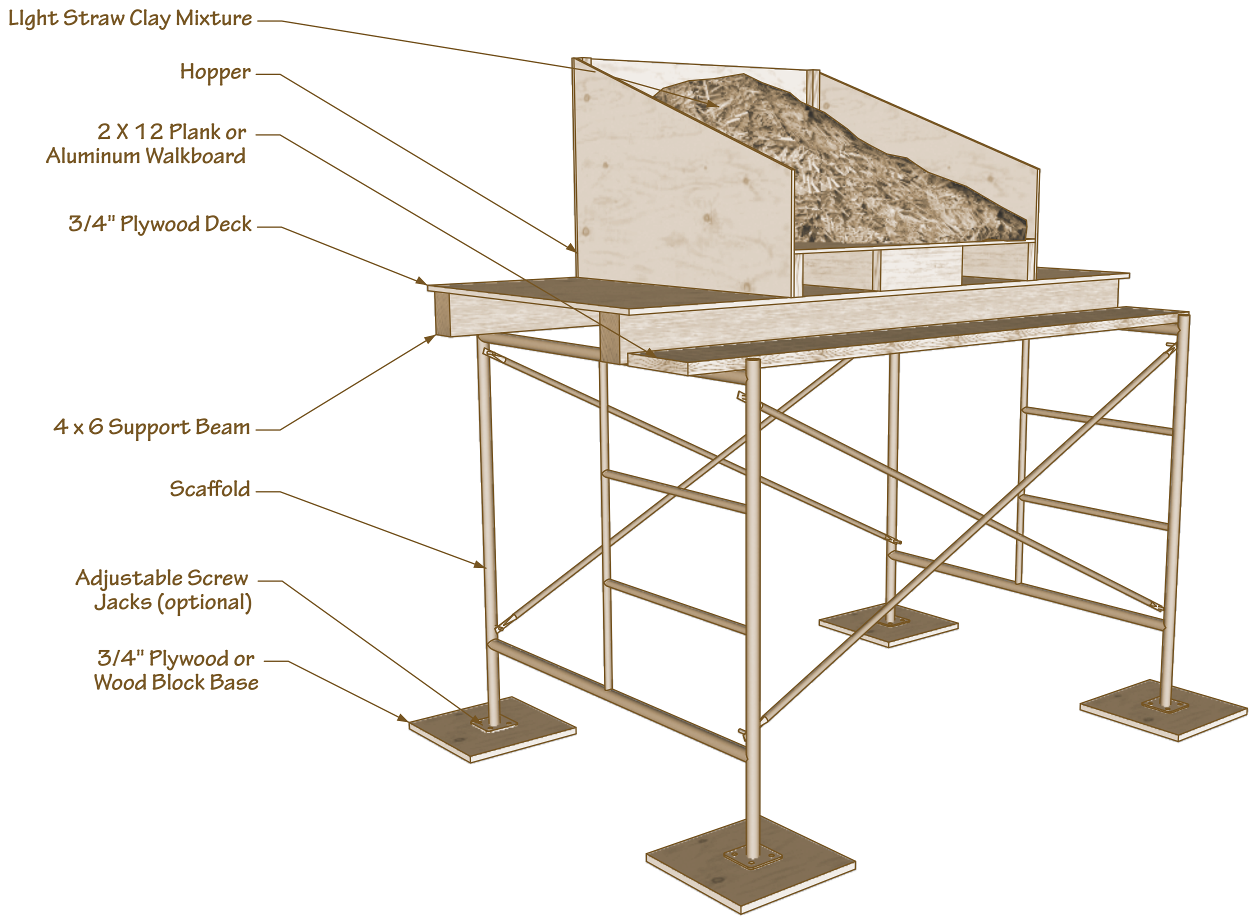


Figure 11.3 Scaffold work station

along their length and are safer than wood scaffold planks, especially after surfaces are coated with slippery straw clay.

Install the bottom row of slip forms before erecting scaffolding. Erect scaffolding 6" from the wall to allow access for the installation and removal of the other slip forms, which have a lip that projects 4¼".

How much scaffolding will you need? Ideally, one would have enough scaffolding to set it up around the entire project and leave it in place until the roof is finished. Alternately, if there is less scaffolding available, smaller sections can be set up, disassembled and reassembled several times as required.

Platforms

Once the scaffolding is in place, we set up walk boards and platforms. Although scaffolding that is fully decked in aluminum walk boards could also be used for clay/straw platforms, it is expensive to surround a building this way (requiring three walk boards per scaffold). We typically set up a single row of aluminum walk boards for worker circulation to the wall side of the scaffolding. As the height of the walk board is adjusted upwards, the loader adjusts their body mechanics to move the LSC from the stationary hoppers into the forms in an ergonomic and efficient fashion.

Scaffold with aluminum walk boards set for filling tier 1.

CREDIT: ECONEST CO.

Using a wheelbarrow highway to deliver material on a heavily treed site that prohibited forklift access.

The site-built platforms are placed to the outside of the walk boards at the top of the scaffold in preparation for receiving hoppers or stockpiling straw clay delivered by wheelbarrows. The platforms consist of ¾" plywood mounted to two beams. (See illustration.) The hopper and platform combination raise the LSC a foot above the highest walk boards, making it more ergonomic to load the walls.

TIP: When screwing plywood to make temporary platforms, don't sink the 2" deck screws. Leave the screw heads proud ⅛" so when you go to remove the screws they are easy to find. Otherwise, it is difficult to find buried screws in holes that become filled with LSC.

CREDIT: ECONEST CO.

Hopper platforms require sufficient "parking" for a minimum of two 4' wide hoppers. Each hopper requires a 5' wide parking space. For example, a 16' platform can be perched on top of 14' of scaffolding to receive three hoppers and still leave space to move around.

Multiple hoppers ensure a constant supply of materials as empty hoppers are removed and replaced

TIP: **Most LSC projects involve workshops or work parties with a dozen or more motivated people. Keep your stuffing team well "fed," and avoid having them wait for material.**

Challenging Sites

On sites with limited access where it is not possible to approach the walls with a forklift on all four sides, delivery options include wheelbarrow, conveyor belt, forklift/reachlift, or crane.

Wheelbarrow Delivery: When wheelbarrows are employed, it is necessary to create a low-slope ramp easily traversed with a steady stream of loaded wheelbarrows weighing about 150 pounds. Wheelbarrow ramps should be a generous 3'–4' width. Ramps inevitably get slippery, so it is helpful to add low-profile wood cleats for traction and clean the ramp as necessary.

Conveyor Belts Delivery: Electric conveyor belts can also be used to transport the straw clay to loading stations that are hard to reach.

On one of our projects, a portion of the building could only be accessed from the inside. We took advantage of the flat floor surface and rigged up a dolly with 4" wheels that rolled the heavy hoppers, with ease, to the walls being filled.

Forklift/Reachlift: With the aid of a forklift or reachlift (forklift with extendable boom), material can be raised onto a specially constructed high platform, built on top of the timber plates, usually 9'–10' above the ground, utilizing the timber structure and/or scaffolding platforms for support. The platforms will vary in size from as small as 4' × 8' up to 12' × 20', as the situation allows and requires. These platforms can be pre-assembled on the ground and then hoisted with the reachlift. The reachlift is then used to set the hoppers filled with straw clay onto these high platforms. From this vantage point, the straw clay is easily tossed with pitchforks into the surrounding forms. On larger platforms, a wheelbarrow can be used to transfer material.

Crane Delivery

When site conditions are such that scaffolding is otherwise unreachable, a site or mobile crane must be used. This is the most expensive delivery option. Lifting slings are attached to the hoppers so they can be lifted by the crane's hook and transported to the scaffolding surrounding the building. With heavy material moving around overhead, extra vigilance is required by all to ensure safety.

CREDIT: DILLON CREASY

Chapter 12

Filling

Loading and Tamping Basics

Attention to loading and tamping is required to achieve strong and stable walls free from flaws. Prepared LSC is uniformly placed into the wall cavity in 6" layers, or "lifts." This is the optimum amount of loose material to load into the wall for achieving consistent densities and tight faces.

Most of the compression is done by a person stomping inside the 12"-wide formwork. With feet parallel to the forms, the stomper presses the straw clay mixture into every corner and space. Wooden tampers fashioned from 2 × 4s are used to compact the straw clay at each Larsen stud and in tight areas where it is not physically possible to use the feet.

All the walls are compacted until they have structural integrity and tight, flat faces. With experience, one acquires a "feel" for the firmness under foot and can translate that feeling into density. Keep in mind that the mixture is forgiving. There is no need to obsess over every handful of mixture going into a wall.

One benefit of the LSC technique is that the wall density can be varied for maximum control of the thermal envelope. Refer to "Wall Density Variations" below, for more detailed instructions on this fine point.

As soon as the first slip form is removed, the quality of the work is revealed—giving feedback on technique and material quality. Straw clay is a kind teacher.

Troubleshooting

With a little practice and by carefully examining each sector of wall as soon as a slip form is removed, a crew can correct any insufficiencies in loading and tamping technique and become expert in a short amount of time. The good news is that any errors that lead to gaps or

CREDIT: ZACH COVENTRY

Left: Tamping with 2" × 4" tamper. Note hopper placement allows for convenient gravity loading.
Below: Feet parallel to the formwork uniformly compressing the LSC.

CREDIT: ECONEST CO.

separations can easily be repaired by chinking before plastering. However, the most efficient process is to get the tamping right and avoid unnecessary repair work later. Here are some common defects to avoid.

- Spongy surfaces that are not woven tightly together can be the result of lifts of more than 6". Larger lifts would require more exuberant stomping, so as a rule of thumb we train people filling the walls to stick to 6" lifts.
- Horizontal crevices occur when lifts of LSC are not sufficiently tamped before additional material is loaded. This shows up where horizontal bamboo reinforcing is not detailed carefully and gaps are left under it.
- "Face fluff," or loose surfaces, result when the material is not sufficiently sticky to bind together when tamped. If material does not stay tamped down but tends to bounce back, especially at the inside and outside faces, this can be corrected during the filling process by the addition of a wetter and richer clay mixture in the next lift which will work its way into the layer below.
- Settling of the infill will occur at the top of the wall as the material dries. This is normal and will be minimized by the horizontal stabilizing bars. (Refer to "Stabilizing Bars: Horizontal Reinforcing," below.) This space is thoroughly filled in once the walls are stable, prior to plastering.


CREDIT: ECONEST CO.

Refer to the section on chinking in Chapter 13 for repair techniques.

Wall Density Variations

Slip density, slip volume, and compaction force are the three factors influencing the final density of the LSC wall.

In locations with good solar access, the south wall will benefit from more mass, or thermal storage capacity, so we target a wall density of 30–40 pcf, using a medium-to-thick slip density and applying more compaction when tamping.

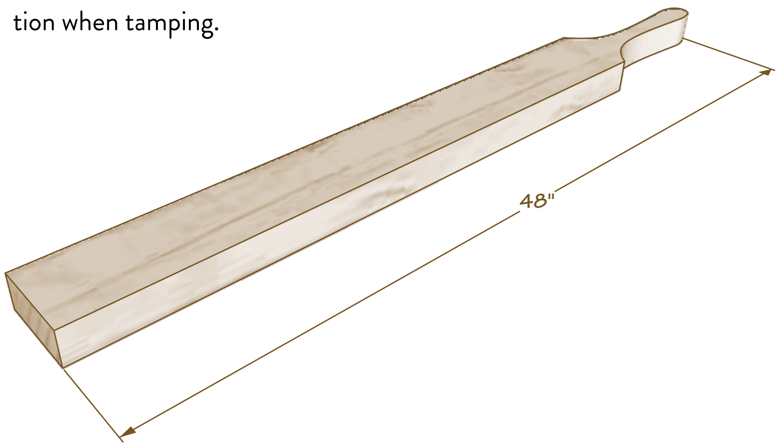


Figure 12.1 *The tamper is used to detail all edges and other places where feet cannot effectively reach.*

TIP: If the slip is too thick, it is difficult to disperse over the straw, and it will tend to accumulate on the walls of the tumbler. Preventing build-up on the tumbler walls prevents the tumbler from overworking and overheating. It is easy to clean the smooth inner wall of the tumbler with a pitchfork and hoe. Save the thick gooey material that is cleaned from the tumbler for chinking later. Clean the tumbler whenever there is more than a ¾" build-up.

North walls, where there is no solar gain, should be more highly insulated to reduce heat loss. We shoot for a density of approx. 20 pcf using a thin, sticky slip. In the loading process, the north walls receive two unique treatments to keep their insulating qualities high. First, they are "half" tamped. This is achieved by tamping the inside and outside face while leaving the center core un-tamped. Secondly, we use straw/clay that is drier for the center of this wall. If the entire center of the north wall were built this way it would be weak, so we do a full tamp with moist materials every third load. This sandwich technique creates pockets of light, dry straw clay. This drier application on the north wall aids the curing process. With no solar gain, the core of the north wall takes the longest time to dry because it has the lowest drying stress. Using drier material helps this wall dry out at the same rate as the rest of the building.

East and west walls can take advantage of both mass and insulation properties. Thirty pcf, with a medium slip density, is ideal.

The appearance of the south and north wall will be quite different. The south wall will be lighter, more the color and texture of the straw, while the north wall will reflect the color and solidity of the clay.

CREDIT: ECONEST CO.

Tamping the north wall. For increased insulation the middle is left untamped, and lighter, dryer material is placed there.

Protecting the Timber Frame during the Filling Process

Where there are timber-frame elements that are exposed to the interior of the finished building, it is time-consuming to restore them to their original state of beauty if they get muddy or oily during the wall-filling process. Loading the walls from the outside will minimize contact with the timber frame, as will a wall-building team that is trained to be mindful. Protect vulnerable timbers with paper, cardboard, or plastic and masking tape. Remove the protection as soon as possible so the masking tape does not dry up and require a solvent or sanding to remove it.

Stabilizing Bars: Horizontal Reinforcing

To strengthen and stabilize the wall, horizontal rods called *stabilizing bars* are installed at 24" vertical intervals. The stabilizing bars give lateral strength to the wall, particularly while the straw clay is curing into a seamless monolithic mass. This becomes even more significant when constructing thinner 4"- to 8"-thick walls

Upper timber is protected with kraft paper.

CREDIT: ZACH COVENTRY

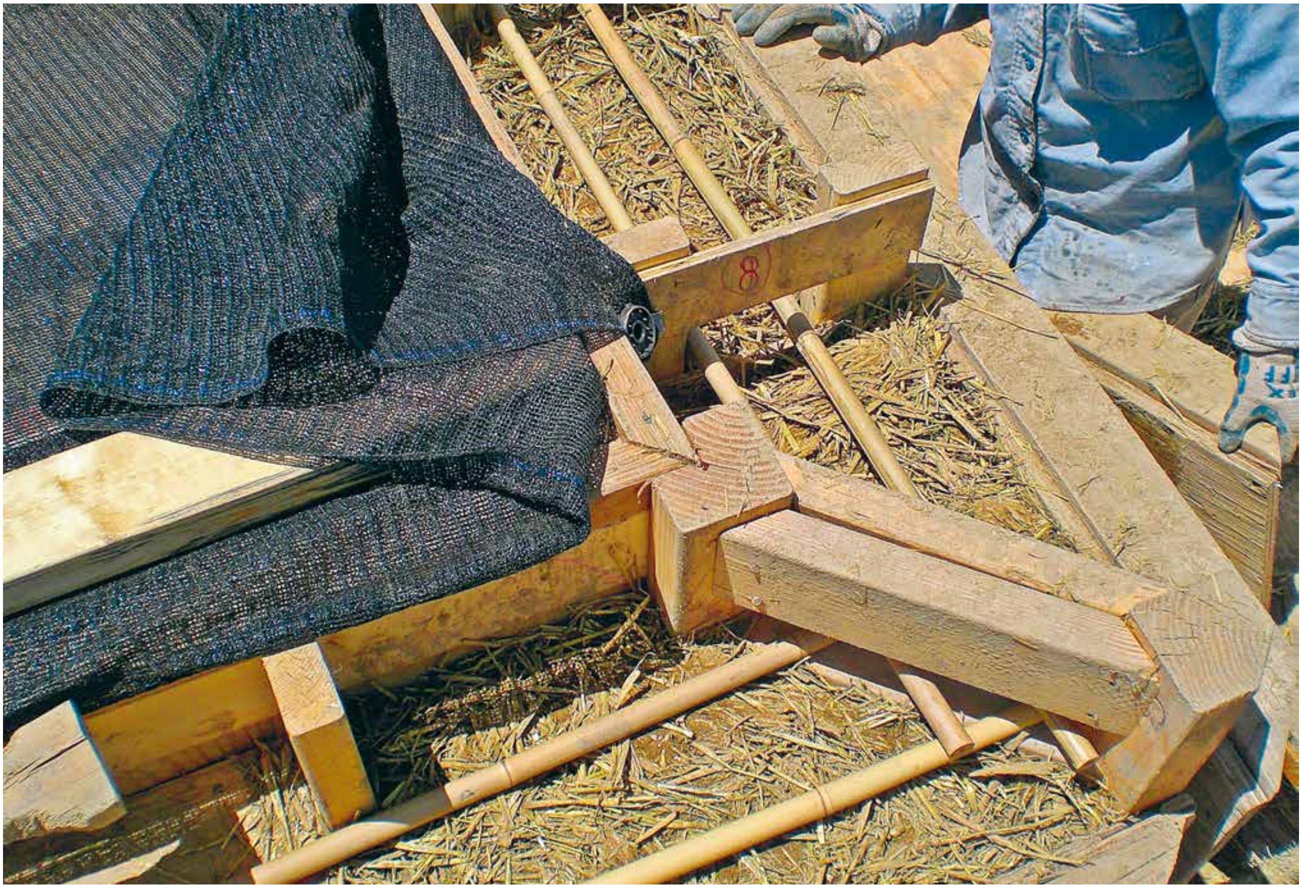
used in small auxiliary buildings or for interior walls. Regardless of wall thickness, once the wall is cured, it is a powerful structure of woven clay, straw, and bamboo.

A variety of materials can be used for stabilizing bars. Bamboo is our first choice because of its superior strength. We use 7′ lengths of ¾″-diameter dry bamboo. Bamboo is the fastest of all stabilizing bar materials to install. Because of its relatively small diameter, it is easily threaded through 1″ holes drilled in the door and window jambs. Locally available straight hardwood saplings of uniform diameter wood also work for this purpose, as would 1″ × 1″ hardwood or 2″ × 2″ softwood.

Placing the Stabilizing Bars

As each tier has been completely filled and tamped to the top of the slip form, a pair of stabilizing bars is installed on the top of the gussets. Each bar will extend past its end gussets, overlapping the adjacent set by 6″,

Twin bamboo stabilizing bars placed at top of each tier.



CREDIT: ECONEST CO.

and will extend through holes drilled in the window and door jambs by 1"; they will be trimmed when the windows/doors are installed (ideally after the walls are cured). Bed the bars in well-compacted LSC. A space below a bar will result in a space after the wall is cured. The biggest cause for horizontal gaps in the cured wall is from stabilizing bars that are not firmly bedded. For this reason, we are careful to train everyone involved in filling the walls to be meticulous in bedding their horizontal stabilizing bars. Refer to "Loading Tier I" below, for best practice.

Loading the Walls/ Leapfrogging the Forms

The bottom row of slip forms will be installed once all full forms are installed and electrical and plumbing rough-in are completed.

It typically takes four to five days to load and compact all of the walls of an average EcoNest. Our priorities are to build both sides of each corner simultaneously, weaving the perpendicular walls together, and to finish full-height sections of wall in a single day so that formwork on completed sections both inside and out can be stripped at the end of the day. It is better to stop the day's production at a door or window jamb, completing a section to its full height, than it is to complete one or two tiers around the whole building. On long wall sections where there is no door or window jamb to conveniently finish a day's work, we create a wall dam that terminates the work in the middle of a Larsen truss so that the next day's work can key into it so that the joint is not visible.

Although an individual can alternate between loading and compacting the walls, it takes time and energy to continually jump in and out of the forms. It is far more productive

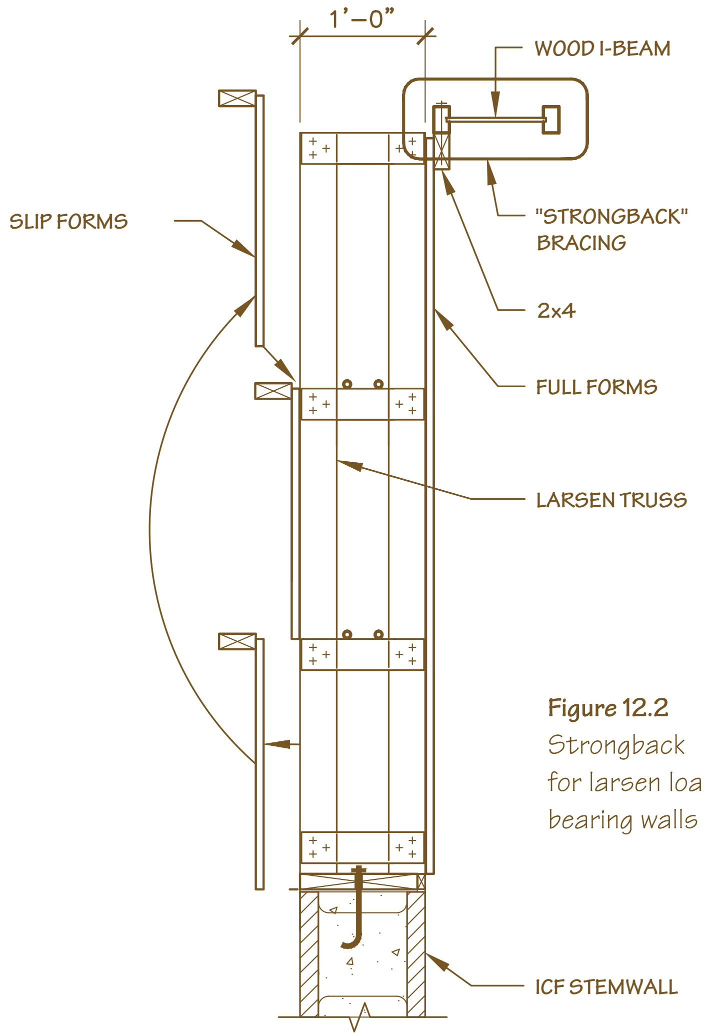


Figure 12.2 *Strongback for larsen load bearing walls*

if a buddy system is used where one person continually fills the walls and their partner remains in the formwork compacting and tamping the material.

Loading Tier I

1. Tier 1 slip forms are screwed in place prior to installing scaffolding. Screws in all formwork should be slightly proud of the formwork for ease of removal. Screws that are buried in the plywood are hard to find and difficult to extract.

TIP: Use small 6"–12" clamps to persuade any warped slip forms into a flush fit against the Larsen trusses, prior to screwing them in place.

2. Set up scaffolding so that the walk board is approximately level with the top of the first slip form. With filled hoppers in place, the walls are ready to load.

3. Electrical wiring running along the center of the sill is the first thing to be covered with LSC and requires careful detailing.

The buddy system. Filling is most efficient when two people work together, one tamping and the other loading.

CREDIT: ECONEST CO.

While the LSC is normally fed into the formwork in 6" lifts, Tier I begins with a 4" lift for this reason.

4. The tight corners where the sill meets the Larsen truss are tamped twice—using the 2 × 4 tamper. The most common voids are found at this intersection, and this double-tamping will eliminate the problem.
5. Once the bottom is detailed, loading and tamping continues with 6" lifts until the LSC is level with the plywood at the top edge of the slip form and mounded so that it is approximately ½" higher in the center of the wall.
6. The double stabilizing bars are now installed in the center of the wall on a solid bed of compacted LSC. The bars will bear on the gussets as the subsequent tier is compacted. This overfilling assures that there will be no voids under the stabilizing bars.

Tier I is now complete.

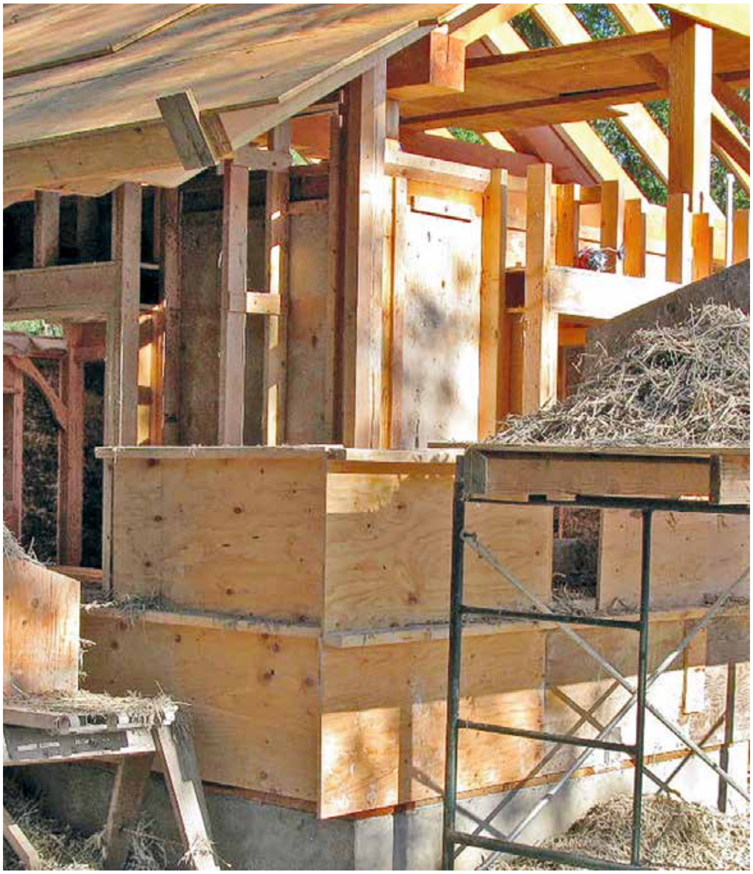
Installing tier I slip form flush with the bottom sill.

CREDIT: ECONEST CO.

Loading Tier II

1. Tier II slip forms are installed immediately after the stabilizing bar has been placed on the top of Tier I. For a clean-looking wall, "whiskers" of straw need to be cleared from the top groove of slip form 1 and tucked into the wall cavity prior to installing the next form. Install the second slip form keying the bottom edge of the plywood into the groove of the lower form and secure with screws.
2. Raise the walk board so it is approximately level to the top of the second tier for safe and efficient loading and tamping.
3. Continue loading and tamping straw clay until this second tier is filled, tamped, and stabilized with the second set of horizontal rods.
4. Tier I slip forms can be removed as soon as Tier II is half filled and compacted.

Tier II corner formwork in place and ready to load.



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Loading Tier III

1. Remove Tier I slip form by carefully sliding it down or sideways before pulling it away from the wall, using the form like a giant trowel. This sliding technique is used so that straw fiber stuck to the form is not pulled out by the suction, which would leave a shaggy wall surface. The bottom slip form now becomes the slip form for Tier III.
2. Install as before, and continue loading and tamping until Tier III is full and stabilizing bars have been installed.

Tier IV: Topping Off the Wall

The top tier can present a special condition because it is shorter than the tiers below it. This is because the LSC begins above the stem wall, which sits well above the finished floor level. The height of this stem wall will vary from project to project depending on the site and climatic conditions. (Our objective is to keep the LSC well above the wet zone at the ground.)

1. If the top of the Larsen truss is within 16" of the top of Tier III, the Tier III formwork can simply be unscrewed and slid up the wall and reattached flush with the top of the Larsen trusses. If the gap is larger, Tier II slip form is slid up to the bottom of Tier III for additional support.

2. The newly placed form is loaded and compacted to within ½" from the top. This deliberate gap makes it easy to install both the exterior blocking and the top plate without interference from overfilled wall cavities. The gap is later chinked.

3. The 2 × 4 exterior blocking is placed on top of the straw clay and tapped down until it is flush with the tops of the Larsen trusses. A snug-fitting 2 × 4 block will stay in place as it tapped down, compressing the straw clay beneath. This exterior blocking serves two distinct purposes. First, it creates a positive

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Tier III formwork in place and ready to load.

connection for resistance to uplift forces, giving tie downs and hurricane clips a good load path to the studs. Second, it creates a rigid stud-to-top plate connection, thereby adding substantial resistance to lateral (earthquake, wind) forces.

TIP: A three-pound hammer works well for persuading the blocking into place.

4. After the blocking is secured, the 11⅜" wide LVL (laminated veneer lumber) top plate is installed. With the top plate in place, the formwork is removed from both sides of the wall.

Tall Walls

Most often, when there is a partial or full second story, we maintain the Larsen truss system but fill these higher areas with the same lightweight insulation as will be used for the roof. This is because the cost of using LSC increases with height disproportionately to the benefits.

However, when we do build taller LSC

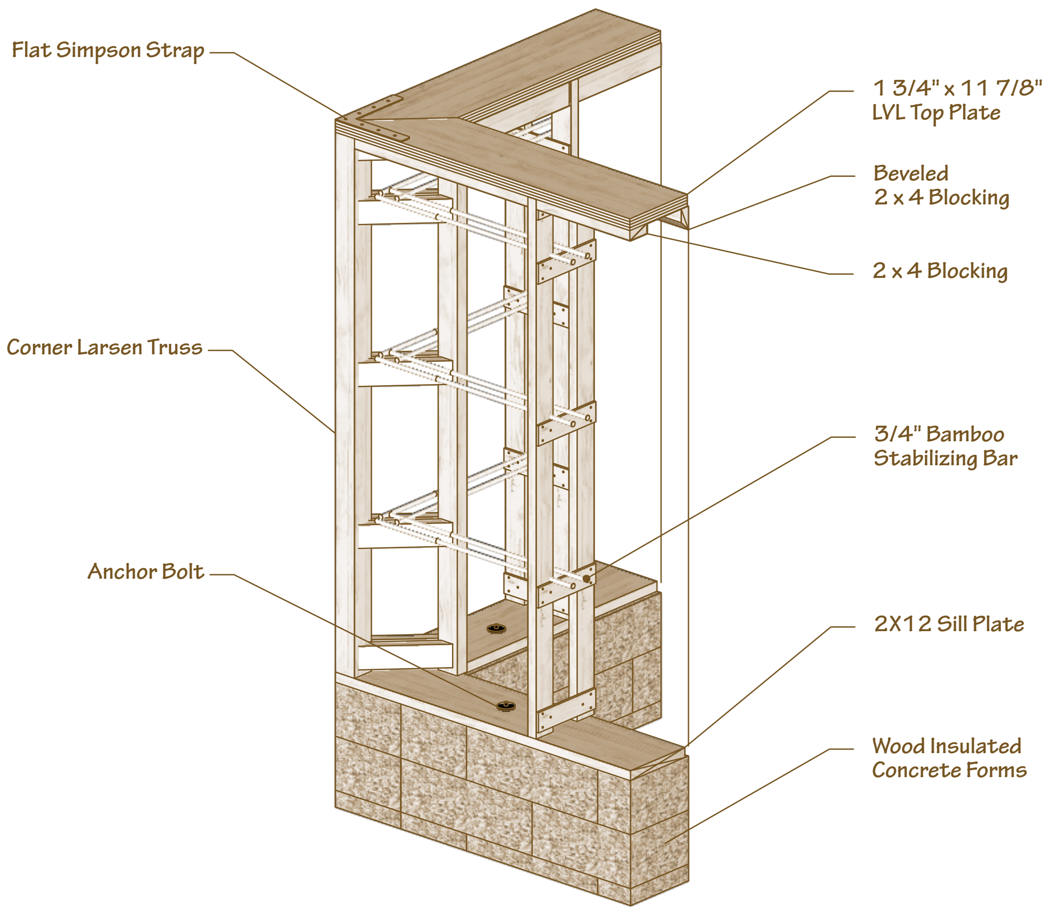

Figure 12.3 Exterior wall corner detail with top plate

walls, we build the wall in two phases to reduce settlement. We build the first story and install a top plate before building above it.

Gable Ends

It is possible to do gable ends with straw clay, and we have done several projects this way. However, LSC gables take almost twice as much time to build as the lower story for the following reasons:

- Higher work requires more scaffolding.
- Angled form work must be custom built and the triangular pieces are hard to re-use.
- Loading and stuffing high above the ground requires a higher level of safety measures and is physically more demanding.

A bigger bang for the buck for gables is to build super-insulated 12"-thick walls with conventional non-toxic insulation.

CREDIT: JENS WIEGAND

Tier IV complete with top plate and gable framing in place.

Removing and Re-using Forms

Once the wall is complete, the formwork should be removed immediately so that the walls can begin the drying process. If formwork is left on, moisture is trapped in the wall; lacking air movement, surface mold will begin to grow behind the form within 48 hours. For this reason, plan to complete a wall section in a day and remove the wall forms the same day. Should there be an interruption in completing a wall, we recommend removing the wall forms from an unfinished wall and then re-installing them when the work resumes.

If the forms are not to be re-used immediately, they should be cleaned and stored. We re-purpose the solid plywood used for the interior forms as the roof sheathing. The slip forms can be disassembled and components repurposed in the construction or can be re-used as formwork on subsequent projects. They will last through many projects if properly cleaned and protected.

CREDIT: JENS WIEGAND

Where LSC is placed in the gables, formwork must be customized for roof slope.

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Loading and tamping the gable.

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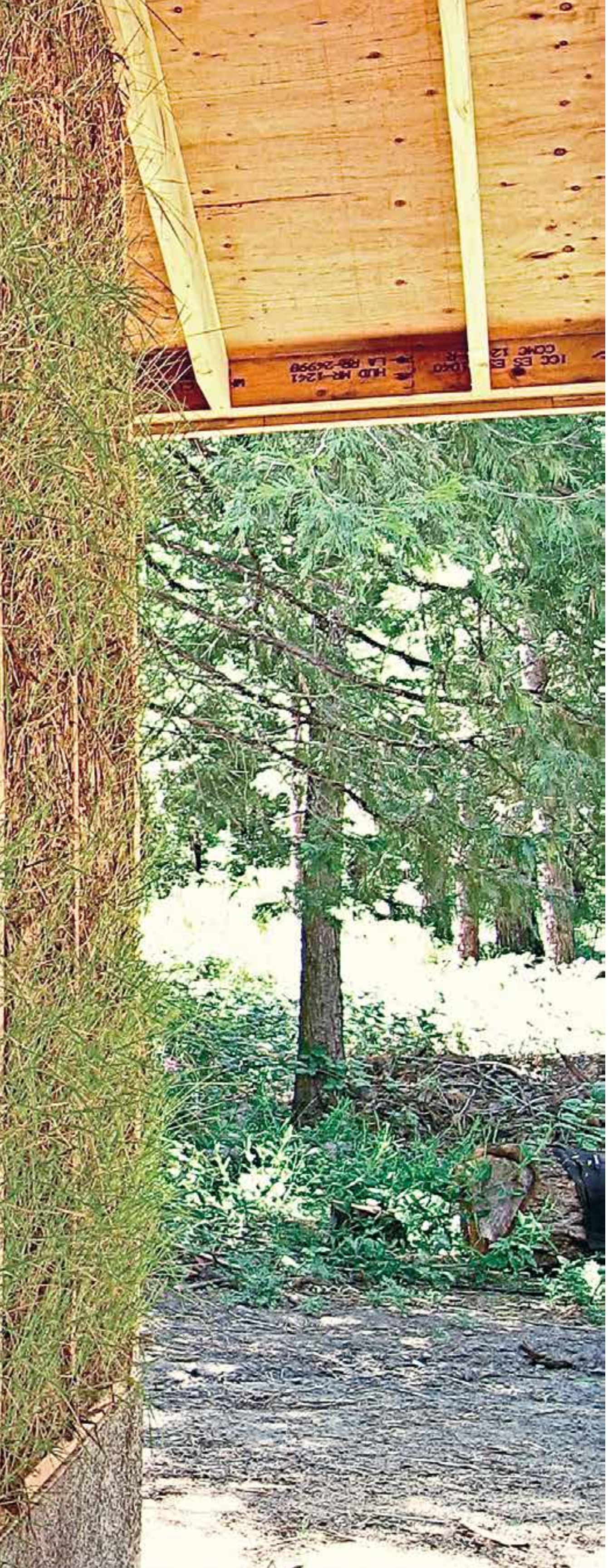
CREDIT: ECONEST CO.

Sprouting Walls

Wet LSC walls sprout. Don't be alarmed! These sprouts, from grain seeds left in the straw, are natural helpers. As they grow they release moisture into the atmosphere while their roots further bind the straw and clay. As the wall dries, these built-in moisture meters will slowly die, indicating that it is time to measure moisture content with a bale probe—anticipating plaster installation. The dead sprouts are left in place and help the plaster adhere to the wall.

Left: Completed gable with formwork removed. Above: Measuring moisture content in the LSC wall with a bale probe.



CREDIT: JOYCE WARD

Chapter 13

Drying and Prepping for Finish

The LSC Building Season

Ideally, plan your construction for the beginning of the dry, warm season so that your building will have optimal conditions for drying. Your workforce will also have optimal conditions for building—doing outdoor work in fair weather and moving to enclosed heated space to do the finish work once winter arrives.

For the past 20 years, we have been headquartered in the desert Southwest and then the dryer parts of the Pacific Northwest, where we are able to construct LSC walls, spring, summer, and fall. (However, fall LSC-building starts in our climate may require auxiliary drying techniques.) It is important to build well ahead of potential freezing weather, as clay is not sticky when it freezes and will not bind the straw together.

Drying LSC Walls

LSC is a wet technique, and walls must be dried in a timely manner for a project to succeed. The climatic conditions must be assessed and an appropriate drying strategy must be in place before construction begins. Temperature, wind, site exposure, and relative humidity all affect the rate of drying. Walls in the Southwest will dry out faster than walls in the Northwest. Walls will dry out faster in hot, dry, windy conditions and much slower in still, humid, or cold conditions. In favorable drying conditions, the walls will naturally dry out approximately a half inch each side per week, totaling one inch a week. Under optimal conditions, a 12"-thick wall could be dry and ready for plaster in 12 weeks.

When climatic conditions do not do the job of drying the walls, the following auxiliary measures can be implemented to assist the interior drying.

- Industrial fans
- Commercial dehumidifiers available from rental shops
- Wood-burning stove that is fired daily, or other radiant heat source
- Household heating system operational as soon as the heating season starts

Be diligent about getting the roof on your building *as soon as possible* to ensure the wall-drying process is not hindered. A little rain will not harm the walls under construction; however, we protect the walls from heavy rain as soon as possible. A heavy rain on exposed completed walls can set the wall-drying back a few weeks. During construction and before a roof is on, pay attention to weather reports.

TIP: In a pinch, plywood slip forms screwed to the tops of the Larsen trusses can serve as good temporary umbrellas against uncooperative weather.

Three-foot diameter industrial fan accelerates the drying process.

CREDIT: JENS WIEGAND

Hybrid Strategy

In wet climates with a short drying season, we have successfully used a hybrid wall-drying strategy that combines the benefits of a thinner, faster-drying LSC wall on the inner face of the exterior walls and insulation on the outside.

Two EcoNest projects built in the short dry season of the Pacific Northwest illustrate different applications of this concept.

The first home, east of Portland, Oregon, has 6" straw clay walls wrapped with 4" of cellulose to meet the state energy code. The second home, on the west shore of Vancouver Island, Canada, has 8" straw clay walls wrapped with 4" of rock wool boards. Both homes are finished with vertical cedar siding.

Cold Climate Strategy

Building walls more than 12" thick for enhanced insulation can present drying challenges and is only recommended for ultralight LSC mixes of less than 15 pcf. Design Coalition, based in Madison, Wisconsin, is at the forefront in pioneering the research and use of ultralight LSC.

Installing cellulose insulation wrap over 6" dry LSC wall.

CREDIT: RON HAYS

Right: Completed home with vertical cedar siding. Below: Completed hybrid wall.

CREDIT: RON HAYS

CREDIT: RON HAYS

Settlement

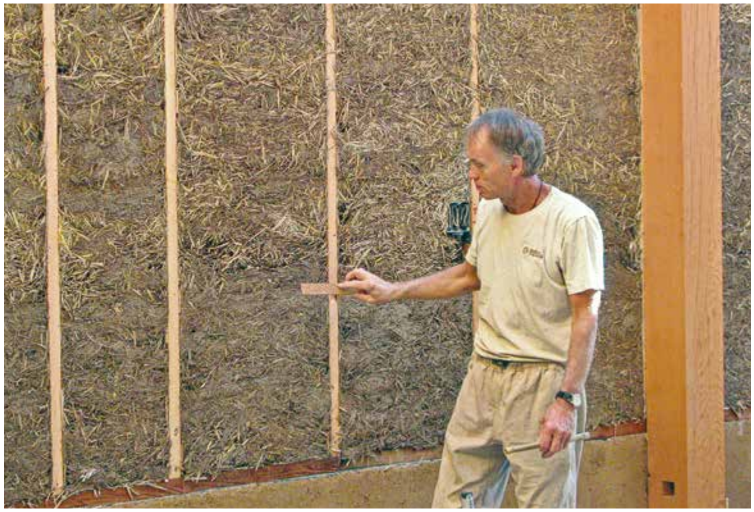
Settlement of LSC walls occurs over time as they dry out and cure.

Settlement is influenced by evaporation and the collective weight of the wall. In 1990, while studying the LSC technique in Germany, Robert was told that mastery of the technique is to build with as little water as possible. This has proven to be solid advice. Nevertheless, the weight of an uncured LSC wall is formidable. A linear foot of an 8'-tall wall will contain an average of 100 lbs. of water. This is why it is important to evenly distribute the weight of the LSC with stabilizing bars; doing so greatly reduces overall settlement and gaps.

Chinking

Shrinkage gaps and voids are chinked with a heavy mixture of LSC.

Chinking is the process of plugging a hole or filling narrow cracks. Holes, gaps, cracks, and spaces in LSC walls are all referred to as "voids." It is satisfying to remove the formwork and discover a perfectly compacted wall free of initial voids. As the walls dry out, though, voids may develop that will require chinking. Voids are commonly found beneath electrical boxes, where it is difficult to compact the LSC.


CREDIT: JENS WIEGAND


CREDIT: ECONEST CO.

Above: Examining the filled wall for voids. Below: Chinking a void under the electrical box using a tapered shim to root the material deeply into the void.

Voids exceeding the size of a tennis ball are best filled and allowed to dry before finishing the walls. Smaller voids can be filled with the base coat of plaster when finishing the walls.

In the case of a load-bearing matrix, the biggest gaps show up below the top plate. These spaces that extend through the wall are first stuffed with 6–8 inches of sheep's wool or rock wool insulation in the center and then plugged with two inches of chinking on both sides.

Preparing a Chinking Mixture

As previously mentioned, the sticky residue build-up in the tumbler is ideal chinking material. During production we carefully harvest

Settlement gaps are first filled in the center with wool insulation and then chinked on the inside and outside edges.

CREDIT: ECONEST CO.

this compound daily and store it for chinking the walls later. This heavy mixture will remain workable for four or five days, becoming more malleable with time as the clay is fully activated. After five days, the mixture stiffens up and requires rehydrating with slip.

To prepare fresh chinking material, chop straw in a leaf mulcher to a length of 1"–3", with most of the material being 1". Combine equal volumes of chopped straw and thick slip in a wheelbarrow and use your hands to squish the materials into a homogenous paste. Like perfectly prepared spaghetti, a good chinking compound will stick to the wall when hurled at it. This chinking mixture can be used immediately or allowed to cure for improved workability. Cover the mixture when not in use, and store out of the weather. Electric leaf mulchers make fast work of chopping straw and are available from a variety of sources, including Sears and hardware stores. Chopped straw is also used in clay plasters, so investing in a 13-amp electric mulcher is worthwhile. (They are excellent for making mulch too!)

How to Chink

Wooden shims measuring an inch wide and tapering from ⅛"–¼" over 10 inches make good chinking tools.

Use the shim to probe the void, pushing any surrounding loose, fluffy material deeper into the cavity. The secret to strong chinking is to root the new mixture deeply into the void.

With a combination of poking with the shim and massaging the material into the wall with thumb and fingers, the compound is distributed into the entire void, adhering and becoming monolithic with the surrounding straw clay walls. The wall is easily made whole and tight because of the forgiving nature of straw, clay and water.

TIP: Nitrile gloves offer protection and dexterity and are perfect for making and applying chinking.

Tightening Springy Walls

The following story attests to the ease with which LSC walls can be repaired after completion. In this case, the problem was generated by freak weather conditions. Immediately after we completed the LSC walls for an early spring project in New Mexico, the temperature

Chinking material composed of equal parts thick slip and chopped straw and aged for three or four days. Bamboo and wood shim, seen in the wheel barrow, are used as tools for rooting the chinking compound.

CREDIT: ECONEST CO.

CREDIT: JENS WIEGAND

CREDIT: JENS WIEGAND

Above: Massive void caused by installing poor material. The material which was installed too dry has been excavated and the wall has been rehydrated with a thick slip. Below: Fresh chinking material is rooted deep into moistened wall.

CREDIT: JENS WIEGAND

dropped suddenly and stayed below freezing for a week. The moist wall surfaces froze and expanded, loosening the tightly woven faces, turning them into a springy surface unsuitable for plaster. The walls would first require tightening. Months later, after the walls had dried and we were ready to chink, we massaged thick slip into the loose straw of the wall, rehydrating the surface and effectively re-integrating and anchoring it into the sub-surface. Without much effort, the damage was corrected and the walls were plaster-ready.

CREDIT: JENS WIEGAND

Above: The new surface is planed out with the surrounding wall. Below: With the chinking complete the wall is "as good as new."


CREDIT: ECONEST CO.

Chapter 14

Completing the Exterior Envelope

With many tons of massive insulation in place, we proceed to enclosing the Nest. Our goal is to create an airtight and vapor-permeable, or "vapor-open," envelope that will protect these walls and the residents within from the elements—without sacrificing the vital connection to nature in the process.

The Roof: Crafting A Good Hat

Culturally, we associate shelter with "a roof over one's head." A generous roofline elicits a feeling of security for good reason. A well-executed roof is as functional as it is beautiful.

The roof of an EcoNest, with typical 4' overhangs, is the most dominant exterior feature of the home. The generous roof plays multiple roles in the longevity of the building, along with the cooling benefits discussed earlier:

Incredibly strong LVL hip rafters cantilever 7' to facilitate the 4' roof overhang.

A good roof can give centuries of life to a structure. Deep overhangs provide protection against the elements.

- It directs precipitation away from the foundation, keeping rain and standing snow away from the natural walls
- Properly sized, it shades the walls in the summer when the sun angles are high and permits solar gain in the winter.
- It can capture millions of gallons of water for re-use over its life.
- It provides a sheltered walkway around the building.

The hip roof is perhaps the strongest of the pitched roofs and, when combined with a gable roof to form a hipped gable design, it can create pleasing proportions, details, and textures.

CREDIT: ROBERT LAPORTE

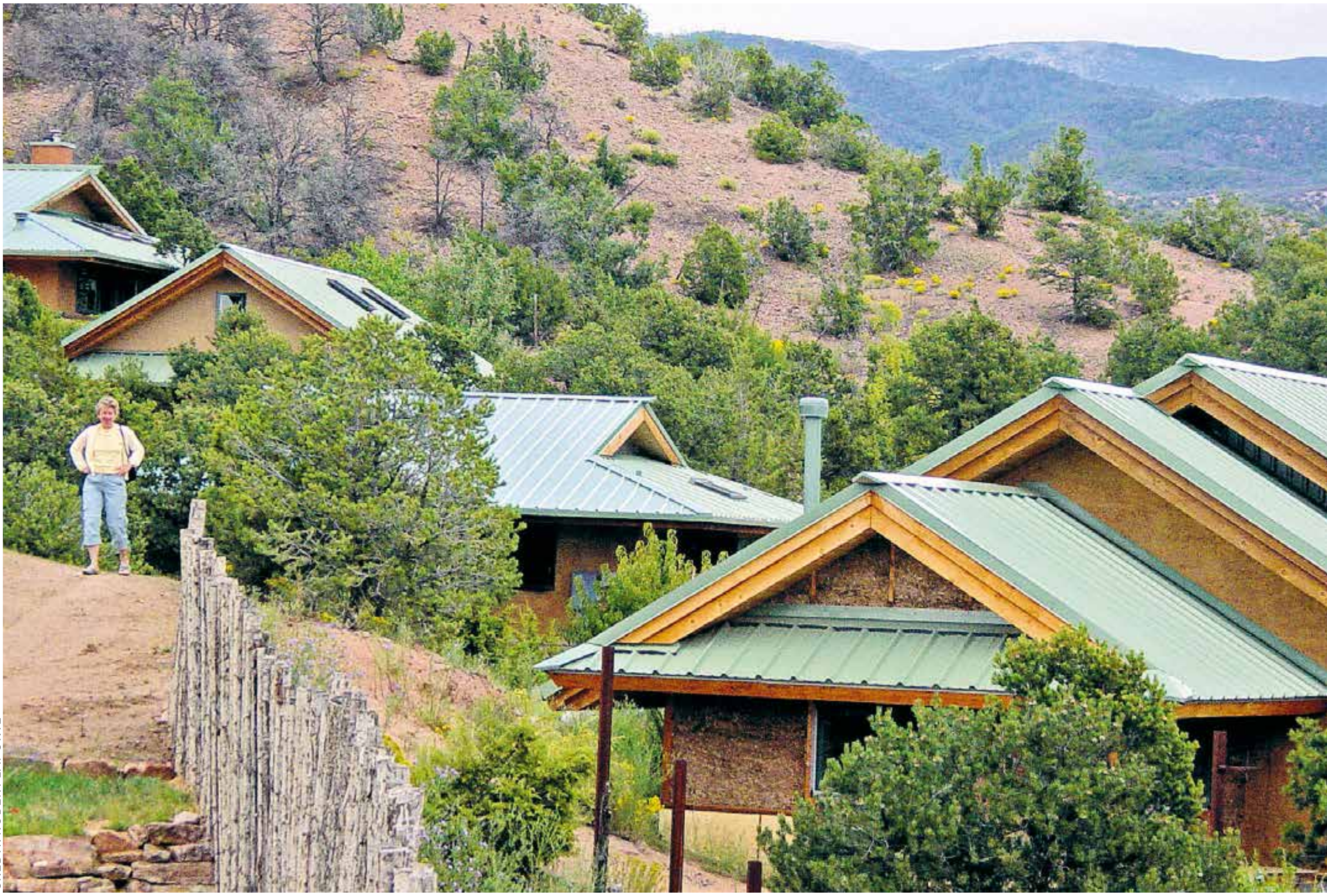
Roof Framing

Before all the straw clay is completed, the roof framing process is underway. Top plates are installed on finished walls and the roof layout has begun. We are motivated to protect the drying walls and timber frame from the weather with expedience.

We use either traditional roof framing with 2×12 rafters or manufactured trusses for EcoNest roofs. Traditional framing requires more time, wood, and skill—but has advantages. It provides a deep cavity for insulation, creating a conditioned attic space under it. This space is useful for storage and running utilities as well as clear access to the utilities for future renovations.

Trusses have the advantage of using smaller-dimension lumber and are a good option where skilled roof framers are not available.

A cascade of roofs at the Tesuque EcoNest Compound.



CREDIT: ROBERT LAPORTE

Below: Roof sheathing in place over principle roof. West wing hip framing over main roof in progress. Opposite: The completed roof.

Roofing Materials

We often use metal roofs, as they are suitable for water catchment, an important feature on many EcoNests. They are strong, durable, maintenance-free, and long-lasting. From a Building Biology standpoint, metal has the advantage of providing shielding from radio/ microwaves. Metal can, however, become electrified from surrounding power installations. The roof should be measured for possible fields and, if necessary, grounded.

For roofing underlayment, a number of less toxic alternatives to tar paper are now available. The new generation of water-repellent high-perm underlayment is now available through **475** and **Small Planet**

CREDIT: ROBERT LAPORTE

CREDIT: ECONEST CO.

Workshop. These "breathable" membranes repel water while allowing any moisture vapor to be released.

Roof Insulation

The criterion for selecting roof insulation in an EcoNest is to use the least toxic alternatives available that are within our client's budget. However energy efficient, we discourage the use of foam-based products because of the high embodied energy and pollution caused by their manufacture and the fire retardants in them.

Dense-pack borate-treated cellulose is our most commonly used roof insulation—where it is available and in common use. Other insulation alternatives include cotton by **Ultra Touch** and wool by **Oregon Shepherd**.

The hip gabled metal roof of the Johnson nest in Santa Fe, NM.

If fiberglass is the only viable insulation alternative, then we select a brand without formaldehyde.

Gutex, a high-performance tongue-and-groove wood fiber board insulation, can be used in place of roof sheathing to increase thermal performance. This product, with an R-value of 3.4 per inch, effectively creates a vapor-open roof assembly.

Soffits

The bottom side of the roof overhang is called the *soffit* and will either be horizontal or sloped depending on the roof design. We commonly use 1 × 6 tongue-and-groove wooden boards to finish the soffit. We have also used paneled soffits, which are more economical because the material costs are less and the installation is faster. Panels of exterior-grade-finish

CREDIT: KIM KURIAN

CREDIT: ECONEST CO.

Soffit detail showing plywood panels.

CREDIT: ECONEST CO.

Detail of tongue-and-groove Aspen soffit with 5' deep overhang protecting the exterior timber-frame of this porch.

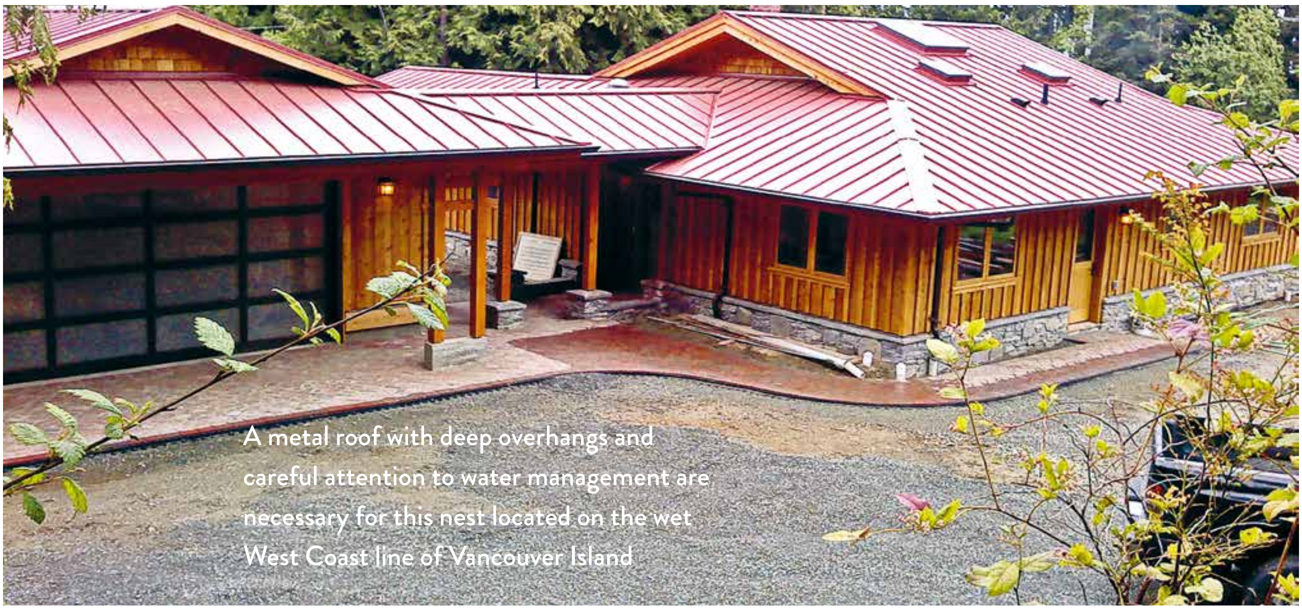
plywood are installed, and the joints are covered with small, thin battens for a visually quiet enclosure.

Where a fire-resistant soffit is required, fiber cement panels may be substituted for wood and are commonly available in a variety of textures and patterns. Plaster soffits are also fire resistant.

Roof Ventilation System

One of the keys to a healthy roof is the roof's ability to stay dry by handling moisture vapor that enters the roof cavity from above or below.

Fibrous insulation requires a ventilation channel to exhaust moisture and prevent condensation in the roof cavity. A baffle creates a



A metal roof with deep overhangs and careful attention to water management are necessary for this nest located on the wet West Coast line of Vancouver Island

CREDIT: KEARY CONWRIGHT


CREDIT: ECONEST CO.

The continuous ridge vent seen in this photo has a continuous soffit vent counterpart so that there is a flow of air keeping the roof sheathing free of condensation.

continuous ventilation space between the insulation and the roof sheathing from the eave to the peak, helping to cool the roof in the summer and preventing condensation in the winter. Air enters through a continuous soffit vent and exhausts out of a continuous vent at the peak of the roof. Both soffit and ridge vents are available as continuous strip vents at your building supply or **Cor-A-Vent**.

Smart Barriers: Preventing Condensation

In many locations, the building code has mandated a vapor barrier separating the insulation and the conditioned space. Impermeable barriers, so antithetical to Building Biology, will trap moisture that finds its way into the insulation, causing loss of insulation performance and degradation of the structure.

At the time of this writing, we are seeing breakthroughs in best practice for keeping the roofing system free of condensation and vapor issues. Europeans have long been using a class of air barrier that is vapor open, keeping moisture-laden air out of the insulation cavity while allowing any moisture vapor that finds its way in to diffuse out instead of accumulating. Fortunately, "smart barriers" have now been introduced into North America from Europe. **Pro Clima** and **Siga** are now available in the USA.

Walls

About Permeability

During Robert's research in Germany, he inspected lime-plastered wattle-and-daub timber-frame buildings that were completely sound for seven centuries preceding World War II. After the war, some of these ancient buildings were plastered with Portland cement stucco. Because the cement held water at the interface where the plaster meets the timber, the timbers had severely decayed over a few short decades, and the buildings were sadly beyond repair.

The same thing happened in New Mexico with the old adobe churches. Traditionally, they received a new coat of earth stucco yearly. When cementitious stucco became available, it was thought to be a great labor-saving innovation. It was put on most of these churches; unbeknownst to the parishioners, the adobe walls of their churches were dissolving behind the stucco because moisture that was trapped in the walls was unable to escape through the cement. Today, as a result of the research and restorations by the non-profit group Cornerstones,[7] many of these historic New Mexico churches have been saved. The cementitious plasters have been torn off and replaced with traditional coatings.

Perhaps the most difficult interface between building departments and natural builders seeking permitting has been the code requirement for a water-resistive barrier on the exterior of the building (R 703.2). This provision is important for the protection of conventional frame construction from deterioration that can occur when water vapor enters the cavity, reaches dew point, and condenses.

This is *not* relevant to Light Straw Clay construction because the clay content in the massive 12"-thick walls creates a tremendous hygric buffer capacity. A critical concentration of moisture does not ever penetrate deeply enough from either the interior or the exterior to reach dew point. Furthermore, many of the "housewraps" and liquid coatings used to create the prescribed water-resistive barrier would have a detrimental effect on the LSC wall system because they would inhibit sufficient drying. Fortunately, the 2015 International Residential Code now recognizes Light Straw Clay Construction and the need for a permeable skin. Refer to Appendix C at the end of this book for an excerpt from the new Light Straw Clay code.

The exterior coating of an EcoNest is meant to prevent bulk water from entering the wall system while allowing vapor to freely move through the wall. An LSC wall system *manages* moisture. It will take up excess and hold it, unharmed, until conditions change, and then re-release it into the atmosphere. This capacity to wick moisture away from more vulnerable cellulose wall components is the key to the longevity of an LSC wall system. It is crucial that this "breathability," or permeability, of the clay be unhindered, so the exterior and interior finishes must also be sufficiently permeable. Lime plaster, clay-based earth plaster, mineral coatings, and vented wood siding are all acceptable skins for a straw clay wall.

Natural Plasters

The rudiments of plaster are introduced in our Natural Building Workshops. However, like timber framing, plastering is a craft that takes many years to perfect. Traditionally, the skills and formulas were passed on from master to apprentice. There are excellent books written about plaster, and some are listed in the Resources section of this book. LSC and **Faswall** are flat surfaces perfectly textured to receive plaster. Perimeter walls receive a traditional three-coat application, with a total thickness of approximately ¾".

There are four basic steps to plasterwork.

1. Lathwork is the process of bridging dissimilar materials in order to prevent cracks in the plaster as these materials move differently. On an LSC wall, lath is required to bridge over any exposed wood.

2. The first coat, called the *scratch coat*, is ⅜" thick. It is the foundation that adheres to the substrate and lath. The scratch coat is raked to create a grooved surface for a mechanical bond with the next coat.

3. The second coat or *brown coat*, also ⅜" thick, creates the final shape of the wall.

4. The third coat, called the *finish coat*, imparts the final color and texture.

In the following paragraphs we will describe the types of natural plasters we have used for EcoNest exteriors and the characteristics that distinguish them.

Clay-based Earth Plasters

An LSC wall is quite self-sufficient in and of itself. It can remain unplastered for many years with very little wear or deterioration. The goal of plastering is to achieve a durable and finished surface that will provide additional protection and enhance the beauty of the wall.

Earth plasters can have many years of serviceable life in sheltered locations, provided that there is a good roof overhang and no horizontal driving rains. In less-sheltered locations, the earth plaster serves as a "sacrificial coat" that will require re-application, occasionally or frequently, depending on the weather conditions.

Although the least durable of the wall coatings, clay-based plasters have many advantages.

The use of local, natural clay soils represents the solution with the lowest embodied energy. The resulting finish will "anchor" the building, harmonizing it with its landscape.

Clay-based plasters are forgiving to apply, with unlimited working time. The plasters can be re-moistened and reworked to remove minor imperfections. The LSC wall system—with its natural tooth and porosity—is an ideal surface to receive clay-based plasters.

Scratch and brown coats of clay plaster with local Santa Fe soils.

CREDIT: PATRICK OWEN


CREDIT: PAULA BAKER-LAPORTE

The Light Straw Clay Code permits several types of plaster lath for bridging dissimilar surface materials. We have found that low-tech, natural solutions work well with clay-based plasters. In fact, clay bonds better to natural reed than to metal lath. Inexpensive reed matting, which is commonly sold as landscape fencing at the big box hardware stores can be easily cut to the required sizes and lends itself to rounded corners. Natural burlap with an open weave can also be used.

Although this is the least permanent of the finishes discussed, the lifetime of a clay-based plaster can be greatly extended with additional applications of lime or mineral paints. When lime is applied over a clay base, it is essential the clay plaster be raked to create a well-keyed scratch coat. Mineral paints are applied to a finished plaster surface.

TIP: It is very important when making clay plasters with local soils that only mineral soil is used. If any organic top soil contaminates the plaster, mold can bloom on the wall surface, especially in damp or humid climates. This can cause a permanent and unattractive discoloration on the wall surface. A preventative treatment for inhibiting mold growth is to add ½ lb. boric acid/50lbs of dry plaster, or 1 ounce thieves oil/50lbs dry plaster.

Finish clay plaster above and cement stucco wainscot separated by a cedar band.

Exterior Lime Plasters

Lime plaster is the ancient prescription for protecting earthen walls in harsh climatic conditions. In Germany, there are examples of lime plasters that have preserved three-story buildings for centuries, with little protective roof overhang.

Hydrated lime is created from limestone in a process of heating it to 1,830°F, releasing CO_2 into the atmosphere. The quicklime that results from this process is then slaked in water, the longer the better. Sometimes, these lime pits are passed down from generation to generation, a precious inheritance for future generations of builders.

When the lime plaster is exposed to air, it recombines with CO_2 to form limestone again.

Essentially, the building is coated with a thin layer of protective stone. Carbon released in the production of lime is recaptured in the process of curing, offsetting some (but not all) of the environmental costs.

The complex chemistry involved in the making and application of the various types of lime plaster requires thorough understanding before it can be successfully rendered on a building.

There are two main types of lime used for plaster:

- *Non-hydraulic lime*, also called *hydrated lime*, is derived from relatively pure limestone. This hardens from carbonation-exposure to air and takes a long time to cure and reach full strength. Because of this, it is most often used as a thin final coat over other substrates. This is the standard lime that is widely available from building supply outlets and is not to be confused with agricultural lime.
- *Natural hydraulic lime* (NHL) derives from limestone with reactive silica and aluminum impurities. Like cement, it hardens in the presence of water. NHL then continues to cure through carbonation. **St. Astier** is a resource for natural hydraulic lime plasters and information.

Both types have been used successfully on LSC walls.

We have found that the best lath material for use with lime plasters is expanded metal. A separation membrane is required between wood framing and the metal lath; otherwise the lime can bond with the wood and it can crack when the wood movement exceeds the elasticity of the plaster.

Technically, lime plaster is more challenging to work with than clay plaster because it sets up quickly. It must cure slowly, thus requiring routine misting and protection from direct sun. It requires five to seven days to set at temperatures above 45°F. A provision for supplementary heating should be in place for work where temperatures could drop below this during the curing process. Once the lime has been successfully applied, the result is a durable and beautiful finish with approximately three times the permeability of cement stucco.

Like cementitious plasters, lime is caustic and requires eye, skin, and lung protection.

The natural whiteness of lime plasters makes it easy to color with mineral pigments in the finish coat. It is important to maintain a high enough ratio of lime to pigment, though, so the strength of the finished plasters is not compromised. Pure mineral pigments can be obtained from ceramic supply outlets.

Ochres and Oxides, listed in the Resources section, specializes in plaster pigmentation and is a resource for information and pigments for plastering.

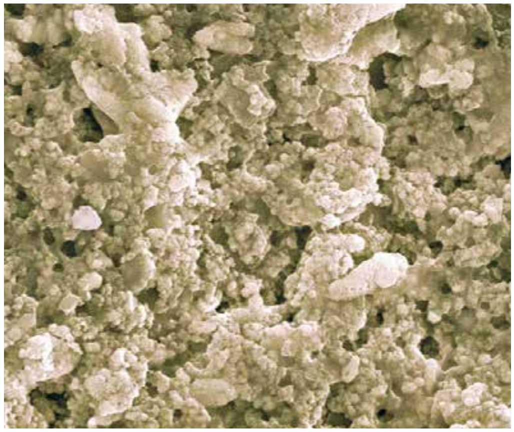
Mineral Silicate Paints

Mineral silicate paints use potassium silicate (water glass) as their binder. They can be used as a finish coat over lime or clay plaster to impart qualities of weather resistance and add color. Originally formulated in Germany in 1878 for cold-climate fresco work, mineral silicate paints were soon adapted for finishing buildings. Original applications on building facades dating back more than 100 years have proven to be durable without the need for re-application. The mineral silicate paints permanently bind with the siliceous substrate

Rich pigment in St. Astier lime finish coat is troweled over a lime brown coat.

CREDIT: PAULA BAKER-LAPORTE

rather than sealing over it, thus maintaining the breathability of the skin. The coatings are colorfast, VOC free, anti-microbial, and flame resistant. This is a good finish coat for those who prefer to work with clay plaster where there are demanding weather conditions. Sources include **Keim**, **Eco-House** and **SiliCote**.



CREDIT: KEIM USA

This magnified picture of Keim shows its porosity, which creates a vapor-open finish that binds permanently with silica-rich substrates.

Wood Siding

Wood siding is a beautiful, simple, and natural solution for protecting the LSC wall system. Wood siding must be installed over a ventilated space known as a *rain screen.* This rain screen serves to break the driving force of

Scott Alison's barn has a durable and colorful Keim mineral silicate paint. The Keim coating was able to fix cosmetic crack failures in the lime plaster under it.

CREDIT: ZACH COVENTRY

Allison Barn close up.

CREDIT: ZACH COVENTRY

wind-driven precipitation. Before installing the furring strips that create the rain screen, we apply a thin layer (⅜") of clay or lime plaster over the LSC wall, which serves as an effective air barrier, sealing off any pathways for air leakage and intercepting any moisture that finds its way through the siding and ventilated rain screen.

We often use a combination of plaster and wood siding exterior finishes because they go well together. Wood siding is a practical treatment for roof dormers. Plastering, on the other hand, requires multiple protection measures on surrounding building components, and it is inherently a messy process. Wood is a clean, one-step installation, especially practical in these hard-to-reach places.

Maintenance of wood siding is minimized by the large 3'–4' roof overhangs that are typical of our designs. We prefer to protect the wood surfaces with natural, breathable products. We commonly use: **Seal-Once**, **WeatherBos**, and **Rubio Hybrid Wood Protector**.

Windows and Doors

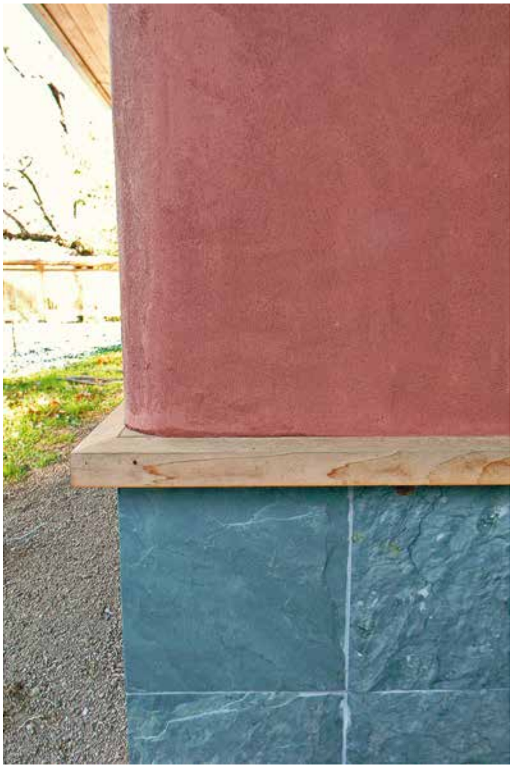
Prior to installing the windows, a generous layer of sheep's wool or rock wool is placed on top of the LSC sill so that the ¾" plywood

Cedar board-and-batten siding on stone wainscoting make very appropriate exterior finishes on Vancouver Island where these natural resources are abundant.

CREDIT: KEARY CONWRIGHT


CREDIT: ECONEST CO.


CREDIT: ECONEST CO.


CREDIT: ECONEST CO.


CREDIT: ECONEST CO.

Top left: Earth plaster above flagstone.
Top right: Clay plaster above cement stucco.
Bottom left: Lime over slate tile.
Bottom right: Lime above cement stucco.

sub-sill floats an inch above the insulation. Screw the sub-sill in place, compressing the insulation.

Windows are installed flush to the outside, using the manufacturer's nailing fin. This position eliminates a vulnerable sill. It is then flashed thoroughly, using a non-bituminous flashing system per manufacturer's directions. The deep window sill on the inside reveals the formidable depth of the wall, which speaks to the solid nature of the home.

Exterior Wainscoting

The lowest portion of an exterior wall is the most vulnerable. It has the least protection from the roof, and it is the splash zone where rain will hit the ground and spray upwards onto the wall. Snow can also accumulate next to this part of the wall. As discussed earlier, our typical stemwall extends a minimum of 16" above grade.

We typically give architectural expression to this dividing point between stemwall and LSC on the exterior with a wainscot.

We have used several different wainscot treatments, including stone, simulated stone made of concrete, stone tile, steel siding, and cement stucco. All of these are capped with a capstone or a decay-resistant wood sill. Stone is the most durable and expensive of the choices.


CREDIT: KIM KURIAN

Chapter 15

Crafting the Interiors

All of the efforts to make a naturally healthy building envelope can either be enhanced or negated by the choices made in the interior. How can one navigate through the thousands of choices available? To create the most vital interiors possible, we follow the principles of Building Biology as explained in Section I. These principles include using:

- non-toxic natural materials and finishes throughout.
- unsealed or naturally sealed hygroscopic finishes for the most beneficial indoor climate for clean air, ion balance, humidity balance, and good acoustics.
- color in accordance with nature.
- daylighting.

Why leave nature behind when you walk through your front door?


CREDIT: ECONEST CO.

Ceiling Finishes

In our homes, we use three main materials for ceiling finishes: wood, plaster, and rice paper. It is absolutely unnecessary to seal ceiling materials, as they are well out of harm's way. Leaving them unsealed has the advantage of added hygroscopicity and better acoustical attenuation.

Diffusing Daylight through the Ceiling

In our single-story designs, we are often able to get a lot of mileage out of each roof skylight by leaving a conditioned attic space open and creating translucent rice paper ceiling panels where we want to bring in daylight.

One of the hallmarks of our single-story designs has been the use of a timber frame and rice paper "mandala" ceiling screen to create a diffusion of daylight through the center core of our buildings. Our goal is to bring a soft and soothing daylight throughout the home, using a minimal number of skylights, so that daytime ambient electrical lighting is not required.

Building the Mandala

The mandala framework is a decorative grill that fits into the structural timber frame. While the primary opening for the mandala grill is an integral part of the timber frame,

A rice paper ceiling brings diffused natural light into this interior hallway.

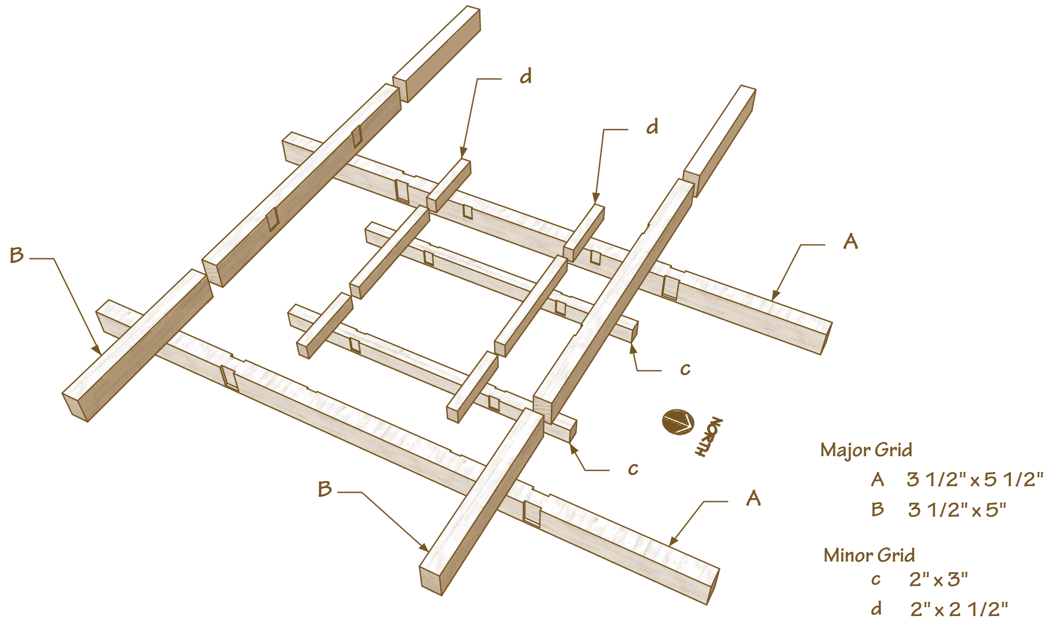


Figure 15.1 The mandala framework exploded view. Sizes shown are for a typical 12' grid. Sizes will increase for larger cores.

the grill is one of the last things to be installed in the finished home.

Locally sourced clear wood is recommended for strength, proportion, and serenity. Our favored woods here in the Pacific Northwest are clear, tight-grain Port Orford cedar and Douglas fir.

The Mandala Grill

We construct the grill with simple "housed" joints because it is held in place by the surrounding timber frame, and the weight of the rice paper panels is insignificant. The housing is a shallow recess in one frame member that receives the full section of its mating timber end. All housings are 1⁄32" narrower than the member they will receive because at the time of assembly the fiber of the incoming member is slightly compressed by peening the end with a chisel hammer. The resulting union is a tight fit. All housings in the major grid are ½" deep, and all housings in the minor grid are ¼" deep.

The installation sequence is as follows (refer to illustration):

1. Cut and install the major grid's full-length beams "A" (running north/south) into the main timber frame.
2. Cut and install the east/west segmented beams "B" into the "A" beams. The height of these B members is ½" less than the A members, allowing them to be fully housed. Clamps are helpful for assembling the tight-fitting members.
3. Repeat the process for the minor grid c and d.

This mandala ceiling brings a calming diffused natural light into the core of the home.

CREDIT: PAULA BAKER-LAPORTE

4. Full-length "c" members are housed into B members and segmented d members are housed into A and c members.

Installing the Rice Paper Panels

On top of the mandala timber frame, individual removable wood frames are built with clear, straight ⅝" x 1" wood, and covered with rice paper. The frames are invisible above the timber frame once in place. The rice paper is taped to the frames with special double-sided tape. Rice paper laminated with polyester (for strength) is sold as individual sheets or rolls that are 36" or 54" wide.

After the frames are built, it is easiest to get a wrinkle-free application on larger frames if two people work together, one tensioning the paper as the other presses it down onto the tape. Here are step-by-step instructions for a successful installation:

1. Make a jig with a sheet of clean flat plywood at a comfortable working height that is accessible from four sides.
2. Screw 1 × 2s to create a fence along two adjacent edges of the plywood, meeting at a corner.
3. Place two sides of the panel against this fence. Lock this squared-up frame in place by screwing blocks at the other three corners. Do all same-sized panels and then re-size the jig as needed.
4. With the panel secured, install the double-sided tape along each length of the frame but do not remove the backing that will contact the rice paper. For sides that are greater than 3' long, cut the backing of the tape in the middle so that the paper can be installed on one half at a time.
5. Place rice paper on top of the frame and pin in place with push pins.
6. Unpin and lift one corner of the paper and remove the backing from the double-sided tape on one side.
7. With tension on the paper, slowly make contact with the frame and press the rice paper against the exposed tape.
8. Repeat for the other three sides.

The keys to success are taking your time, working with an assistant, and keeping tension on the paper.

Supplies are available through **eShoji** or **Shoko Hardware**.

Plaster Ceilings

Ceiling plaster is usually applied over gypsum board. Because plaster will not adhere well to gypsum board, it is necessary to first prime the surface with a sanded adhesion coat. This is a paint blended with sharp fine sand, which provides the necessary tooth. The primed surface resembles sand paper. Adhesion primer can be purchased through **American Clay** or mixed on site by adding the appropriate sand to a nontoxic paint of your choice.

The plaster can be a single skim coat or more, depending on the desired result.

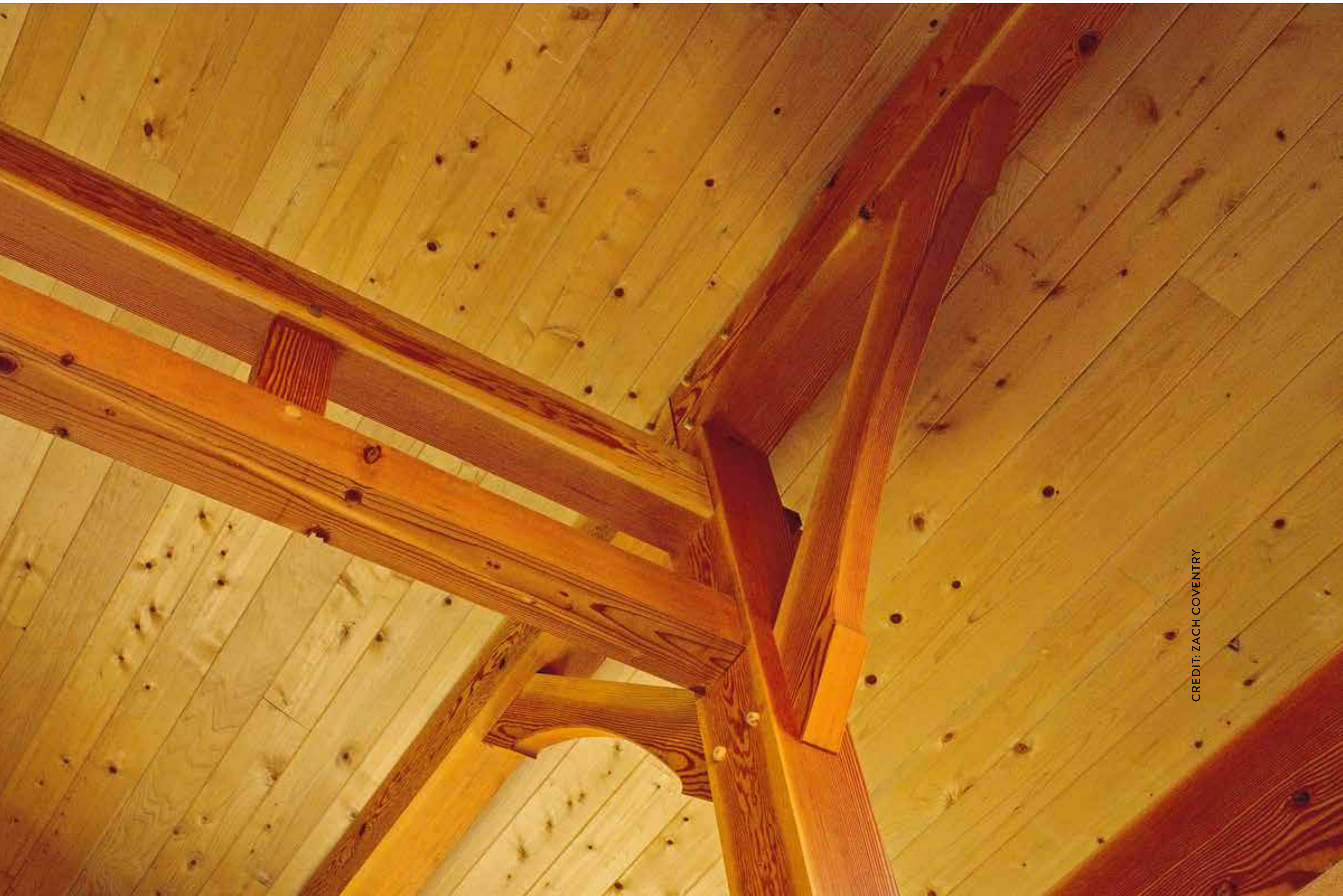
Wood Ceilings

The most common ceiling finish in our homes is 1 × 6 T&G (tongue-and-groove). Because of the simplicity of installation, this choice is a fast and economical option. We favor light-colored, "quiet" grained woods that are locally available. We select the most knot-free woods for the public spaces and use the busier woods in closets and bedrooms. We leave the wood unsealed.

Interior Walls

Mass Interior Walls

There are several types of walls used in the EcoNest interiors. We often introduce additional mass to the interior of the home to improve the stability of the indoor climate by decreasing temperature and humidity fluctuations. These mass walls also improve acoustics by absorbing sound rather than reflecting it back into the room or transmitting it through the wall. Adobes (unfired clay bricks) and wattle and daub are natural and ecological choices for interior mass walls.


CREDIT: ZACH COVENTRY

Ceiling of Scott Allison's barn. The Port Orford cedar tongue-and-groove ceiling provides a nice light background behind the fir timber frame.

Adobes are commonly available in New Mexico and Arizona. We order unstabilized adobes to avoid the asphalt emulsions or cement that is often added to increase strength and water resistance. Stabilization is not necessary for interior applications, and these additions increase the embodied energy while decreasing the hygroscopic capability. In parts of the country that do not make adobes, compressed earth blocks may be available.

If there is a brick factory near you, then you may be able to obtain unfired bricks. We found that our local factory was willing to sell us unfired bricks before they went through the kiln. This is the most ecological and beneficial way to use them for an interior wall. Fired bricks, although no longer vapor permeable, can also be used and will still contribute to temperature stability and acoustical attenuation.

Wattle and daub consists of a heavy mixture of clay soils with just enough straw in it to strengthen the mixture. A 4.5 × 4.5" gridwork is assembled with bamboo or wood and attached to a perimeter framework. This serves as an armature to hold the daub in place while

The Japanese style ceiling of our sauna features western red cedar over clear Port Orford cedar purlins and rafters.

CREDIT: JONATHAN SHAW

CREDIT: LAURIE DICKSON

it sets up. The daub is shaped into loaves, which are hung over and pressed in to the armature. One advantage of this technique is that it can make fairly thin—but heavy—walls where space is limited.

Other Interior Walls

The majority of the interior walls are conventionally framed with 2 × 4 or 2 × 6 lumber and sheathed in a gypsum plaster board such as **Kal-Kore** or **Imperial Board**.

CREDIT: ECONEST CO.

Plaster Wall Finishes

As described above, it is not uncommon to find several different types of wall construction within an EcoNest. The plaster finish throughout unites all of the parts into a single composition. Using natural pigments for coloration in plaster creates a lively field of texture and hue that replicates color as found in nature.

The professional plasterer, once in high demand, was all but a lost resource in North America once factory-made sheetrock/drywall became widely available. Currently, plaster is enjoying a renaissance because of the exquisite feel that it renders to the inside of a home. Painted drywall is a lifeless and ineffective alternative by comparison.

Top: This unfired adobe wall brings the benefits of a stable and natural indoor climate.
Bottom: A sheer wall is infilled with wattle and daub, bringing welcome mass into the home. The finished wall is shown on the following page.

Here the finished wattle-and-daub wall is soaking up sun shining through the sun bump windows, absorbing warmth which it will radiate into the dining room and adjacent bedroom during the cold winter night.

CREDIT: ECONEST CO.


CREDIT: ZACH COVENTRY

CREDIT: ECONEST CO.

Plasters can be mixed from scratch, and the plaster books listed in the Resources section contain recipes and detailed procedures. We now use **American Clay** plaster in our interiors because the purity of ingredients, variety of colors and textures, and consistent quality of this factory-controlled product make it worth the investment. We often add a small amount of fine mica to the mix to create a subtle sparkle when sunlight hits the walls.

Clay-plastered walls are inherently "delicate." They will easily stain and will chip if they receive a strong impact. American Clay has produced a number of finishes and surface treatments that can improve durability for vulnerable areas. In certain cases, where a client requires a more robust finish, a lime plaster may be used instead.

Plastering Perimeter Walls

The interior perimeter walls are plastered similarly to the exterior perimeter walls with a three-coat system. The major differences are at the door and window openings. Interior window sills of wood, stone, or tile are installed

Top: This creative truth window in Scott Allison's barn reveals the LSC wall and the scratch, and brown coats of clay plaster. Bottom: Charlie Curruthers is a master craftsman with over 30 years of experience with natural plasters. Here he is seen in the yellow shirt with a group of students at an EcoNest plaster workshop.

prior to lathwork and must be protected throughout the course of the work.

Deep window and door recesses can either be trimmed with wood or finished with plaster. We prefer the look of soft rounded corners afforded by plaster. Prior to plastering, they are lathed with reed cut from commonly available rolls of reed fencing.

Plastering Interior Walls and Partitions

Interior mass walls of adobe, brick, or wattle and daub require the same three-coat treatment as perimeter walls. Conventionally framed and shoji pocket walls (discussed below) receive an adhesion primer and a thin plaster skim coat.

Doors

We use solid wood doors throughout. They require a finish to protect them from everyday wear and tear. Wood entry doors are typically centered in the opening to allow the door to swing open more fully. An entry door installed flush to the outside will hit the deep recess

CREDIT: ZACH COVENTRY

CREDIT: ZACH COVENTRY

CREDIT: ZACH COVENTRY

Top: Strips of natural plaster lath are being cut from a large roll of reed commonly sold for landscape fencing.
Middle: Reed is being installed around window.
Bottom: The reed forms a radiused window opening ready for plaster. The reed is neatly tucked between the window frame and the rough buck.


CREDIT: ECONEST CO.

Above: An adhesion primer coat is being applied to an interior plaster board wall. The perimeter wall has already received scratch and brown coat. A thin color coat will be applied to both of these walls and they will blend seamlessly. Note that the wood window sill is in place and will be carefully masked to protect it from wet plaster work. Opposite: Elephant trunk entry beam informs the visitors that they are entering a natural hand-crafted home home.

when opened 90 degrees, so these doors require a sill extension.

Shoji Screens and Pockets for Shoji Screens

We often use shoji screens with pockets to save space and create flexibility between spaces. These pocket walls have been created either with pairs of clear, straight studs oriented parallel to the pocket or solid 1" **Medex** panels for a frameless system.

Shoji pockets typically have a top and a bottom grooved wooden track. The nylon shoji wheels available from Japan through **Soko Hardware** create a very smooth operation. Alternatively **Hafele** makes high-quality pocket door hardware for hanging applications without a bottom track.

Cabinets

Until recently, very few commercially made kitchen cabinets were available with formaldehyde-free sheet goods and low-VOC finishes. The new CARB (California Air Resource Board) standards have changed all of this with some of the strictest formaldehyde and other VOC regulations in the world. Some sources for NAF (No Added Formaldehyde) veneer plywoods suitable for cabinetry include: **Pure-Bond**, **Medex**, **Medite II**, and **Roseburg SkyPly**.

Most factory-made cabinet doors are finished with synthetic sealers.

CREDIT: PAULA BAKER-LAPORTE

CREDIT: EZRA MARCOS

We prefer to finish our cabinetry with natural, breathable finishes. Sources include **Rubio**, **Osmo Wood Protector**, **Block Brothers**, and **AFM Naturals Oil Wax Finish**.

Floor Systems

Our choices for EcoNest flooring are based on regional climate, availability, and local skills. In Iowa, beautiful limestone is available. In Santa Fe, travertine and flagstone abound, along with a tradition of building earth floors. In coastal regions, wood is a logical choice. Whatever the material, we apply the following principles:

- Avoid crawl spaces and basements.
- Include natural forms of insulation under the floor.
- Reduce use of concrete.
- Use material with climatically appropriate thermal properties.
- Use natural, non-toxic finishes.

Alternatives to Concrete

The ground floor of an EcoNest is *earth-coupled*, meaning that it is in direct contact with the ground—with careful considerations for water management and insulation. We are usually able to create a level building site where one does not already exist by cutting and filling. We avoid crawl spaces, which sooner or later become a source of moisture and mold or pest habitat.

Although the concrete slab is considered a given for on-grade construction, we consciously try to lower our use of this environmentally costly product that physically interferes with our connection to the earth.[8]

Opposite: Shoji doors slide into wall pockets opening the entry hall to the living room.

Natural Insulation under Floors

Mineral insulations, such as pumice and perlite, will render an R-value of approximately 1 and 3 per inch, respectively. Although nothing in nature can rival the R-value of plastic foam, these mineral insulations are non-toxic and, notably, are free of fire retardants.

We use an average of 8" of pumice or 4" of perlite directly under the floor on top of a capillary break of 4" of gravel. The surrounding Faswall stem walls (with an R-value of 20) contribute to the thermal isolation of the floor. In short, we are able to achieve a high standard of comfort with low embodied energy and no toxicity. Where a vapor barrier is mandated, it can be placed between the gravel and the insulating minerals on a leveling bed of sand.

Earthen Floors

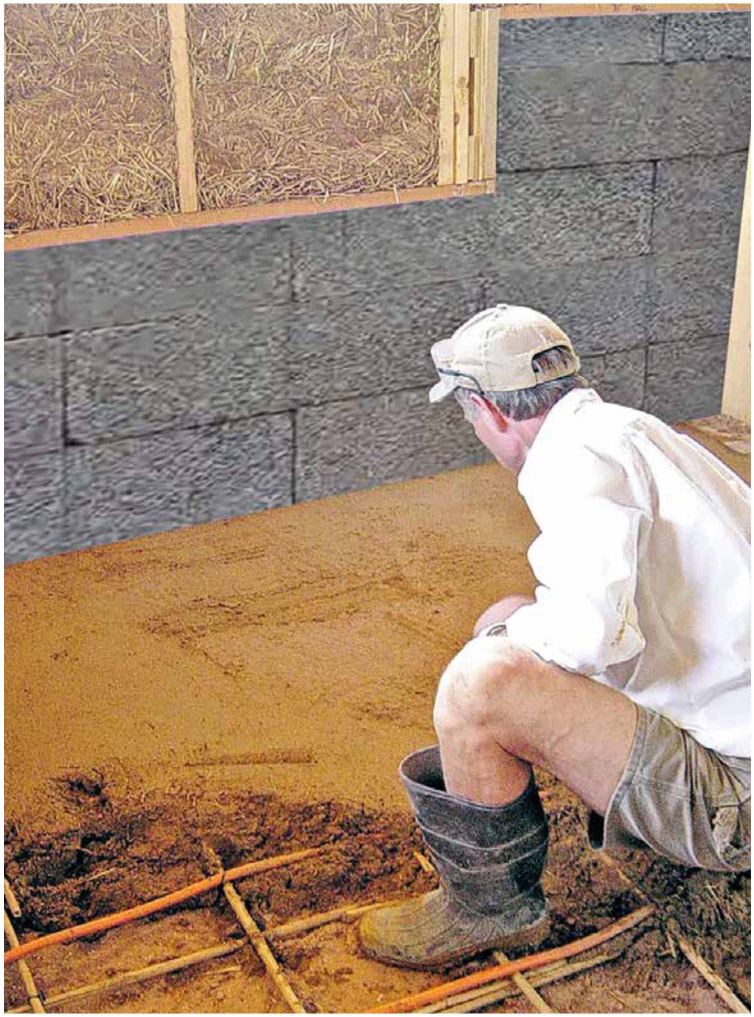
Handcrafted earthen floors are a beautiful solution that bring warmth and an unparalleled experience of "grounding." The subtle undulating leather-like surface is a welcome relief under foot. We often use earth floors in bedroom and meditation rooms, where the darker colors are inviting and the traffic flow is low impact and shoeless.


Earth floors in this bedroom give it a settled and grounded feeling

CREDIT: KEVIN IRETON


CREDIT: ECONEST CO.


CREDIT: ECONEST CO.


CREDIT: ECONEST CO.

Top left: Students trowel an earth floor to a smooth finish during this workshop lead by Sukita Crimmel of Claylin.
Bottom left: The finished floor has been saturated with natural oils and waxes and has the feel underfoot of walking on smooth leather.
Above: This earth floor has radiant heat tubing supported on a grid of bamboo embedded within it.

Once finished with several layers of penetrating oils and waxes, the resulting floors are durable and can be mopped clean. There is now a line of earth floor products offered by **Claylin**; they sell bags of clay soils to make earth floors (in a variety of colors) as well as specially formulated oils for finishing and maintaining them.

Earthen floor construction details can be found in the book *Earthen Floors* listed in the Resources section.

Above: The beauty of a masterfully executed hand chiseled flagstone floors.
Right: Truth window at the McGowan residence reveals the straw clay construction behind the plaster.

Wood Floors

In conventional construction, wooden floors are installed over well-cured concrete slabs or joisted floors, well above ground. We have recently experimented with an earth-coupled, joisted floor. Cedar joists were placed directly on top of pumice insulation/gravel base. (Refer to "Natural Insulation under Floors," above.) The joist spaces were filled with sand. Joists were sheathed over, and an unfinished engineered floor was installed over the sheathing.

In-floor, hydronic heating can be readily incorporated because the sand's mass can distribute heat.

For finishing wood floors, again we prefer natural waxes and oils that will leave the floor with a non-glare finish that feels "breathable" underfoot. Surfaces finished with a layer of plastic will create conditions that negative ions cling to, thus contributing to the build-up of static electricity, but natural waxes and oils do not interfere with the natural DC electro-climate, and they work with the wood to create a natural balance. Sources for natural floor finishes include **Rubio**, **Osmo**, **AFM Naturals**, and **Bioshield**.

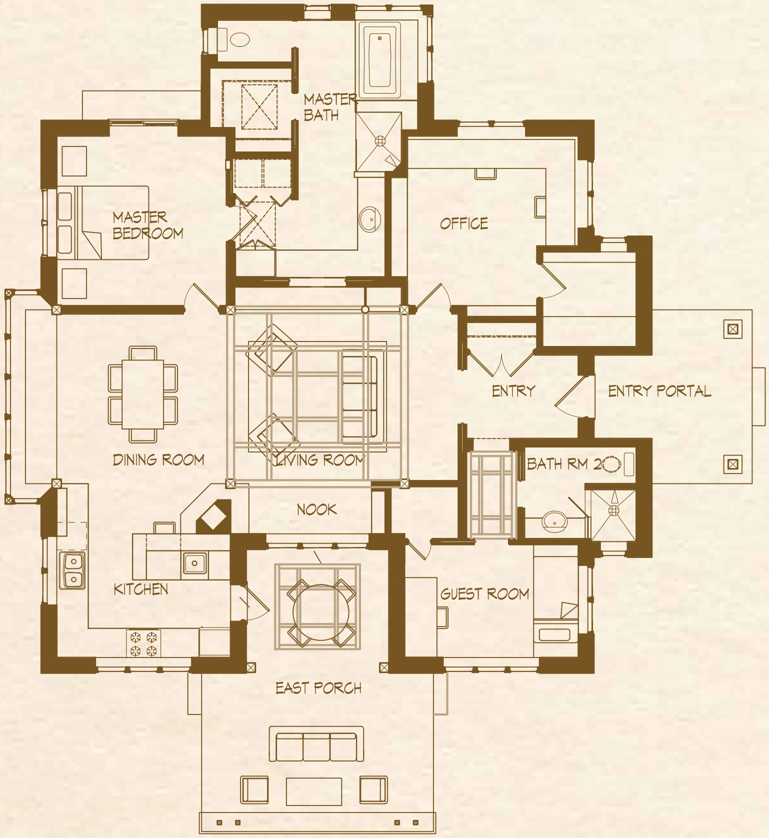
Stone Floors

Because of the durability of stone, we often use it in entries and bathrooms. Stone floors can be laid over earth or concrete slabs. Natural finishes for stone floors include **Meta Crème** and Masonry Boss.

SECTION 3

Case Studies: 2005–2013

CREDIT: ROBERT LAPORTE



CREDIT: ECONEST CO.

New Baker-Laporte Residence, Ashland, Oregon

Robert and Paula's new home in Ashland, Oregon, features the local woods of the Pacific Northwest and has been the product of collaborations with great craftsmen and students. The home was the subject of six workshops over the 2010 to 2013 workshop seasons and has the love of more than 80 workshop students embedded in its construction.

The fir for the timber frame was salvaged from the local Grizzly Peak fire. Ceilings and shoji are crafted from local Port Orford cedar provided by **East Fork Lumber**. The central Tulikivi masonry oven was supplied by Ashland's own Jamie Paiken, of **Alaska Masonry Heaters** and skillfully crafted by Isaac Paiken. A traditional tokanoma, built by Dale Brotherton of **Takumi Company** and his students, graces the living room. Earthen floors in the bedrooms were crafted by students in a workshop led by Sukita Crimmel of **Claylin**, and the earth-plastered walls using **American Clay** were plastered by master craftsman Charlie Carruthers, who taught a plaster workshop.

CREDIT: PAULA BAKER-LAPORTE

Entry to the Baker-Laporte Nest. Sight lines run through the center of the geometry from north at the front entry to south through the sunbump.

Right: Looking from the dining room through the living room the various woods—fir, maple, cherry and Port Orford-cedar create a richness of tones set against a neutral background of pigmented clay plasters.

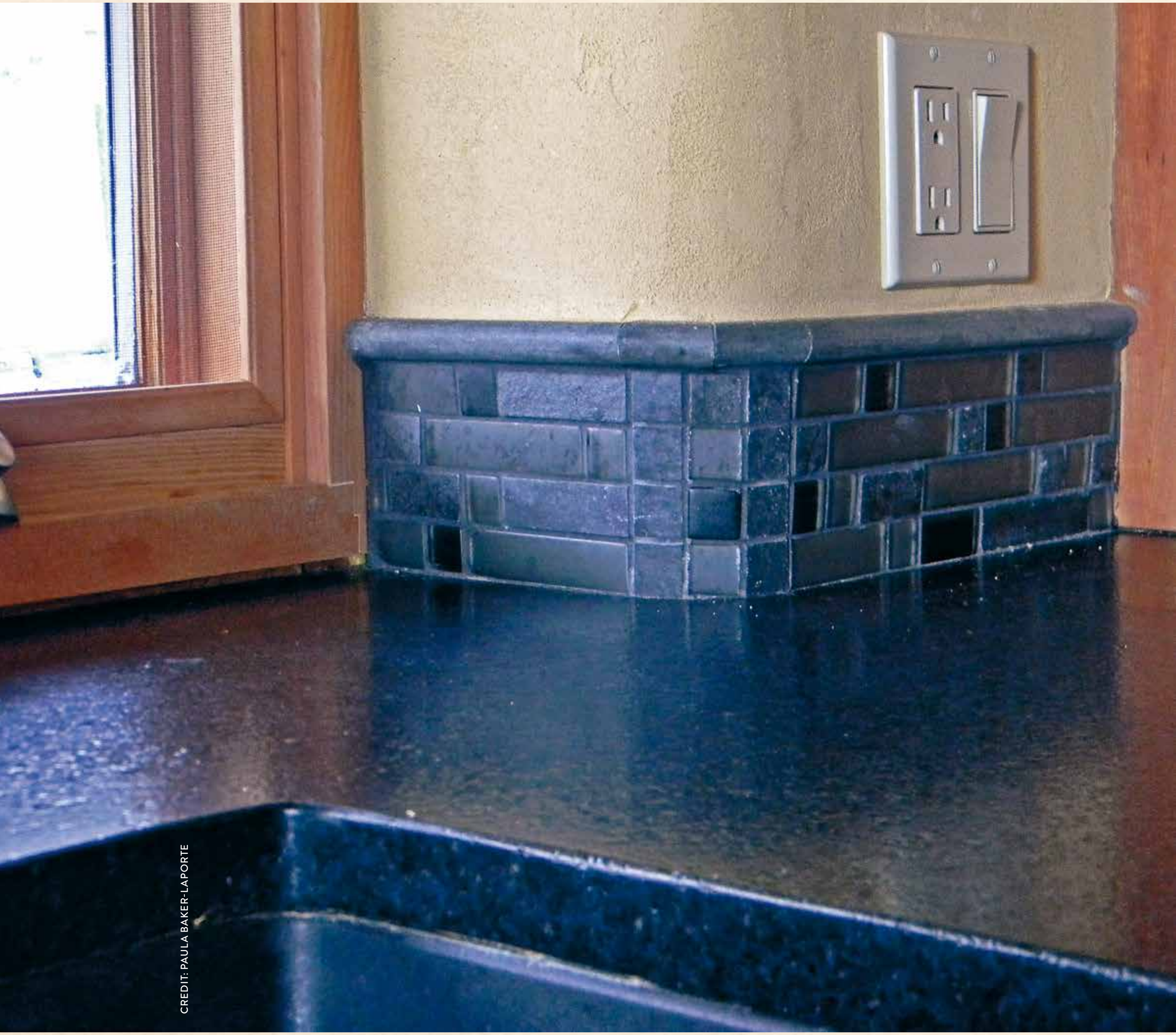
Below: The cherry cabinetry is finished with a natural oil, which enhances the grain of the wood while leaving it "breathable." All dish storage is in the glass front cabinet that extends down to the countertop. Windows on the east and south walls fill the kitchen with light.

CREDIT: JONATHAN SHAW

CREDIT: ECONEST CO.

CREDIT: JONATHAN SHAW

Looking from the central living room space through the dining room and the sun bump. The central timber frame organizes the space into several places. The living room ceiling is 10'4" tall and the central cedar grid work or mandala holds the rice paper ceiling panels, which allow a gentle diffused light into the living room from the skylight above. On the far left, the back of the soapstone Tulikivi is wrapped by a bench. The gentle warmth from a morning fire radiates through the stone for many hours, making this a favorite place to sit even in the evening.


CREDIT: PAULA BAKER-LAPORTE

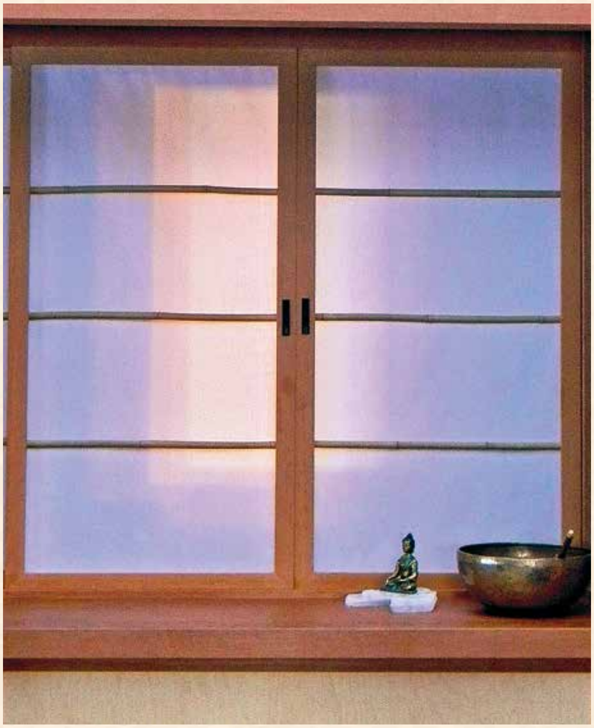
Window detail. A Canadian granite counter top is continuous into the deep window recesses, extending the counter space behind the sink A stone and glass splash is fashioned around the large radius of the straw-clay walls.

CREDIT: JONATHAN SHAW

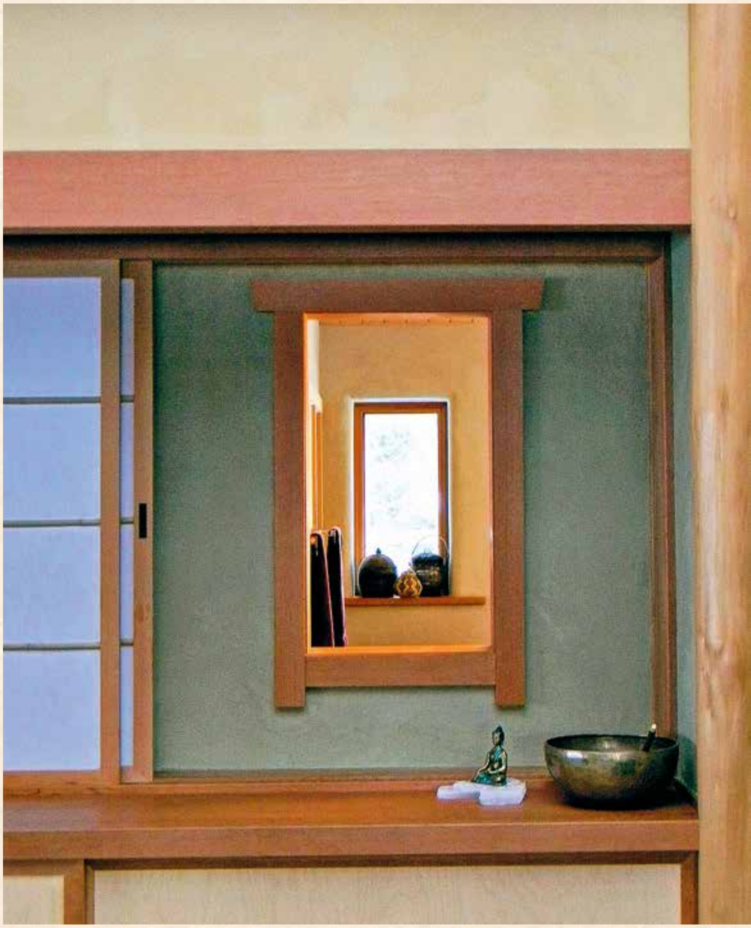
Left: This traditional Tokanoma, or beauty corner, was built in a workshop led by master Japanese Carpenter Dale Brotherton. The shelf is of black walnut and the round pole is a traditional tokabashira from Japan. A bamboo tool is used to slough the bark from the pole, leaving it silky smooth and revealing its natural beauty.

Below left: This storage cabinetry is built in to the living room space.

Below right: The rice paper screens slide out of the way to reveal a view line through the geometric center of the home.



CREDIT: PAULA BAKER-LAPORTE



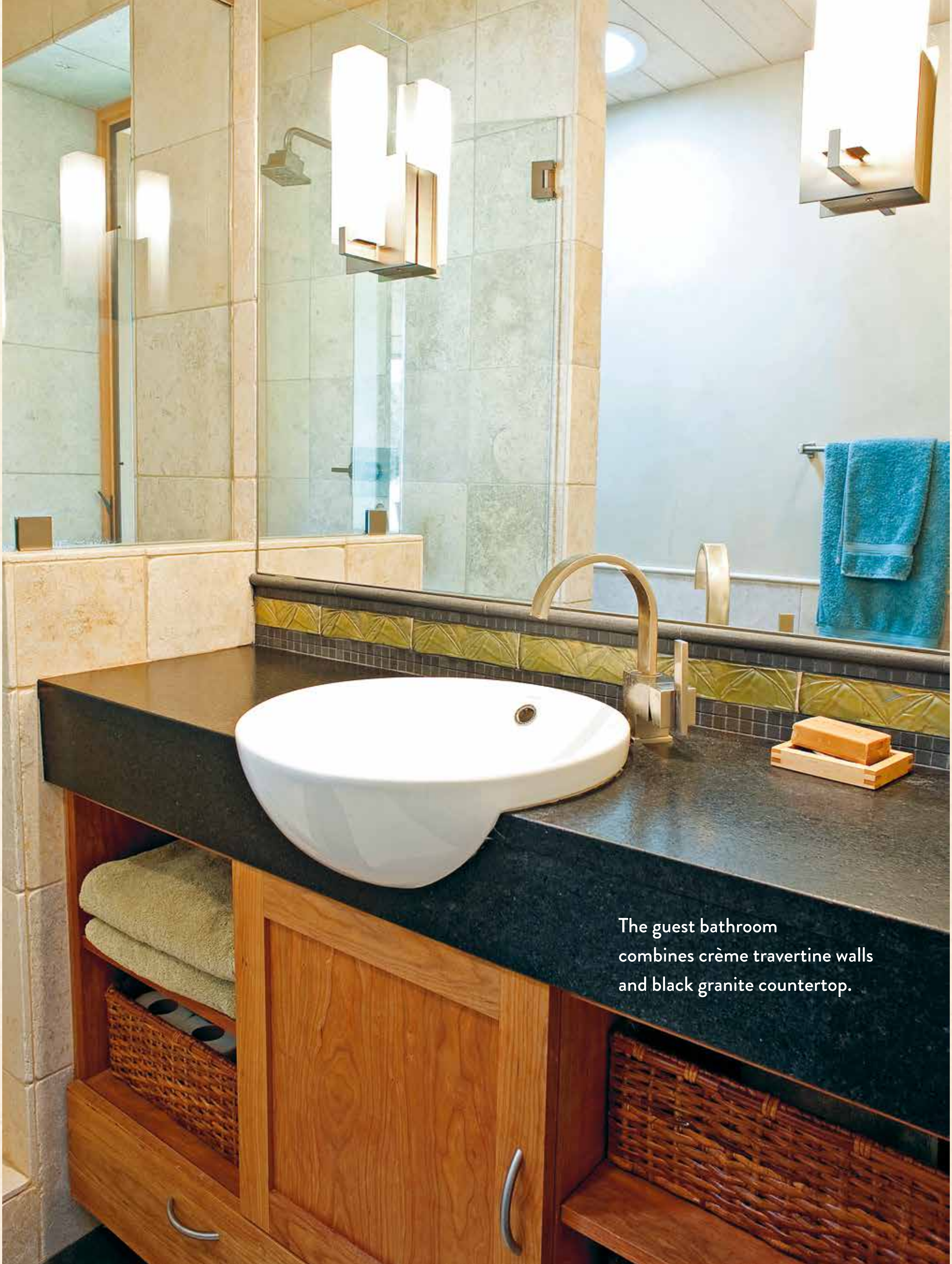
CREDIT: PAULA BAKER-LAPORTE

A raised soapstone counter is a favorite spot for breakfast beside a roaring fire.

CREDIT: PAULA BAKER-LAPORTE

A continuous shelf runs around the kitchen above the windows.

CREDIT: PAULA BAKER-LAPORTE



CREDIT: EZRA MARCOS

The guest bathroom combines crème travertine walls and black granite countertop.

Right: Outdoor "room" off of the kitchen, faces east catching the morning light and shaded from the harsh afternoon sun making it a great spot for dining al fresco at any time. Below: Master bathroom by night.

CREDIT: ROBERT LAPORTE

CREDIT: ROBERT LAPORTE

Prajna Yoga Studio, Santa Fe, New Mexico

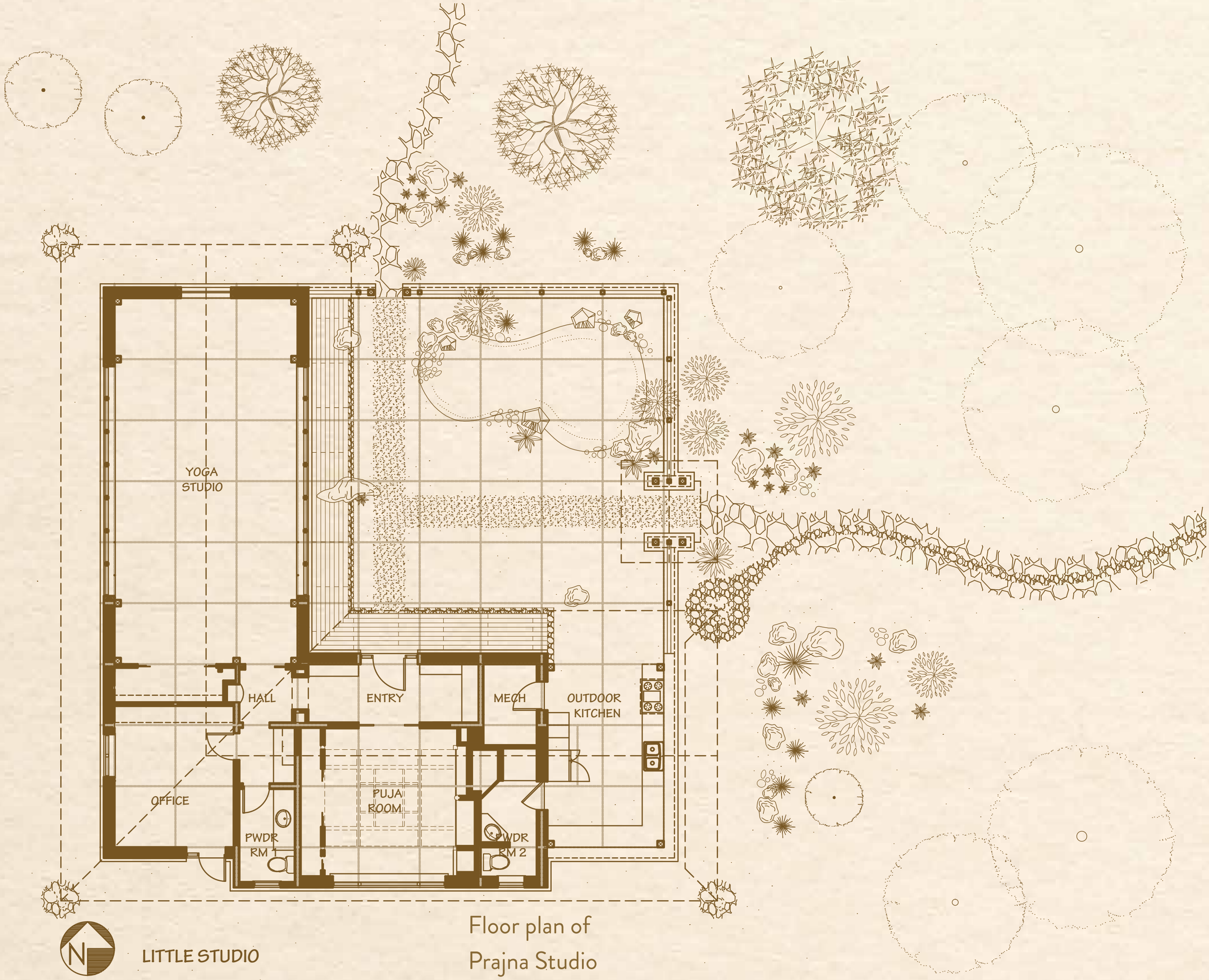
The Littles built their original EcoNest home in 2001, and, after several years of living in a natural home, they decided to build a studio where their students could also experience the benefits of a naturally healthy and Zen-like atmosphere for meditation and the practice of yoga.

This 1,500 sq. ft. yoga studio was added to the Little compound in 2008. It combines two cultural influences of the Far East that parallel their yoga and meditation practices. The aesthetics follow the Zen qualities of the meditation that they teach and practice, while the layout and mathematical formula of the studio are based on the Sthapatya Veda, one of the five ancient Vedas of India from which

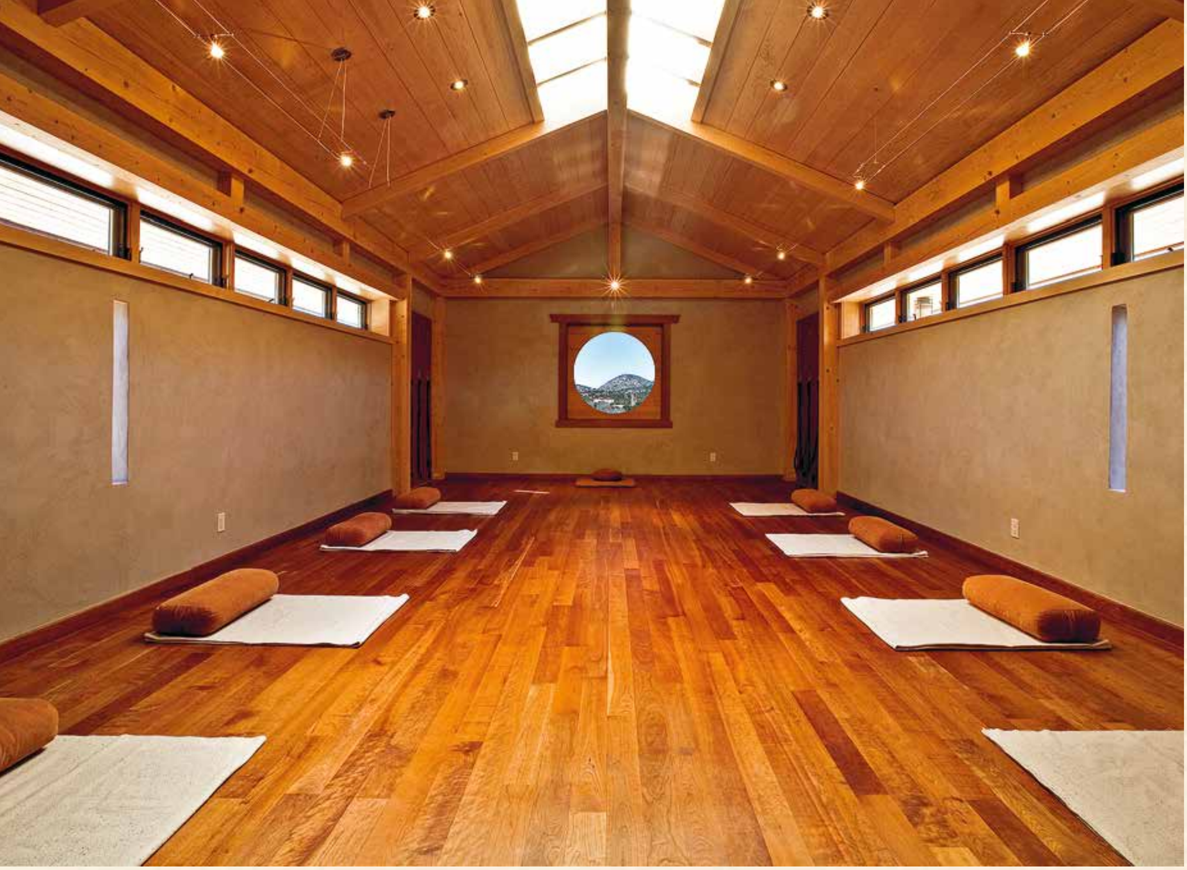
Exterior view. Inset: North entry to prajna studio through the courtyard.

CREDIT: PAULA BAKER-LAPORTE

their yoga practice also stems. The Vedic layout strictly dictates compass orientation, room and opening placements, and the exact dimensions that form a 9 × 9 grid. The structure is an "L" shape that houses a yoga hall, an office, a meditation room, and an outdoor kitchen; together, these elements form the southwest sides of a square composition. The outdoor courtyard completes the square.



Floor plan of Prajna Studio



CREDIT: KIM KURIAN

The Yoga studio is bright and airy, with a band of windows on east and west walls above arm balance height. A ridge skylight and a round window capturing the mountains to the north help to create a balanced even light. Tall slit windows open thru the central axis of the 9-square geometry. Cherry floors are sealed with a natural finish. The Port Orford cedar ceiling and hard troweled American clay plaster on the walls are left unsealed.

CREDIT: JONATHAN SHAW

Studio looking south. The pair of shoji to the left close the entry to the studio. Behind the four shoji to the right is the prop cabinet. Triangular glass over the cabinet carries light from skylights into the studio and the office on the other side.

Above: Tias and Surya Little…inverted.
Right: As prescribed by Sthapatya Veda, a pair of windows on the east and west walls of the studio create a sight line from the entry gate through the studio in the geometric center of the 9 × 9 composition.
Below: A shining Buddha reflects the sun pouring through the sun bump in the puja room.

The puja room is a space for meditation where Japanese and Indian influences meld. The tatami mats on the floor reflect the raised mandala ceiling above. A Japanese style tokanoma, or beauty corner, sits next to an alter in homage to an Indian guru.

A lit cherry-trimmed niche for flowers greets guests as they enter the prajna studio.

CREDIT: JONATHAN SHAW

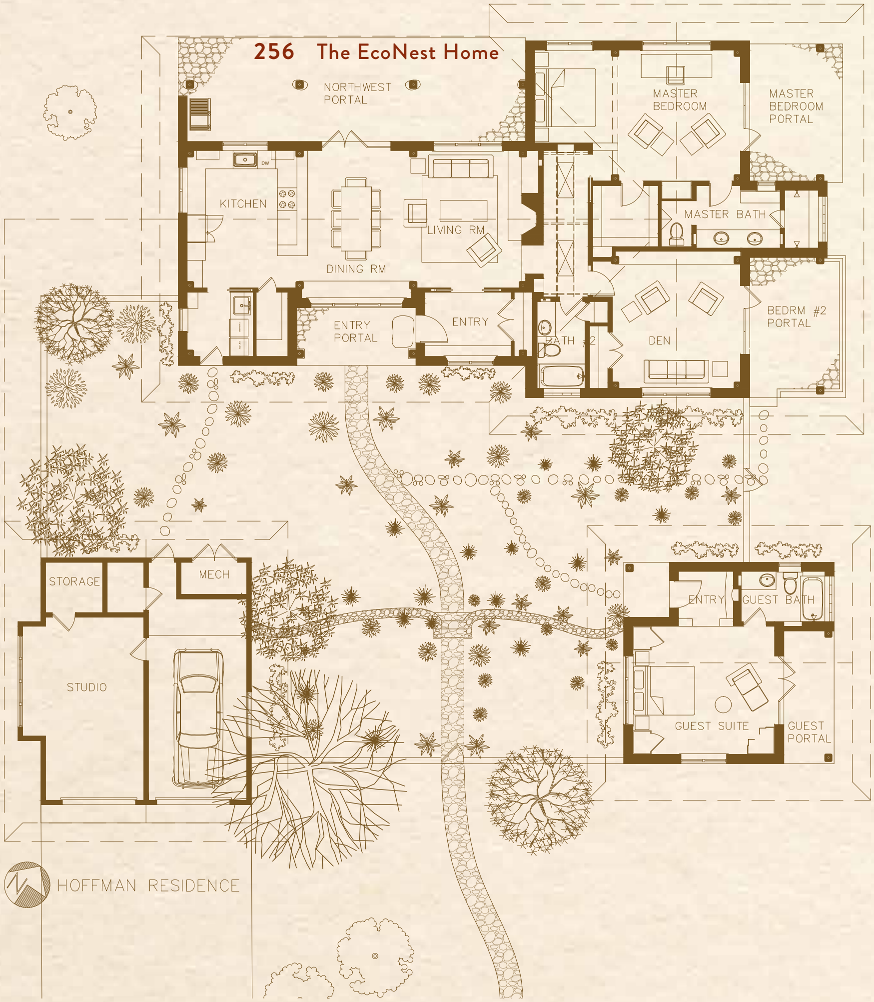
CREDIT: KIM KURIAN

An integral concrete counter sink and backsplash are masterfully executed in the studio bathroom.


CREDIT: KIM KURIAN

Above: Shoes are left outside on the raised wooden deck, and a sensuous feast of texture and warmth from the heated floors awaits bare feet just inside.
Below: The wooden L-shaped deck that runs along the east and north walls of the studio gives way to the landscape in this interplay of wood, boulder, pebble, and plant.


CREDIT: PAULA BAKER-LAPORTE



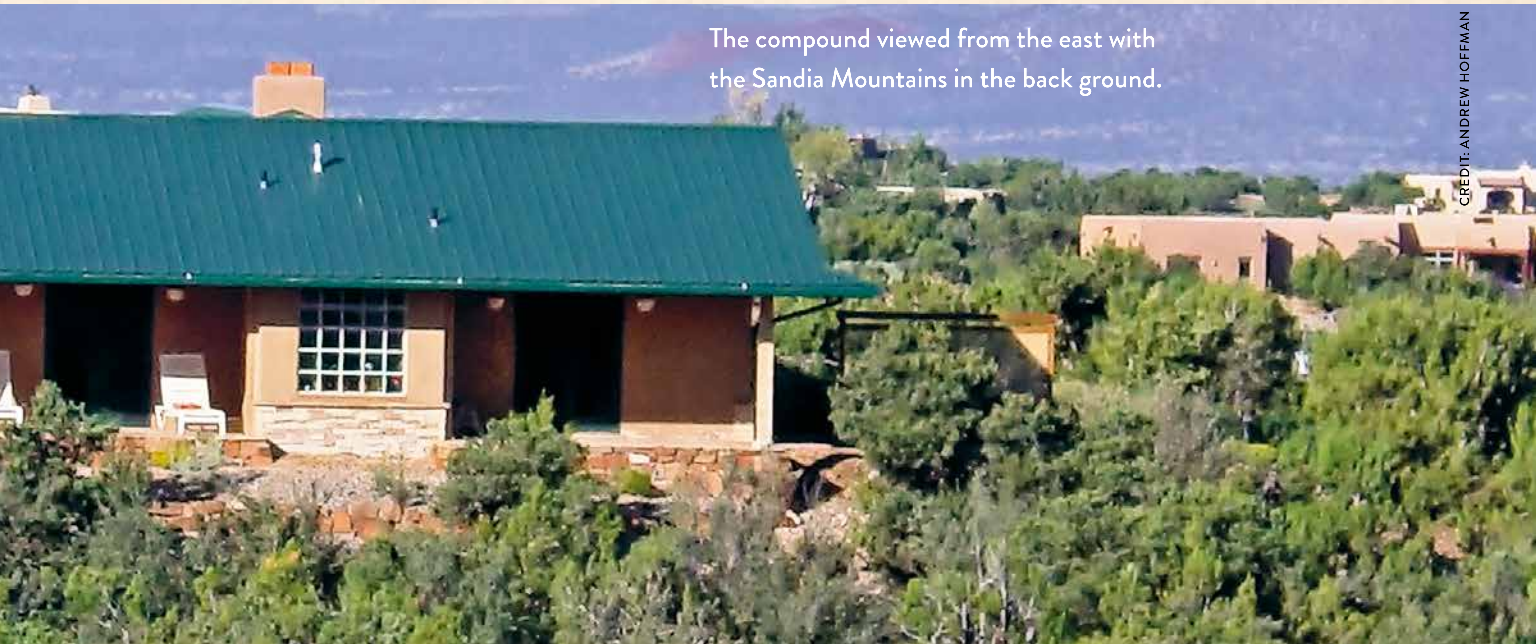
The Hoffman Residence

This home for Andrew and Brook Hoffman is situated on a beautiful view lot in Santa Fe. The compound consists of a main house of 1,880 sq. ft., a 400 sq. ft. guest house, and a garage/woodworking studio. The three buildings are arranged to define an entry courtyard, with the main house capturing the southwest views of the Sandia Mountains and the guest house opening onto the east Sangre de Cristo Mountain views.

Although a departure in form from our previous single-story plans, it shares many features. The auxiliary buildings work with the main house to form a courtyard. The mechanicals are placed in the detached garage and deliberately not in the main house. The spaces are compact.

The honed flagstone countertops have slots for the Hoffman kitchen knife collection.

CREDIT: JONATHAN SHAW



The compound viewed from the east with the Sandia Mountains in the back ground.

CREDIT: ANDREW HOFFMAN

CREDIT: JONATHAN SHAW

Living Room: The timber frame features a taiko, or elephant trunk, beam.

CREDIT: KIM KURIAN

Inset: A gridwork of shelves set in to the living room wall display some of the beautiful wooden bowls that Andrew turns in his studio. Left: Looking towards the kitchen from the great room. Within the three-bay timber-frame the ceiling transitions from a vaulted space over the living room and dining room to a dropped ceiling over the kitchen.

The master bed sits in a cozy nook in this bedroom/sitting room.

CREDIT: KIM KURIAN

Master bathroom

CREDIT: KIM KURIAN

Guest bathroom.

CREDIT: KIM KURIAN

A 400 sq. ft. guest house anchors one corner of the entry courtyard.

EcoNest Stock Plans

Not everyone can afford the luxury of hiring an architect to design a custom home. Over the years, we have developed two series of stock plans with the purpose of making our homes more available to a wider audience. These plans can be purchased by owner-builders who have taken our training or through our EcoNest affiliates. Each set of drawings is accompanied with a project manual with complete healthy-home specifications.

These stock plans are designed to incorporate natural climate-control strategies, including large roof overhangs and passive solar gain through a south-facing "sun bump." A masonry heater is centrally located to supplement modest heating needs.

Peregrine Series

Peregrine Series plans are single story, ranging in size from 732 sq. ft. to 1,922 sq. ft., and can be purposed as a guest house or a main house with one, two, or three bedrooms. Each is designed with the illuminated central core mandala ceiling, with rooms radiating from this central core.

FolkNest Series

The FolkNest series is based on a simple 18' × 36' timber frame and is designed for economical construction. A number of variations on this basic frame, ranging from an 800 sq. ft. single bedroom to a 1,840 sq. ft. three-bedroom plan, can allow for the flexibility of starting with the modest core and adding on in the future.

Visit our website to see the complete Peregrine and FolkNest series and other finished projects. Learn about EcoNest affiliate builders, upcoming workshops, and much more at econesthomes.com.

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Resources

Books: General

Baker-Laporte, Paula, Erica Elliott, and John Banta. *Prescriptions for a Healthy House.* 3rd Edition, Gabriola Island, BC: New Society Publishers, 2008. **newsociety.com.**

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Sobon, Jack A. *Build a Classic Timber-Framed House.* Pownal, VT: Storey, 1994.

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475: a specialized building material supplier serving low-energy and passive house construction, **foursevenfive.com.**

AFM Naturals Oil Wax Finish: organic, plant-based finishes, afmsafecoat.com.

Airgas Safety: safety supplies, glasses, gloves, masks, hearing protections, airgas.com.

American Clay: natural clay-based plaster products, americanclay.com.

Block Oil: blend of oils that penetrates, conditions, and seals wood surfaces, blockoil.125west.com.

Claylin: supplier of premixed earth floors and finishes, claylin.com.

Dayton Bag and Burlap: natural burlap for plaster lath, daybag.com.

Durisol: insulated wood-chip-cement wall forms, durisolbuild.com.

eShoji: supplier of rice paper and shoji accessories, eshoji.com.

East Fork Lumber: Port Orford cedar, western red cedar, and Douglas Fir lumber, eastforklumber.com.

Eastern Star Trading: suppliers of high-quality bamboo, easternstartrading.com.

Faswall: insulated wood-chip-cement wall forms, faswall.com.

Gutex: wood fiber insulating boards (USA distribution), foursevenfive.com.

Hafele: Pocket door hardware, hafele.com/us/products/12380.asp.

H.C. Muddox: supplier of mortar clay, hcmuddox.com.

Hida: Tool & Hardware Co: exceptional tools from Japan, hidatool.com.

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Intello: smart vapor retarder, foursevenfive.com.

Kal-Kore: gypsum plaster board, nationalgypsum.com.

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Lee Valley Tools: high-quality Canadian tool supplier, leevalley.com.

MasonryBoss: penetrates and bonds with masonry surfaces, weatherbos.com.

Medex, Medite II: exterior and interior formaldehyde-free MDF, sierrapine.com/mdf.

Meta Crème: breathable impregnating sealer for stone, tile and masonry, drytreat.com.

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Oregon Shepherd: batt and blown-in wool insulation, oregonshepherd.com.

Osmo North America: natural wood protection, osmona.com.

ProClima: various vapor-open building sealing products (USA distribution), foursevenfive.com.

PureBond: formaldehyde-free, environmentally safe cabinet plywood, purebondplywood.com.

Reed: reed fencing for plaster lath, homedepot.com; lowes.com.

Roseburg: SkyPly hardwood plywood with no added formaldehyde, roseburg.com.

Royer Industries: soil shredders, royerind.com.

Rubio Monocoat: single-coat hard-wax oil, zero VOC, rubiomonocoatusa.com.

Safe Living Technologies: instrumentation and products for detecting and remediating electro-magnetic radiation, slt.co.

Seal-Once: water-based, eco-friendly water-proofers, seal-once.com.

Sears: Shredder Joe leaf mulcher for chopping straw, sears.com.

Schroeder Log Home Supply, Inc.: wool insulation rope for windows and doors, loghelp.com.

Siga: diffusion open-barrier sheeting products (USA distribution): Small Planet Workshop, smallplanetworkshop.com.

Silacote USA: silicate mineral paints, silacote.com.

Soko Hardware: supplier of rice paper and shoji accessories, San Francisco, CA, 415-931-5510.

St. Astier: natural hydraulic lime, TransMineral USA, Inc. 201 Purrington Rd., Petaluma, CA, 94952, 707-769-0661, transmineralusa.com.

Takumi Company: full-service woodworking and construction in top-quality, authentic Japanese style. Contact Dale Brotherton, japanesecarpentry.com.

The Japan Woodworker: high-quality Japanese tools, japanwoodworker.com.

Timberwolf Tools: high-quality timber frame tools, timberwolftools.com.

Transmineral USA: supplier of St. Astier natural hydraulic lime (NHL), limes.us.

Tulikivi: Finish soapstone masonry heaters, tulikivi.com.

Veritas: high-quality woodworking tools, veritastools.com.

WeatherBos: environmentally safe, user-friendly, non-toxic finishes, weatherbos.com.

Worx: leaf mulcher used for chopping straw, worx.com.

UltraTouch: Insulation made from recycled blue jeans, bondedlogic.com.

Organizations

American Masonry Heaters Association
Information on masonry heaters, manufacturers, masonry heater builders. mha-net.org.

Cornerstones Community Partnership
A non-profit working in partnership with communities to restore historic structures using traditional building materials. cstones.org.

ElectromagneticHealth.org
EMR news, commentary, and expert interviews. Extensive audio/video educational resources. electromagnetichealth.org.

International Institute for Building-Biology & Ecology (IBE)
Guiding the general public and working professionals (architects, builders, engineers, physicians and other health care practitioners, design consultants, etc.) to an understanding of the vital, complex relationship between the natural and built environments, and teaching them the means for merging these complementary environments into greater harmony. IBE offers professional certification and lay training through on-line study, and seminars. hbelc.org.

Timber Framers Guild
PO Box 60, Becket, MA 01223, 855-598-1803
tfguild.org.

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Notes

1. Environmental Working Group. Chemical Industry Archives, accessed November 8, 2007, chemicalindustryarchives.org/fact fiction/facts/1.asp.
2. ASHRAE (American Society of Heating Refrigeration and Air Conditioning Engineers) has set minimal standards for ventilation for human health. In 1925, it was set at 30cfm (cubic feet per minute) per person. In 1973, this was reduced to 20cfm per person, and then further reduced to 15cfm. This has been continually reviewed, and requirements are now calculated taking several parameters into consideration.
3. The International Institute for Building-Biology & Ecology has contact information for experts around the country who are trained to do electromagnetic site assessments: hbelc .org/findexpert/enviroconsult.
4. Baker-Laporte, Banta, and Elliott, *Prescriptions for a Healthy House*, 3rd edition, New Society Publishers, 2008.
5. Perkins + Will, "Fly Ash in Concrete," Nov, 2011, transparency.perkinswill.com/Content /Whitepapers/FlyAsh_WhitePaper.pdf; "Coal Ash Is More Radioactive than Nuclear Waste," *Scientific American*, Dec. 13, 2007.
6. The Larsen truss was created by John Larsen, a builder in Edmonton, Alberta, in 1981. It uses small-dimension framing members joined with plywood gussets to build thick, insulated walls for the purpose of energy efficiency.
7. This Cornerstones paper addresses issues found with cementitious plasters: cstones.org /FAQS/Adobe_vs__Cement/.
8. Clinton Ober has written extensively on the health benefits of being directly in contact with the earth. See grounded.com/earthing -the-most-important-health-discovery-ever /earthing-book/.

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APPENDIX A

Workshop Checklist

Hosting a straw clay wall-building workshop is an exercise in logistics. The role of the project co-coordinator is to create a safe and organized building environment. Following are guidelines for preparation and set-up. Thorough follow-through of all the checklist items will build the foundation for a successful and productive workshop. Quantities expressed below are sufficient for a 1,500 sq. ft. EcoNest.

Site work and Foundation

The scope of site work and foundation work will vary from project to project. To maximize the productivity of the workshop work force, plan sufficient time leading up to the workshop to complete the following:

- site work
- foundation
- plumbing rough-in and inspection
- electrical rough-in and inspection
- 75% of the matrix including the kitchen
- power and water supply

Matrix Building

Pre-workshop Set-up (Refer to Chapter 8 for specifics):

- ☐ 1. Install 2 × 12 sills on stemwalls.
- ☐ 2. Construct one or more EcoNest work stations.
- ☐ 3. Construct straight Larsen and corner Larsen jigs.
- ☐ 4. Fabricate and pre-assemble door and window components.
- ☐ 5. Erect key matrix walls that require pre-workshop plumbing rough-ins.
- ☐ 6. Install plumbing vents where appropriate in erected matrix walls.
- ☐ 7. Install electrical wiring in erected matrix walls; remember to support all wire.
- ☐ 8. Set up Larsen truss assembly station (4' × 8' plywood on saw horses).
- ☐ 9. Set up one corner Larsen truss assembly station (4' × 8' plywood on saw horses).
- ☐ 10. Have matrix components cut and ready for assembly.

Matrix Building Tools:

- ☐ Skilsaws (2)
- ☐ Chopsaws (2)
- ☐ Table saws (1 minimum, 2 preferred)

- [ ] Extension cords, heavy-duty, 10-gauge for major runs, 12-gauge for minor runs
- [ ] ½" drill and selection of drill bits, ½", ¾", 1"
- [ ] Air compressor
- [ ] Framing nail guns (2)
- [ ] Staple gun, 7⁄16" crown for fastening plywood gussets to Larsen trusses.
- [ ] Gun oil
- [ ] 6' pipe clamps (2)—for assembling door and window units

Lumber Checklist

- [ ] ¾" plywood—one lift of 46 sheets—later becomes roof sheathing
- [ ] 4 × 4s planed to uniform size for corner Larsen trusses
- [ ] 2 × 4s planed to uniform size for straight Larsens
- [ ] ⅜" plywood for gussets (2–4 sheets) Note: All plywood to be exterior grade
- [ ] 2 × 12 lumber, approved for sills
- [ ] Window and door header material (2 × 6, 2 × 8, 2 × 10, LVL), as per drawings
- [ ] Scaffold support beams (2 × 8s frames, or timber to support 500 lb. hoppers)

Fasteners Checklist

#8 Deck Screws, torque or square drive

- [ ] 1¼" for plywood to plywood—5 lbs.
- [ ] 2" for plywood to framing/forms—25 lbs.
- [ ] 3" for framing to framing—25 lbs.
- [ ] 3½" for top plate—10 lbs.

Nails

- [ ] 3¼" hand nails for framing—25 lbs.
- [ ] 3¼" gun nails for framing—2 boxes

Staples

- [ ] 7⁄16" x 1½" staples for staple gun (air)—1 box

LSC Mixing and Delivery:

- [ ] Rent or buy slip maker or mortar mixer

Clay

For a 1,500 sq. ft. EcoNest

- [ ] 20 cubic yds of screened clay,
- [ ] OR 15 supersacks of brick factory clay (approx. 15 tons)
- [ ] OR HC Muddox mortar clay (approx. 9 tons)
- [ ] Three shovels
- [ ] Twelve 5-gallon buckets
- [ ] Two 1-gallon buckets
- [ ] 200-gallon open water tank (reservoir, a horse trough works well)
- [ ] For screening soils: 3' × 6'—¼"x ¼" metal hardware cloth/screen mounted to a 3' × 7' frame (use 2 × 4s) with legs to make self-standing A-frame—for rescreening soil, as necessary

Straw

- [ ] 7,500 lbs. for 1,500 sq. ft. EcoNest (average) (approximately 7 lbs. straw/cu. ft. wall) + 10%
- [ ] Three utility knives
- [ ] Box of dust masks with exhalation valve and adjustable nose clip (Radnor N-95 or eq.)

Hoppers

- [ ] 8–12 EcoNest hoppers

Equipment

Test all equipment prior to the workshop.

- [ ] Tumbler with 10-gauge extension cord and dedicated 20-amp circuit or generator
- [ ] Forklift, Bobcat with forks, reach lift—reserve four weeks in advance
- [ ] Wheelbarrows—heavy duty—three or more if used as primary delivery system
- [ ] Slip maker and mud pump
- [ ] Slip storage tank with stand—200-gallon minimum
- [ ] Water hose with shut-off nozzle, length as required to water source

Water

Pressurized water is ideal. Failing this, a 1,000-gallon stock tank is a minimum. Set-up to gravity feed to tumbler or slipmaker. A 1,500 sq. ft. EcoNest requires 3,000–4,000 gallons of water.

- [ ] Five to ten 5-gallon buckets

Straw Clay Placement

Formwork

- [ ] Slip forms
- [ ] Cordless screw guns (4, minimum) with chargers

LSC Loading and Tamping

- [ ] Pitch forks (6)
- [ ] Tampers (6)
- [ ] Ladders: two 3' or 4'; two 6', two 8'; one extension ladder
- [ ] Work gloves: Nitrile gloves are ideal for the wet straw clay work in sizes M-L-XL (available through **Airgas Safety**)

Bamboo

- [ ] Bamboo stabilizing bars: ¾" × 7'—100 pieces (available through **Eastern Star Trading**)

Scaffold

Minimum recommended

- [ ] Scaffold, 10 sections consisting of 20 frames and 20 "X" braces,
- [ ] 10 aluminum walk boards, 19" wide × 84" long
- [ ] 20 Scaffold "beams" (4 × 6 timber, or double 2 × 6s, screwed together)
- [ ] Scaffold screw jacks for leveling scaffold on sloping sites
- [ ] 2 × 12, LVLs, beams for unique and unexpected staging conditions.

Safety, Comfort & Education Safety

- [ ] Hydration station with electrolyte supplements (**Emergen C** or equal)
- [ ] First Aid kit
- [ ] Drinking water: 20 gallons per day (with ice during hot weather)
- [ ] 12' × 30' shade cloth or tarp to create covered area for breaks, lunch, discussions
- [ ] Clean portable or composting toilet
- [ ] Hand-washing station with soap

Recycle Station

- ☐ Designated containment for landfill, food compost, aluminum, plastic, metal, wood

Meal Plans

Fortifying your crew is essential to having them create and produce effectively. Fresh, organic, light lunches and fruit snacks support a clear mind and fluid, flexible body.

Administrative, Educational and Promotional Materials:

- ☐ Publicity materials, press releases, posters, host contact info
- ☐ Lodging information, including regional camping options
- ☐ Copies of this book for each student to use as their "textbook"
- ☐ Workshop roster with attendees' information
- ☐ Question log for students' sharing at break times
- ☐ Suggestion box or evaluation forms

Power supply

Whenever possible, supply reliable and sufficient grid or solar power.

Generators may be used as a last resort, but they put a real damper on the serenity of a workshop, introducing a considerable noise and air pollution factor.

Small portable generators are noisy and underpowered for an EcoNest production. Commercial diesel-powered 25 kw and larger units are quieter, reliable, and essential for a full-on, 15- to 20-person Nest building team.

Powerload Checklist

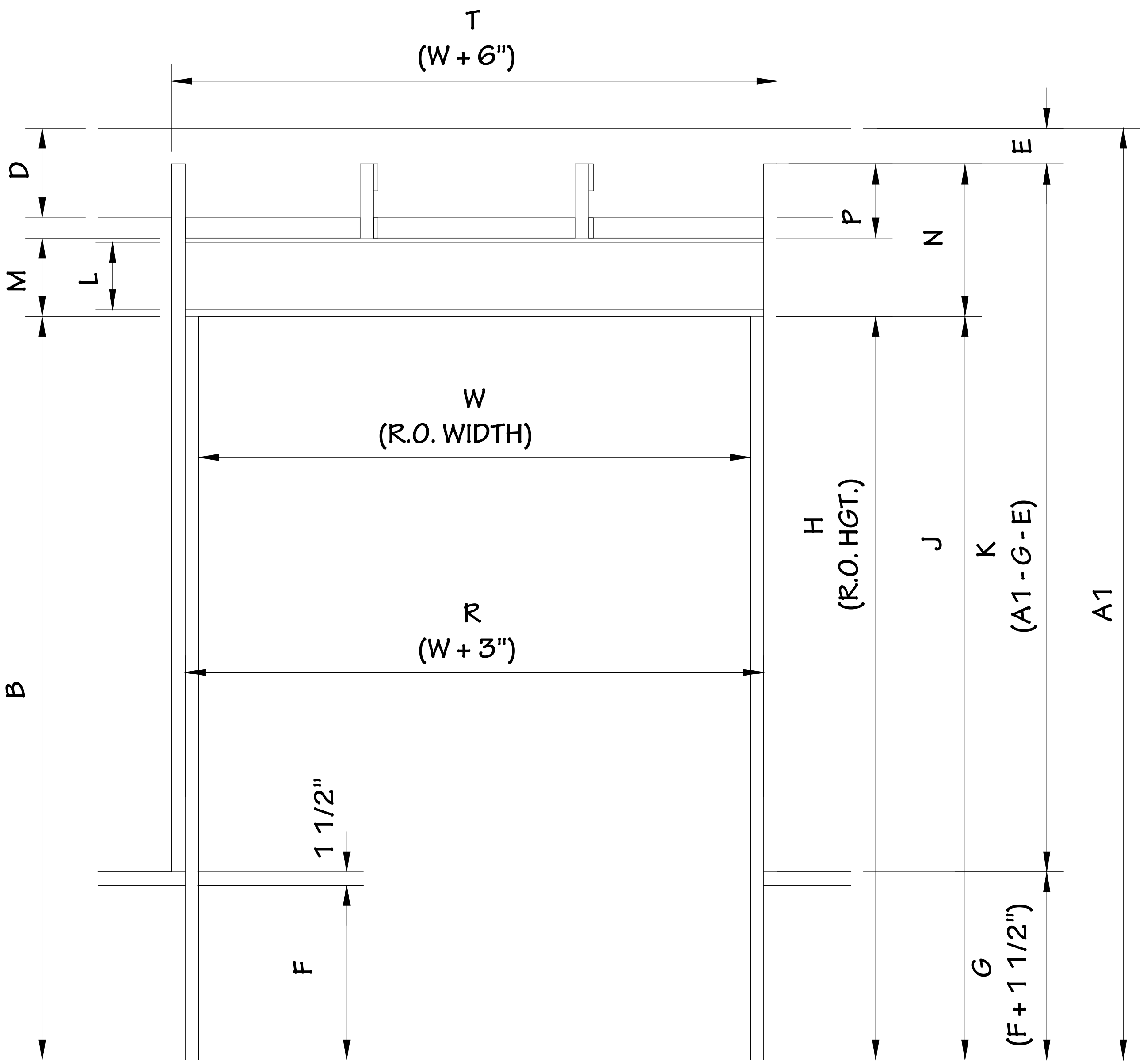
- ☐ 1. Tumbler: 20 amps, dedicated
- ☐ 2. Air compressor: 20 amps, dedicated
- ☐ 3. Chop saws (2): 13 amps, undedicated
- ☐ 4. Table saw: 15 amps, undedicated
- ☐ 5. Skilsaws: 12 amps, undedicated
- ☐ 6. Drill: 8 amps, undedicated
- ☐ 7. Battery charging station: 8 amps, undedicated

When all of the above are running at the same time, a *minimum of four 20 amp circuits are required.*

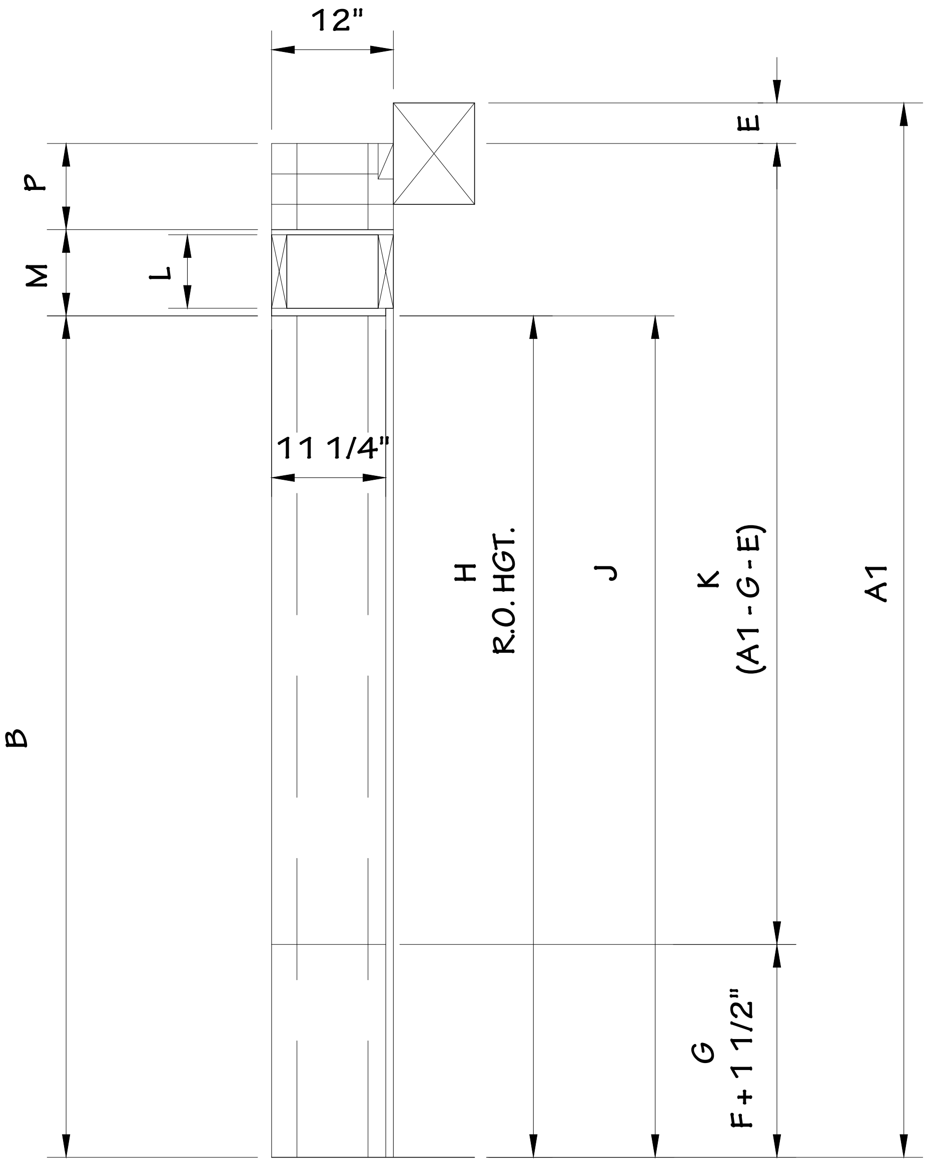
Preparing most of the matrix before the EcoNest workshop begins greatly reduces the power loads during the workshop.

APPENDIX B

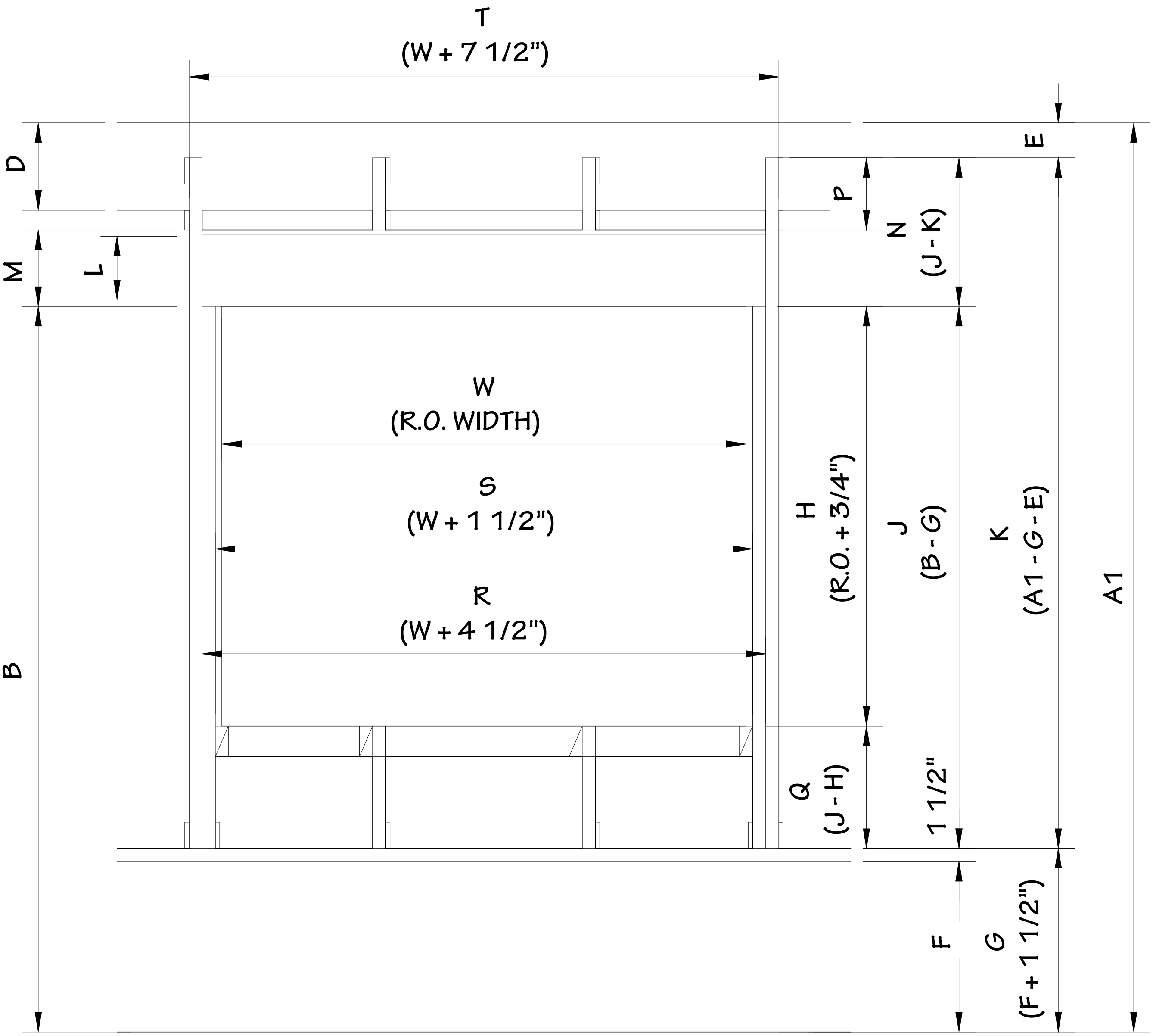
Door and Window Openings in Matrix



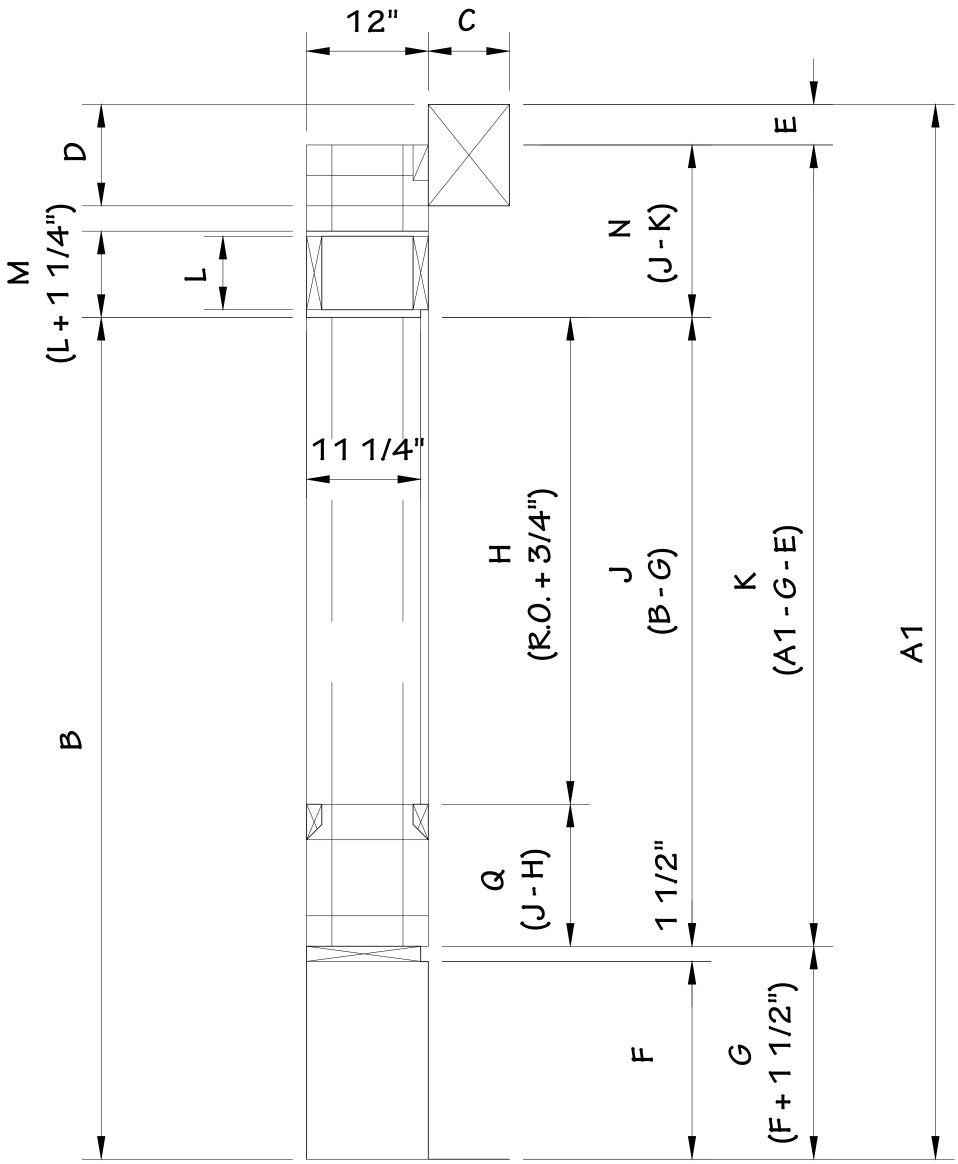
DOOR ELEVATION @ TIMBER BEAM



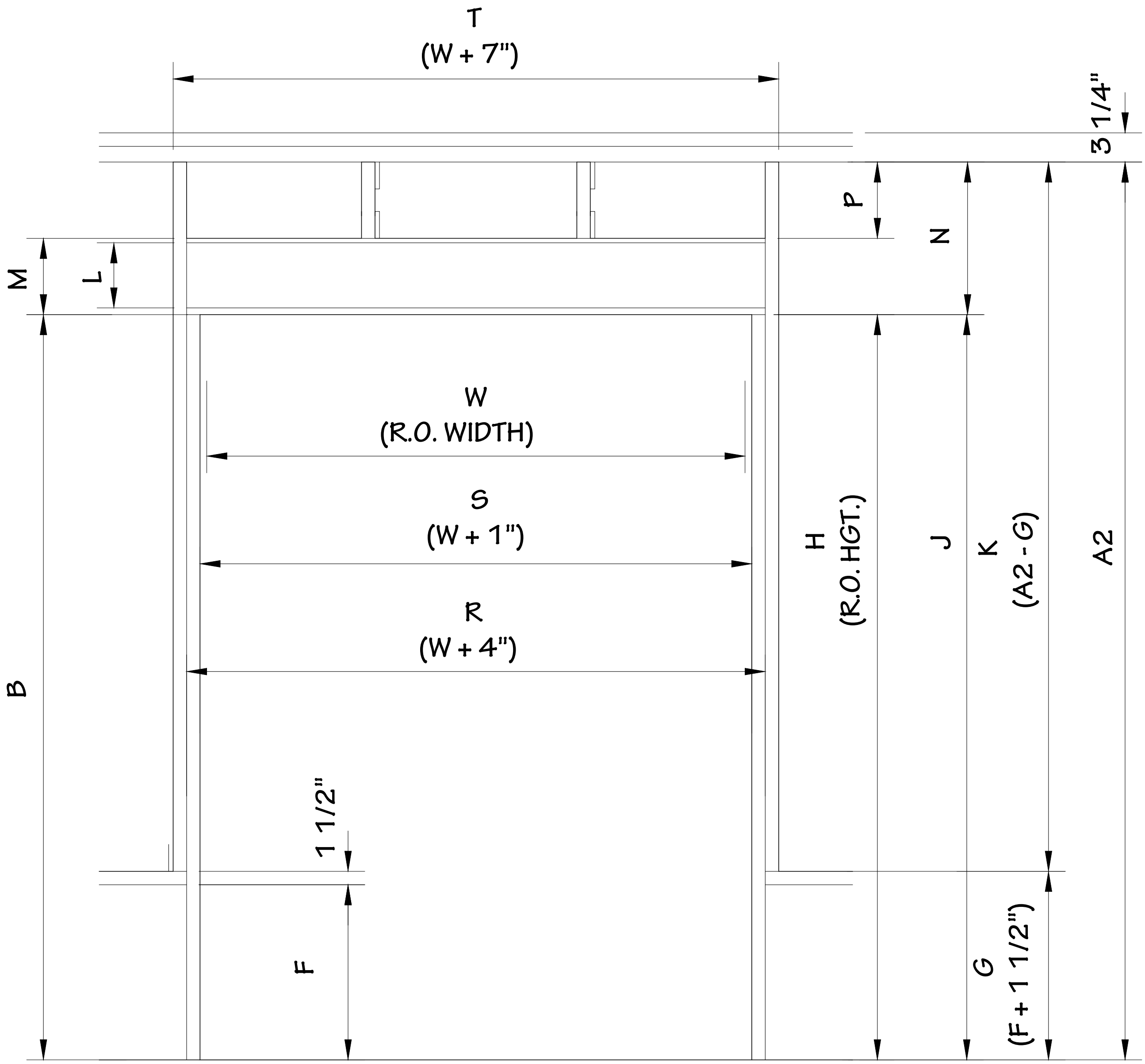
DOOR SECTION @ TIMBER BEAM



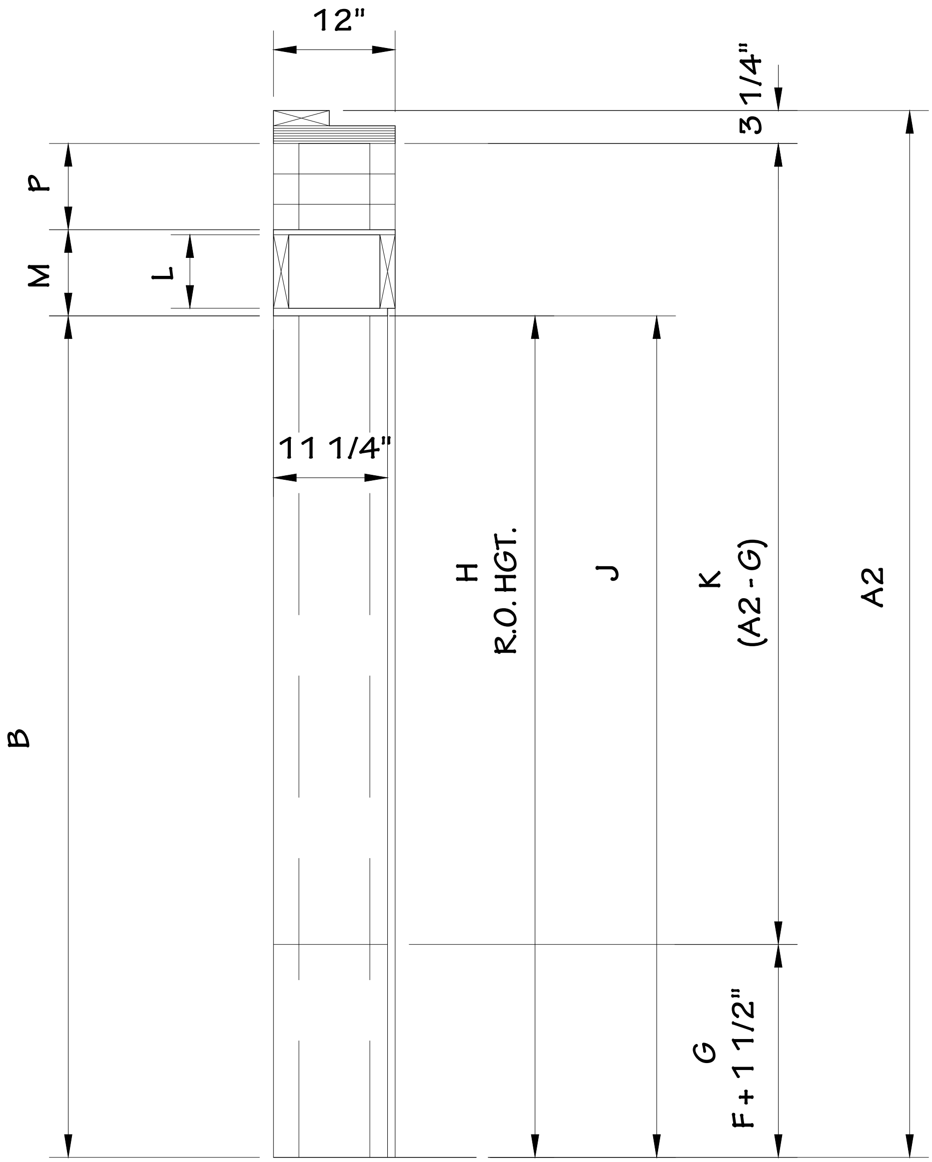
WINDOW ELEVATION @ TIMBER BEAM



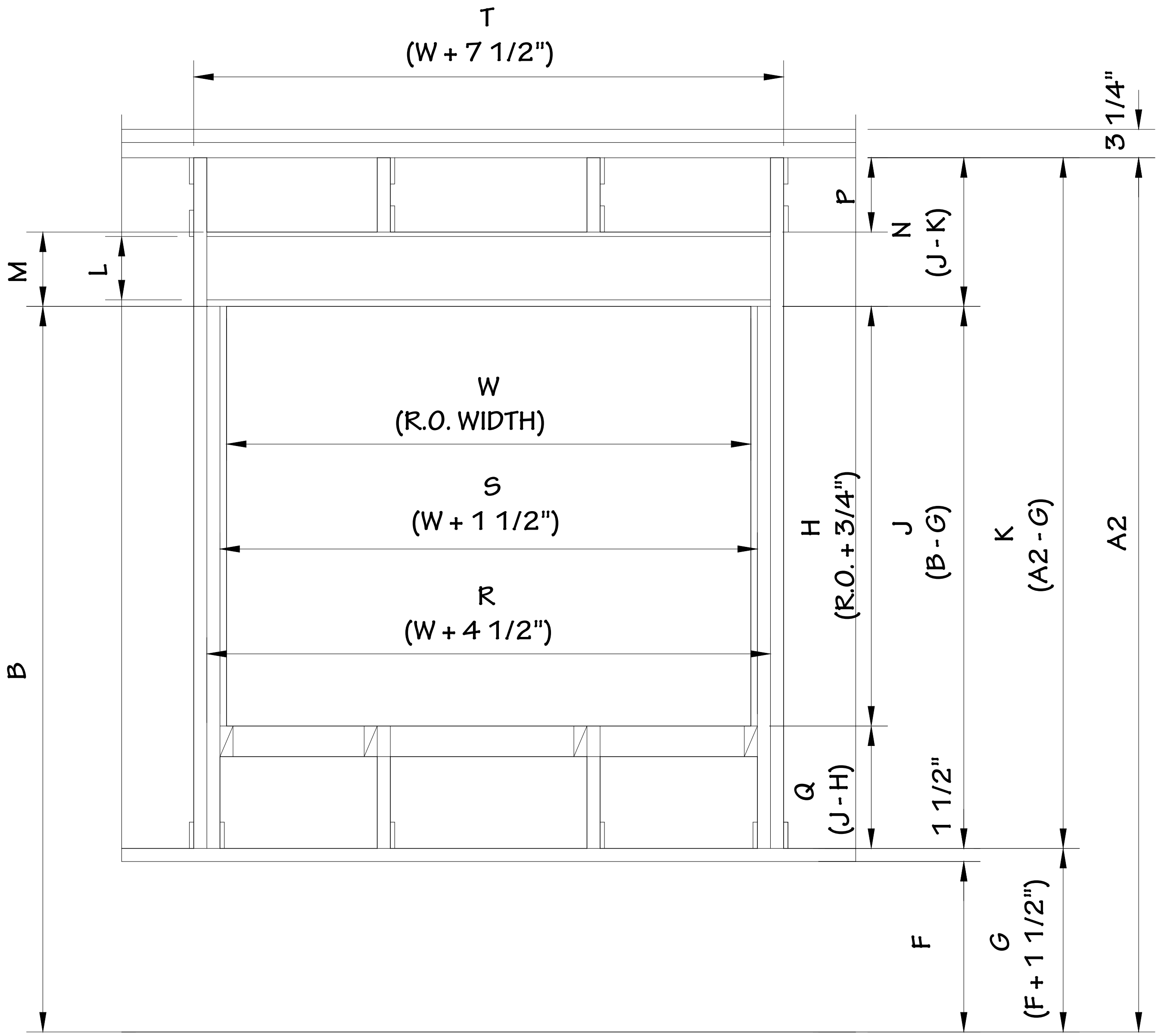
WINDOW SECTION @ TIMBER BEAM



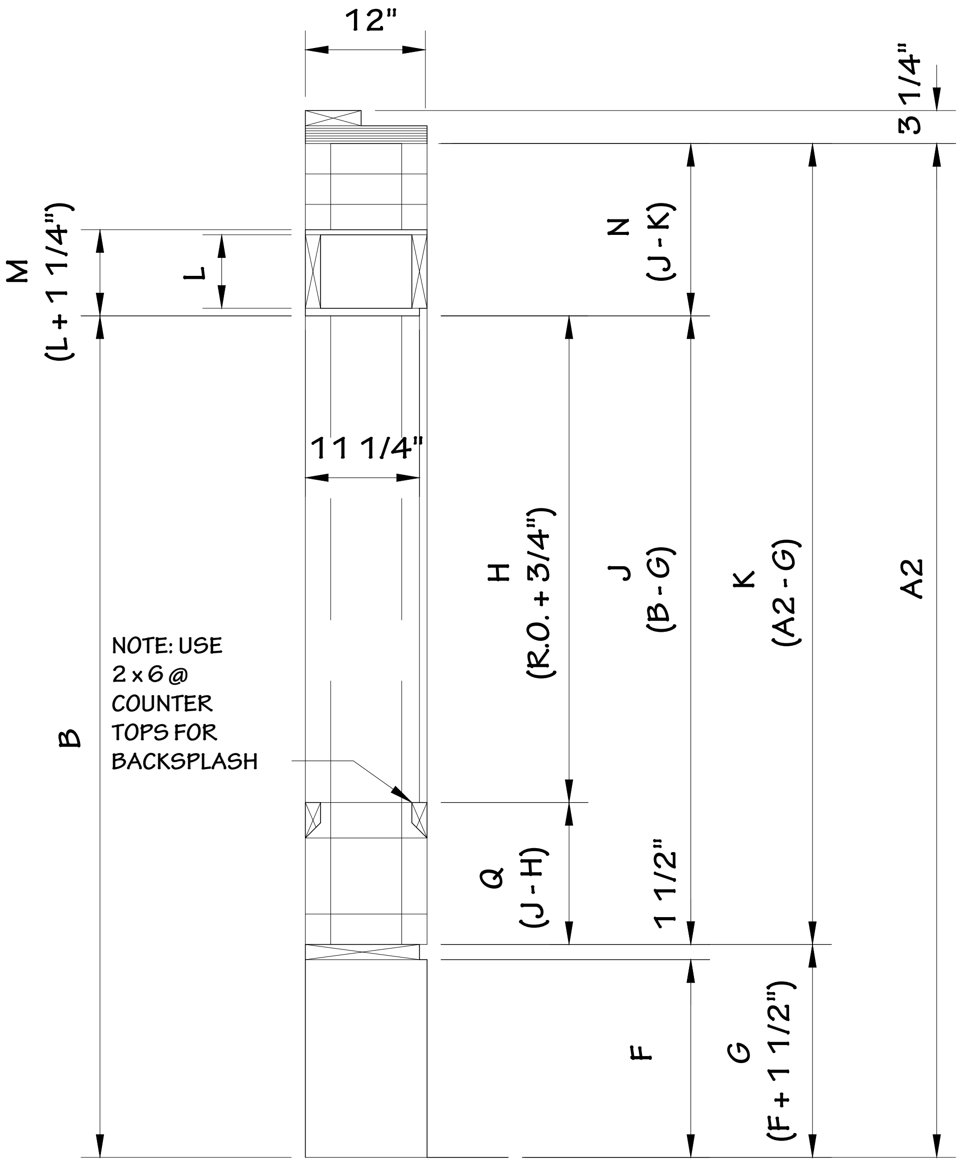
DOOR ELEVATION @ LOAD BEARING LARSEN



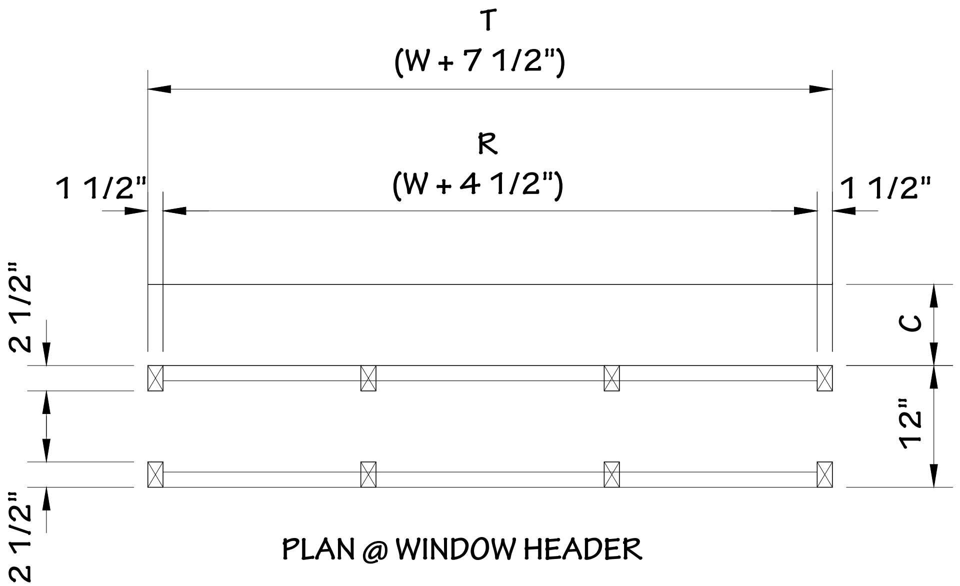
DOOR SECTION @ LOAD BEARING LARSEN



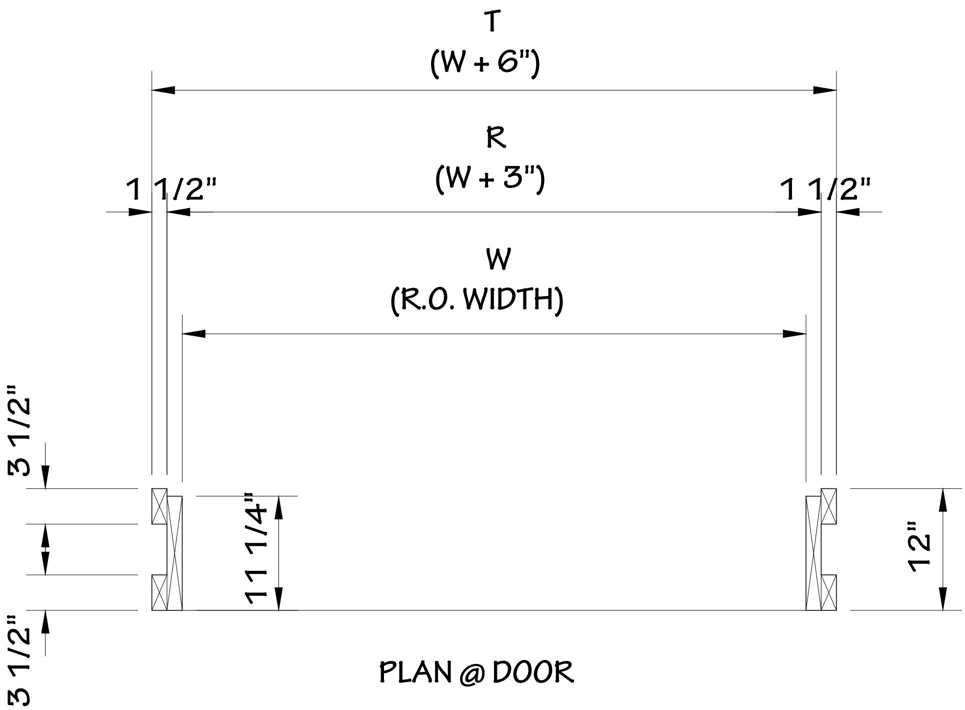
WINDOW ELEVATION @ LOAD BEARING LARSEN



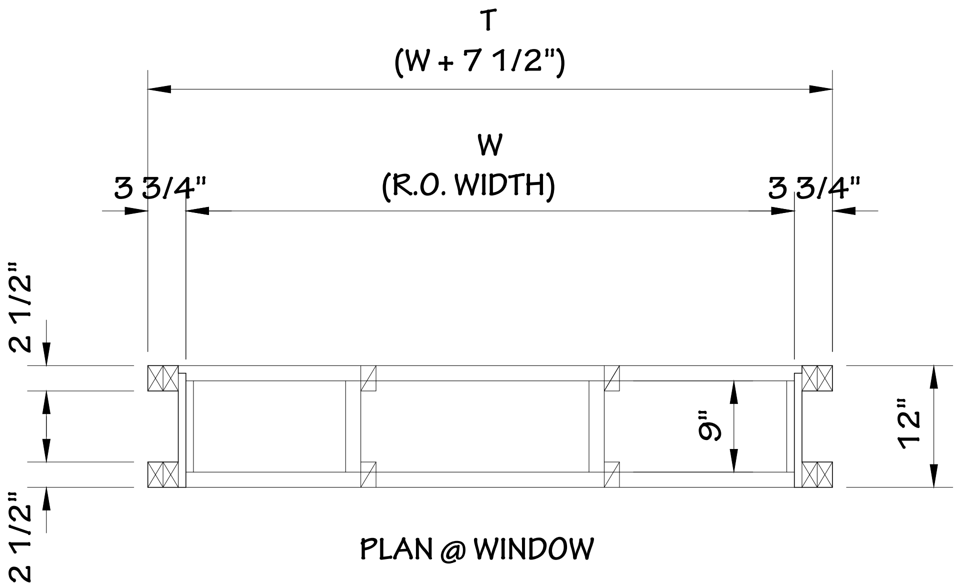
WINDOW SECTION @ LOAD BEARING LARSEN



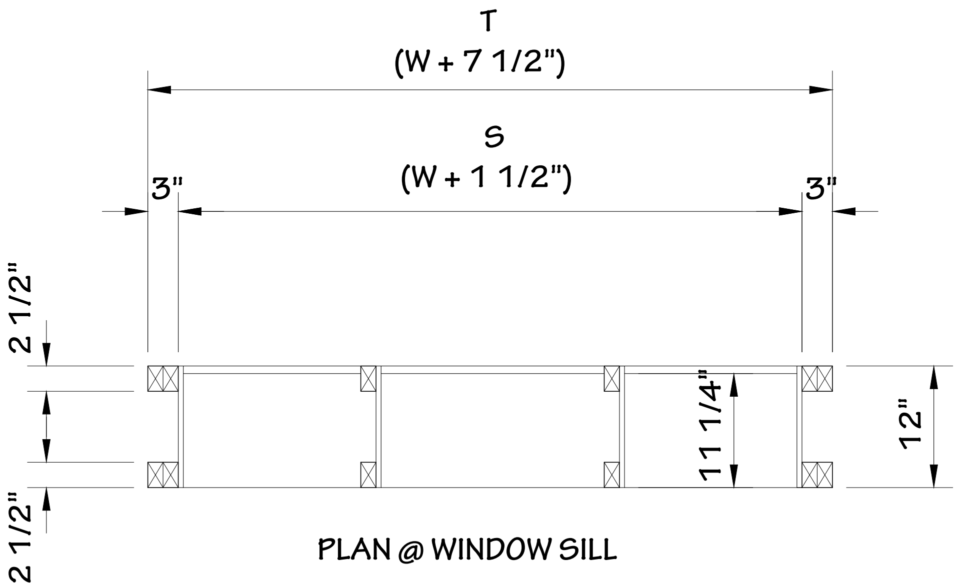
PLAN @ WINDOW HEADER



PLAN @ DOOR



PLAN @ WINDOW



PLAN @ WINDOW SILL

LARSEN WORKSHEET

				W	H	A1	A2	B	C	D	E	F	G	J	K	L	M	N	P	Q		R	S	T
		NOMINAL WINDOW / DOOR SIZE		WINDOW / DOOR ROUGH OPENING		TOP OF SLAB / TOP OF BEAM OR TOP OF PLATE	TOP OF SLAB / TOP OF LARSEN TRUSS	TOP OF SLAB / R.O. HEIGHT	TIMBER BEAM WIDTH	TIMBER BEAM DEPTH	TOP OF TIMBER BEAM / TOP OF TRUSS / PLATE	TOP OF SLAB / TOP OF FDN	TOP OF SLAB / TOP OF SILL PL	JACK STUD HEIGHT	LARSEN TRUSS OR KING STUD HEIGHT	HEADER DEPTH	HEADER DEPTH + 3/4" & 1/2" PLYWD	R.O. HEIGHT / TOP OF LARSEN TRUSS	CRIPPLE STUD HEIGHT @ HEADER	CRIPPLE STUD HEIGHT @ SILL	NUMBER OF CRIPPLE STUDS	HEADER WIDTH	SILL WIDTH	TOTAL WIDTH
		WIDTH	HEIGHT	WIDTH	HEIGHT																			
WINDOWS @ TIMBER BEAM	A																							
	E																							
	F																							
	G																							
	H																							
	I																							
	K																							
	L																							
	AA																							
	BB																							
WINDOWS @ LOAD BEARING LARSEN	M																							
	P																							
	Q																							
	S																							
	U																							
DOORS @ TIMBER BEAM	1																							
	16																							
	18																							
	19																							
D@L	10																							

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APPENDIX C

Excerpt from the 2015 International Residential Code (IRC)

The following is an excerpt reproduced from the 2015 IRC and Commentary, International Code Council, Inc., Washington, D.C. Reproduced with permission. iccsafe.org.

The IRC is a model code. It and its appendices must be adopted by a state or local jurisdiction to become enforceable.”

Commentary that explains the appendix code language is indicated by ❖.

Appendix R: Light Straw-Clay Construction

(The provisions contained in this appendix are not mandatory unless specifically referenced in the adopting ordinance.)

General Comments

Mixtures of clay and straw known as clay-straw, straw-clay, and light straw-clay have been successfully used as a nonload-bearing wall infill material since 1950 in Europe and 1990 in the United States. The use of light straw-clay wall systems has seen a surge in popularity recently because of its attributes. These include light straw-clay's thermal performance (with its balance of mass and insulation) and its low environmental impact, using local, minimally processed materials that ultimately return to the earth without harm. Other beneficial qualities include the low cost of the raw materials and the easily-learned skills needed for installing the material.

Two heavier forms of wall construction using clay and straw have been used in various parts of the world for thousands of years. A monolithic clay and straw wall system known as cob has been used in what are now the United Kingdom, Africa, the Middle East and eastern North America. A system of woven wood or woven bamboo with applied clay and straw known as wattle and daub was in common use for centuries throughout Europe, Africa, Asia and North and South America. Both cob and wattle and daub continue to be utilized today. Many thousands of existing structures using cob or wattle and daub, dating back 300-400 years, have been continuously occupied, attesting to the durability of the materials of clay and straw.

Purpose

In the United States, residential and nonresidential structures using light straw-clay have been completed in 17 states, and most of those have been constructed with full permits and inspections. However, many of these structures have been constructed on a case-by-case basis without t he benefit of a building code for light-straw clay construction.

As of 2014, only the states of New Mexico and Oregon had adopted guidelines or codes for light straw-clay construction. This appendix provides prescriptive and performance requirements for all aspects of non-bearing light straw clay construction. This is especially important because most design professionals, code officials and builders are currently unfamiliar with this wall system.

The purpose of this appendix and its commentary is to provide requirements and guidance regarding construction utilizing straw and unfired clay, which are materials previously not addressed in the code. The nature of light straw-clay as a material and system demands compliance with certain requirements that differ from established practices with conventional materials and systems in the code. The commentary to this appendix is particularly useful in these instances because it explains the reasons for requirements that are new to users of the code and this appendix.

SECTION AR101 GENERAL

AR101.1 Scope. This appendix shall govern the use of light straw-clay as a nonbearing building material and wall infill system in Seismic Design Categories A and B.

❖ In Seismic Design Categories A and B, lateral loads due to wind govern the requirements for wall bracing. In Seismic Design Categories C, D_0, D_1 and D_2 seismic loading often governs. A building's performance when subjected to lateral wind forces is independent of the building's weight, whereas a building's performance when subjected to seismic forces is a function of the building's weight. A wood frame wall with light straw-clay infill is significantly heavier than a conventional wood frame wall for which the code's bracing requirements are formulated. Thus, this appendix is limited to use in Seismic Design Categories A and B, where the relative increased weight of light straw-clay walls is not relevant, and the bracing requirements in the code text and tables remain applicable.

Buildings using light straw-clay construction in Seismic Design Categories C, D_0, D_1 and D_2 are allowed if the building official finds that the proposed design satisfies the requirements of Section R104.11, Alternative materials, design and methods of construction and equipment. This would likely require an approved engineered design for wall bracing that accounts for the weight of light straw-clay walls. However, because this appendix is limited to Seismic Design Categories A and B for wall bracing requirements only, all other requirements of this appendix, where adopted, would apply to a building using light straw-clay construction in Seismic Design Categories C, D_0, D_1 and D_2.

In general, many variations of light straw-clay construction are possible and many have been practiced historically. Designs that do not comply with certain requirements in this appendix may be approved if the building official finds the proposed design satisfies Section R104.11 by means of equivalent alternatives to these requirements.

SECTION AR102 DEFINITIONS

AR102.1 General. The following words and terms shall, for the purposes of this appendix, have the meanings shown herein. Refer to Chapter 2 of the *International Residential Code* for general definitions.

CLAY. Inorganic soil with particle sizes of less than 0.00008 inch (0.002 mm) having the characteristics of high to very high dry strength and medium to high plasticity.

CLAY SLIP. A suspension of clay soil in water.

CLAY SOIL. Inorganic soil containing 50 percent or more clay by volume.

❖ The word "soil" is commonly associated with topsoil, which contains organic matter. Clay soil used for construction purposes is a non-fertile (inorganic) mineral subsoil that contains clay, silt and sand. Sections AR103.3.2, and AR103.4.1 and Commentary Figure AR103.3.2 describe methods for determining the suitability of this material for light straw-clay construction.

INFILL. Light straw-clay that is placed between the structural members of a building.

LIGHT STRAW-CLAY. A mixture of straw and clay compacted to form insulation and plaster substrate between or around structural and nonstructural members in a wall.

❖ The density range of light straw-clay is 10 to 50 pounds per cubic foot (160 to 801 kg/m^3).

NONBEARING. Not bearing the weight of the building other than the weight of the light straw-clay itself and its finish.

STRAW. The dry stems of cereal grains after the seed heads have been removed.

VOID. Any space in a light straw-clay wall in which a 2-inch (51 mm) sphere can be inserted.

SECTION AR103 NONBEARING LIGHT STRAW-CLAY CONSTRUCTION

AR103.1 General. Light straw-clay shall be limited to infill between or around structural and nonstructural wall framing members.

AR103.2 Structure. The structure of buildings using light straw-clay shall be in accordance with the *International Residential Code* or shall be in accordance with an *approved* design by a registered *design professional*.

AR103.2.1 Number of stories. Use of light straw-clay infill shall be limited to buildings that are not more than one *story above grade plane*.

> **Exception:** Buildings using light straw-clay infill that are greater than one *story above grade plane* shall be in accordance with an approved design by a registered *design professional*.

AR103.2.2 Bracing. Wind shall be in accordance with Section R602.10 and shall use Method LIB. Walls with light straw-clay infill shall not be sheathed with solid sheathing.

❖ The "solid sheathing" prohibition in this section refers only to the application of sheathing that will inhibit air-drying of newly installed straw-clay material. Because light straw-clay is installed wet and is not fully dried to equilibrium (see AR103.5.1) before the application of plaster, any solid impermeable permanent sheathing that would inhibit its drying is prohibited.

AR103.2.3 Weight of light straw-clay. Light straw-clay shall be deemed to have a design dead load of 40 pounds per cubic foot (640 kg per cubic meter) unless otherwise demonstrated to the *building official*.

❖ Densities of light straw-clay can vary depending on wall design, project location and desired thermal properties. Historically, densities ranging from 10 to 50 pounds per cubic foot (160 to 801 kg/m^3) have been utilized. Structural engineering is not required for one-story light straw-clay structures that comply with the prescriptive structural requirements of the code and this appendix. However, structural calculations may be needed when departing from these requirements, or may be otherwise advantageous.

Densities of light straw-clay stated in this appendix are for the straw-clay material only and do not include other elements such as the wall's plaster or other finish and its framing.

AR103.2.4 Reinforcement of light straw-clay. Light straw-clay shall be reinforced as follows:

1. Vertical reinforcing shall be not less than nominal 2-inch by 6-inch (51 mm by 152 mm) wood members at not more than 32 inches (813 mm) on center where the vertical reinforcing is nonload bearing and at 24 inches (610 mm) on center where it is load bearing. The vertical reinforcing shall not exceed an unrestrained height of 10 feet (3048 mm) and shall be attached at top and bottom in accordance with Chapter 6 of the this code. In lieu of these requirements, vertical reinforcing shall be in accordance with an *approved* design by a registered *design professional*.
2. Horizontal reinforcing shall be installed in the center of the wall at not more than 24 inches (610 mm) on center and shall be secured to vertical members. Horizontal reinforcing shall be of any of the following: $^3/_4$-inch (19.1 mm) bamboo, $^1/_2$-inch (12.7 mm) fiberglass rod, 1-inch (25 mm) wood dowel or nominal 1-inch by 2-inch (25 mm by 51 mm) wood.

❖ The term "reinforcement" in this section means a component of the wall system that contains or keeps the light straw-clay infill in place during construction and in service. This includes containment of the light straw-clay where the wall is subjected to lateral out-of-plane wind or seismic forces as required by the code.

Item 1: Vertical reinforcing can be composed of nonload-bearing elements, with containment of the light straw-clay as their sole function, or elements that also serve a structural function, such as load-bearing studs. Vertical reinforcing and wall frame construction are based on the conventional wood framing requirements of Section R602, with similar methods and requirements for studs, plates and headers, etc. The main departure from the requirements in Section R602 in light straw-clay construction is the constraint on the use of solid sheathing, as noted in the commentary to Section AR103.2.2. This section is not intended to prohibit commonly accepted vertical reinforcing methods that are structurally equivalent to 2-inch by 6-inch solid wood members, such as "Larsen trusses" or similar composite members. Commentary Figures AR103.2.4(1), AR103.2.4(2) and AR103.2.4(3) show examples of wall framing for light straw-clay construction.

Item 2: Unlike the placement of steel reinforcing bar in typical concrete construction, which is used for tensile and shear reinforcing, horizontal reinforcing members in light straw-clay are used primarily for the doweling effects of the reinforcing within the wall system. The horizontal reinforcing helps: (1) Maintain overall integrity of the wall assembly during construction and in service; (2) Transfer of out-of-plane wind or seismic forces from the light straw-clay mass to the vertical reinforcing framing members and; (3) Control the vertical shrinkage and settling of the light straw-clay material as it dries. In practice, the horizontal reinforcing is placed while slightly compressing the moist straw-clay mix in order to limit "rebound" and help control shrinkage.

AR103.3 Materials. The materials used in light straw-clay construction shall be in accordance with Sections AR103.3.1 through AR103.3.4.

AR103.3.1 Straw. Straw shall be wheat, rye, oats, rice or barley, and shall be free of visible decay and insects.

❖ Straw, like wood, is composed primarily of cellulose and lignin. Construction-grade straw can be readily identified by visual examination. The best straw is composed of the dry (i.e. not having been wetted since cut) intact stems only of wheat, rye, oats, rice or barley plants and must be free of visible decay and contaminants such as insects, fertile topsoil and green plant material, since mold and mildew can grow in the presence of these readily-digested food sources.

Straw is best harvested dry and kept dry until it is mixed with clay slip and installed. The straw will have a golden color and a glossy surface. Excessive exposure to moisture will result in straw with reduced color and gloss. This straw is not optimal for light straw-clay construction.

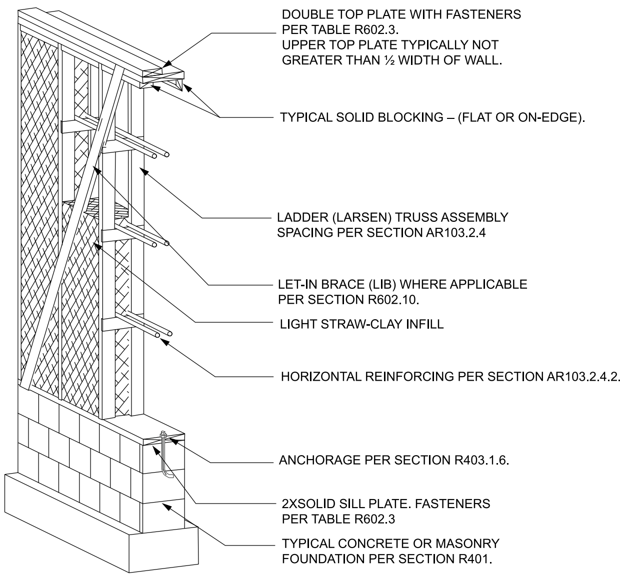

Figure AR103.2.4(1)
LIGHT-STRAW-CLAY WALL WITH LARSEN TRUSS

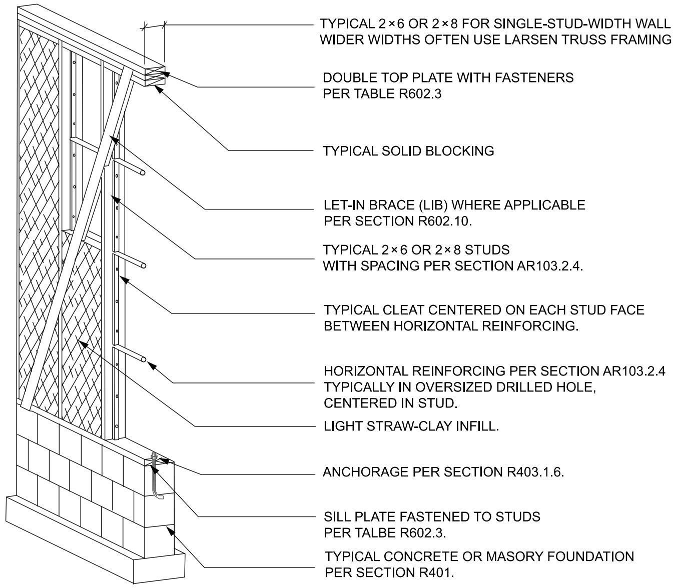

Figure AR103.2.4(2)
LIGHT STRAW-CLAY WALL WITH SINGLE-STUD WIDTH

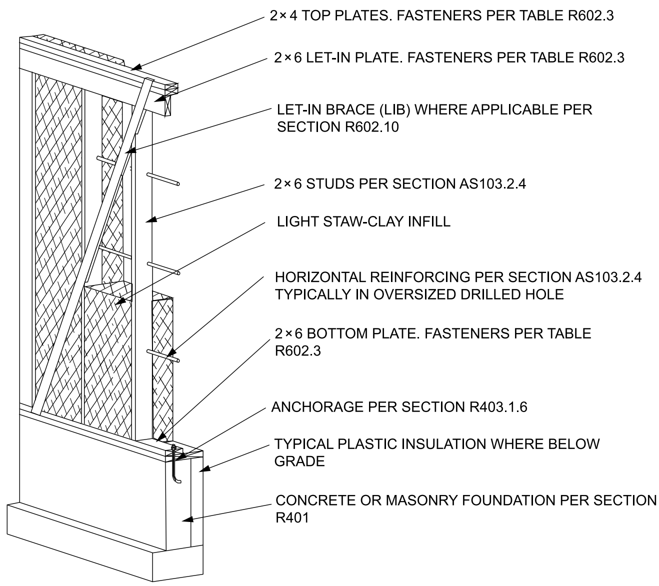

Figure AR103.2.4(3)
LIGHT STRAW-CLAY WALL WITH BLIND STUD

AR103.3.2 Clay soil. Suitability of clay soil shall be determined in accordance with the Figure 2 Ribbon Test or the Figure 3 Ball Test of the Appendix to ASTM E2392/E2392M.

❖ This section is intended to ensure that the quality of the clay slip used to make light straw-clay is suitable for the intended application. Clay soil appropriate for light straw-clay construction contains particles of sand and silt in addition to microscopic particles of clay. However, only the microscopic clay particles that form the protective bonds around and between the individual strands of straw, ensure stability and longevity. The percentage of clay in the clay slip will determine the effectiveness of the coating and binding of the straw. See Commentary Figure AR103.3.2 for recommended mixture ratios and testing methods.

A ribbon or ball test, as stated in this section, is sufficient to determine suitability for wall densities between 30 and 50 pounds per cubic foot (480 to 801 kg/m^3). A lab test known as a "soil texture test" or "physical analysis test" yields an even more accurate analysis, giving precise percentages of clay, sand and silt.

A lab test that measures percentages of sand, silt and clay is strongly recommended for lower-density, higher-insulating light straw-clay mixes. This is because there is much less clay soil added to the mix, so the little clay soil present must have a relatively high percentage of clay to provide the protective bonds that ensure stability and longevity of the wall. Inexpensive soil texture or physical analysis tests are readily available through university cooperative extension and agricultural soil laboratories in most parts of the U.S. and Canada.

AR103.3.3 Clay slip. Clay slip shall be of sufficient viscosity such that a finger dipped in the slip and withdrawn remains coated with an opaque coating.

❖ This requirement is intended to provide a simple field method to verify that enough clay is present in the slip to achieve adequate coverage of the straw and ensure cohesive integrity of the installed light straw-clay mix. This test works for all densities of light straw-clay.

AR103.3.4 Light straw-clay mixture. Light straw-clay shall contain not less than 65 percent and not more than 85 percent straw, by volume of bale-compacted straw to clay soil. Loose straw shall be mixed and coated with clay slip such that there is not more than 5 percent uncoated straw.

❖ The intent of this section is to describe straw and clay percentages for densities in the 30 to 50 pounds per cubic foot range (480 to 801 kg/m^3). The percentage of straw described in this section means straw-plus-air in the wall. These percentages are not meant to limit higher percentages of straw-plus-air used in lighter mixes where the subsoil content in the wall is lower and meets the recommended testing in Commentary Figure AR103.3.2. Commentary Figure AR103.3.4 is useful for clarifying the percentages of components used to achieve the range of light straw-clay densities.

AR103.4 Wall construction. Light straw-clay wall construction shall be in accordance with the requirements of Sections AR103.4.1 through AR103.4.7.

AR103.4.1 Light straw-clay maximum thickness. Light straw-clay shall be not more than 12 inches (305 mm) thick, to allow adequate drying of the installed material.

❖ Historically, 12 inches (305 mm) has been considered the maximum wall thickness for straw-clay mixtures 30 pcf and greater. Current research suggests that higher percentages of clay in the slip allows for lighter density

DENSITY (pcf)	MINIMUM % CLAY IN SUBSOIL (1)	MINIMUM CLAY: SILT RATIO	CLAY TESTING METHOD (2)	MAXIMUM LIGHT STRAW-CLAY (thickness, inches)
10	70	3.5:1	A	15
12	46	1.7:1	A	15
13	40	1.33:.1	A	15
15	35	0.95:1	A	15
20	30	0.60:1	A	12
30	25	0.42:1	A or B	12
40	Test Method B	Test Method B	B	12
50	Test Method B	Test Method B	B	12

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1. The minimum percentage criteria may be met by using unprocessed ray clay subsoil or subsoil refined by removal of sand and silt.
2. Subsoil Testing Methods:
   a. Lab test for percent of clay, silt and sand via hydrometer method.
   b. Ribbon test or the Figure 3 Ball Test in the Appendix of ASTM E2392/E2392M.

Figure AR103.3.2
RATIOS AND TESTING OF LIGHT STRAW-CLAY MIXTURES

straw-clay mixtures (with higher *R*-values) while still achieving adequate drying in walls up to 15 inches (381 mm) thick. Section AR103.4.1 is intended to ensure safe drying parameters for denser mixes (30 pcf and greater), and is not intended to limit the wall thickness for lighter mixtures where a history of successful drying of walls with lower densities that exceed 12-inches (305 mm) is demonstrated to the building official.

See Commentary Figure AR103.3.2 for the recommended maximum thicknesses for light straw-clay of various densities. This figure also shows the relationships between light straw-clay components and the recommended clay soil testing method for those densities.

AR103.4.2 Distance above grade. Light straw-clay and its exterior finish shall be not less than 8 inches (203 mm) above exterior finished *grade*.

AR103.4.3 Moisture barrier. An *approved* moisture barrier shall separate the bottom of light straw-clay walls from any masonry or concrete foundation or slab that directly supports the walls. Penetrations and joints in the barrier shall be sealed with an *approved* sealant.

❖ Moisture barriers to protect the straw-clay from the rising dampness inherent to masonry or concrete foundations include materials historically used for this purpose such as asphalt-impregnated roofing felt, plastic sheeting, elastomeric gasketing, clay, tar, and liquid applied products manufactured for use as a moisture barrier over concrete or masonry.

AR103.4.4 Contact with wood members. Light straw-clay shall be permitted to be in contact with untreated wood members.

❖ Light straw-clay installation is similar to the installation of wet-blown cellulose insulation in that both are installed damp, dry in the following weeks and then remain dry throughout their service life. In addition, clay has a long history of preserving wood. Clay is hydrophilic (i.e., water-attracting) and is highly water-blocking due to its strong surface bonding with any available water. Also, because of clay's very large total surface area (due to its layered microscopic structure), it has considerable capacity to capture and store water. Even when straw-clay is applied wet and in full contact with wood, the clay functions to pull water away from adjacent materials as the composite dries, including wood and its own straw fibers. In this way, and with its ability to act as a water barrier (e.g., clay is used to line ponds to prevent leakage), the clay keeps the moisture in adjacent materials below the levels necessary to support microbe growth (i.e., rot) and, therefore, acts as a preservative (see commentary, Section AR103.5.3).

AR103.4.5 Contact with nonwood structural members. Nonwood structural members in contact with light straw-clay shall be resistant to corrosion or shall be coated to prevent corrosion with an *approved* coating.

❖ A light straw-clay installation is similar to a wet-blown cellulose installation in that the material is damp only temporarily. This limited wetting is a common construction condition and standard coatings such as primer paint and electro-galvanizing are acceptable to prevent corrosion of nonwood structural members. In this section, the term "nonwood" is intended to mean metal that is susceptible to corrosion with prolonged exposure to moisture.

AR103.4.6 Installation. Light straw-clay shall be installed in accordance with the following:

1. Formwork shall be sufficiently strong to resist bowing where the light straw-clay is compacted into the forms.
2. Light straw-clay shall be uniformly placed into forms and evenly tamped to achieve stable walls free of voids. Light straw-clay shall be placed in lifts of not more

LIGHT STRAW-CLAY DENSITY (pcf)	STRAW (pcf)	SUBSOIL (pcf)	SUBSOIL (1) VOLUME %	STRAW (2) VOLUME %	AIR VOLUME %	STRAW + AIR VOLUME %	*R*-VALUE (hr/F°/cu.ft./BTU/inch)
10	6.7	3.3	2.0	7.4	90.6	98.0	1.80
12	6.7	5.3	3.1	7.4	89.4	96.9	1.72
13	6.7	6.3	3.7	7.4	88.9	96.3	1.69
15	6.7	8.3	4.9	7.4	87.7	95.1	1.63
20	6.7	13.3	7.9	7.4	84.7	92.1	per AR104.1
30	6.7	23.3	13.8	7.4	78.7	86.2	per AR104.1
40	6.7	33.3	19.9	7.4	72.8	80.2	per AR104.1
50	6.7	43.3	25.7	7.4	66.9	74.3	per AR104.1

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1. Uses 168 pcf for subsoil specific (2.7 g/cc).
2. Uses 90 pcf for straw gravity (1.45 g/cc). Straw Volume % and associated columns may increase for 20 pcf walls and above due to the weight from additional subsoil.

Figure AR103.3.4
CHARACTERISTICS OF LIGHT STRAW-CLAY AT VARYING DENSITIES

than 6 inches (152 mm) and shall be thoroughly tamped before additional material is added.

3. Formwork shall be removed from walls within 24 hours after tamping, and walls shall remain exposed until moisture content is in accordance with Section AR103.5.1. Visible voids shall be patched with light straw-clay prior to plastering.

❖ **Item 1:** Commonly used formwork for light straw-clay installations includes plywood, OSB panels and solid wood boards; often in practice these materials are then repurposed as subflooring and roof sheathing. In contrast to poured concrete, which is liquid and extremely heavy, light straw-clay is semi-solid, lightweight and is placed using only a person's body weight to tamp it into place. Accordingly, the formwork for light straw-clay is typically constructed much more lightweight than concrete formwork. For example, it often uses only 2 × 4s for whalers and is attached temporarily with screws to the permanent wall framing as part of the formwork's structure and bracing.

Typically, formwork is first installed completely on one side of the wall, then incrementally on the other side from the bottom and then upward as the straw-clay is also incrementally placed. This allows a person to tamp the material standing partially inside the formwork, and allows for possible reuse of the lower forms ("slip forming") once the material in the form above is tamped in place (see commentary, Section AR103.4.6, Items 2 and 3).

Item 2: This item is intended to ensure the mix is compacted using light tamping only; to achieve the desired density, consolidate the mix, ensure adhesion between stalks of straw and achieve wall integrity without crushing the straw stalks. Intact straw stalks and the air spaces inside and between them ensure that the maximum wall *R*-value is achieved for that density of mix. For this reason, compaction is not normally accomplished by mechanical means. Rather, it is done by a person standing inside the formwork and "walking in the forms" as the straw-clay mix is inserted. The installer ensures complete distribution of material to all corners, making sure that no voids are left, and uses his or her body weight to lightly compress the straw-clay to the desired density.

Item 3: This section is intended to allow the light straw-clay to begin drying as soon as possible after placement and to avoid the possibility of mold growth on the surface of the straw-clay beneath the forms. Forms can generally be removed as soon as the straw has "set" (i.e., moist stalks have relaxed into place). Optimum time is generally 1 to 4 hours after placement.

AR103.4.7 Openings in walls. Openings in walls shall be in accordance with the following:

1. Rough framing for doors and windows shall be fastened to structural members in accordance with the *International Residential Code*. Windows and doors shall be flashed in accordance with the *International Residential Code*.
2. An *approved* moisture barrier shall be installed at window sills in light straw-clay walls prior to installation of windows.

AR103.5 Wall finishes. The interior and exterior surfaces of light straw-clay walls shall be protected with a finish in accordance with Sections AR103.5.1 through AR103.5.5.

AR103.5.1 Moisture content of light straw-clay prior to application of finish. Light straw-clay walls shall be dry to a moisture content of not more than 20 percent at a depth of 4 inches (102 mm), as measured from each side of the wall, prior to the application of finish on either side of the wall. Moisture content shall be measured with a moisture meter equipped with a probe that is designed for use with baled straw or hay.

❖ This provision is intended to require sufficient drying of the straw-clay in order to achieve dimensional stability and a stable surface for a noncracking plaster application. However, a "full-dry" condition (in full equilibrium with ambient conditions) is not needed for successful plastering, because plasters as required in Section AR103.5.2 are highly permeable and allow the straw-clay to continue drying after plastering.

It is not always possible to obtain consistent moisture meter readings if only a few locations are sampled. Sampling multiple locations yields more reliable information about the overall dryness, particularly as the less-dense mixes offer less surface contact area for the probes of electrical moisture meters. As an additional measure, vertical wall shrinkage should be observed as the material dries and plastering should begin only when shrinkage has stopped and any voids are filled. Depending on wind, temperature and humidity conditions, the time required for straw-clay to reach a plaster-ready state may vary from a few weeks to several months.

AR103.5.2 Plaster finish. Exterior plaster finishes shall be clay plaster or lime plaster. Interior plaster finishes shall be clay plaster, lime plaster or gypsum plaster. Plasters shall be permitted to be applied directly to the surface of the light straw-clay walls without reinforcement, except that the juncture of dissimilar substrates shall be in accordance with Section AR103.5.4. Plasters shall have a thickness of not less than $^{1}/_{2}$ inch (12.7 mm) and not more than 1 inch (25 mm) and shall be installed in not less than two coats. Exterior clay plaster shall be finished with a lime-based or silicate-mineral coating.

❖ The purpose of a lime-based or silicate-mineral coating over exterior clay plaster is to improve the plaster's resistance to erosion from weather. This section does not require exterior plaster, but rather describes its characteristics if used.

Some admixtures in clay plasters have a history of imparting desirable plaster characteristics, such as enhanced moisture resistance, durability and crack resistance. These admixtures include wheat paste, manure, casein and prickly pear juice. It is not the intention of this section to exclude the use of these or other admixtures that can demonstrate erosion resistance from weather equivalent to lime-based or silicate-mineral coatings.

The centuries-old European predecessors and the light straw-clay buildings built to date in North America have all been constructed without the use of a water-resistive barrier. The light straw-clay materials in this appendix are highly vapor permeable, which allows passage of water vapor without harm to the wall. Code precedents exist for construction systems such as adobe construction and log construction, which do not require the use of a water-resistive barrier. In these systems, as in light straw-clay construction, there is sufficient moisture buffer capacity to hold and re-release moisture without damage to structural members or degradation of the wall due to weather-related moisture. For these reasons, a water-resistive barrier is not required in light straw-clay construction.

AR103.5.3 Separation of wood and plaster. Where wood framing occurs in light straw-clay walls, such wood surfaces shall be separated from exterior plaster with No.15 asphalt felt, Grade D paper or other approved material except where the wood is preservative treated or naturally durable.

Exception: Exterior clay plasters shall not be required to be separated from wood.

❖ Clay is hydrophilic (i.e., water-attracting, drawing moisture to it and away from adjacent materials) and is highly water-blocking due to its strong surface bonding with any available water. In addition, because of clay's very large total surface area (due to its layered microscopic structure), it has considerable capacity to capture and store water. Historical examples include the centuries-old half-timbered buildings still in use in Germany, with straw-clay infill and clay plasters in direct contact with the original wood frame structure. This combination of hydrophilic properties, water-blocking properties and water storage capacity protects adjacent materials that might otherwise be harmed by extended exposure to moisture. Because of this, clay plasters are not required to be separated from wood (see also commentary, Section AR103.4.4).

AR103.5.4 Bridging across dissimilar substrates. Bridging shall be installed across dissimilar substrates prior to the application of plaster. Acceptable bridging materials include: expanded metal lath, woven wire mesh, welded wire mesh, fiberglass mesh, reed matting or burlap. Bridging shall extend not less than 4 inches (102 mm), on both sides of the juncture.

❖ This section is intended to prevent cracking of the plaster where it spans across wall framing members or substrates that interrupt the face of the installed light straw-clay. The bridging materials provide greater tensile and shear strength for plasters in areas that are prone to differential movement and provide a material to which the plasters can mechanically bond across substrates that otherwise offer little or no means for bonding.

AR103.5.5 Exterior siding. Exterior wood, metal or composite material siding shall be spaced not less than $^3/_4$ inch (19.1 mm) from the light straw-clay such that a ventilation space is created to allow for moisture diffusion. The siding shall be fastened to wood furring strips in accordance with the manufacturer's instructions. Furring strips shall be spaced not more than 32 inches (813 mm) on center, and shall be securely fastened to the vertical wall reinforcing or structural framing. Insect screening shall be provided at the top and bottom of the ventilation space. An air barrier consisting of not more than $^3/_8$-inch-thick (9.5 mm) clay plaster or lime plaster shall be applied to the light straw-clay prior to the application of siding.

❖ Plaster installed in a continuous layer over the interior or exterior light straw-clay surface meets the intent of this section, which is to provide the required air barrier.

SECTION AR104
THERMAL INSULATION

AR104.1 R-value. Light straw-clay, where installed in accordance with this appendix, shall be deemed to have an *R*-value of 1.6 per inch.

❖ Current research indicates that *R*-value in light straw-clay varies predictably with density. Higher percentages of clay in the slip and improved quality control of the light straw-clay mix allows for lighter density straw-clay mixtures with higher *R*-values. These lighter mixtures are particularly well suited to colder climate regions. This appendix does not intend to limit the use of these lighter and more insulating mixtures. Commentary Figure AR103.3.4 summarizes the *R*-value findings for densities from 10 to 15 pounds per cubic foot from the 2004 USDA Forest Products Laboratory *Engineering Report of Light Clay Specimens* (see the bibliography) and may be used for calculating thermal performance for walls using these lighter density mixes. The *R*-value stated in AR104.1 and those in Commentary Figure AR103.3.4 are for the light straw-clay material only, and exclude any additional thermal resistance provided by plaster or other finish over the light straw-clay.

SECTION AR105
REFERENCED STANDARD

ASTM E2392/
E2392M—10 Standard Guide for Design of Earthen Wall Building Systems AR103.3.2

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About the Authors

Paula Baker-Laporte is a Fellow of the American Institute of Architects and is considered one of the leading proponents of healthy building in North America. After struggling with Multiple Chemical Sensitivities and regaining her own health, she became deeply interested in creating the most health-enhancing built environments possible, eventually turning to the European-based study of Bau Biologie or Building Biology. Together with Robert Laporte, Paula created the EcoNest concept and she has worked as the architect for the EcoNest Company for nearly 2 decades. She is the author of *Prescriptions for a Healthy House* and *Econest: Creating Sustainable Sanctuaries of Clay, Straw and Timber*.

Robert Laporte introduced light straw clay construction to North America, combining it with a family of other hand-crafted techniques including traditional timber framing, earthen floors, and natural plasters to create a holistic natural building system. He has built over 50 houses using this system, in climates ranging from the arid deserts of New Mexico to the frigid cold of Manitoba. Together with Paula Baker-Laporte, Robert created the EcoNest concept and has trained hundreds of professional builders and aspiring owner-builders in using the techniques. He is the co-author of *EcoNest: Creating Sustainable Sanctuaries of Clay, Straw and Timber*.

A Guide to Responsible Digital Reading

Most readers understand that buying a book printed on 100% recycled, ancient-forest friendly paper is a more environmentally responsible choice than buying one printed on paper made from virgin timber or old-growth forests. In the same way, the choices we make about our electronic reading devices can help minimize the environmental impact of our e-reading.

Issues and Resources

Before your next electronic purchase, find out which companies have the best ratings in terms of environmental and social responsibility. Have the human rights of workers been respected in the manufacture of your device or in the sourcing of raw materials? What are the environmental standards of the countries where your electronics or their components are produced? Are the minerals used in your smartphone, tablet or e-reader conflict-free? Here are some resources to help you learn more:

- The Greenpeace Guide to Greener Electronics
- Conflict Minerals: Raise Hope for the Congo
- Slavery Footprint

Recycle Old Electronics Responsibly

According to the United Nations Environment Programme some 20 to 50 million metric tonnes of e-waste are generated worldwide every year, comprising more than 5% of all municipal solid waste. Toxic chemicals in electronics, such as lead, cadium and mercury, can leach into the land over time or can be released into the atmosphere, impacting nearby communities and the environment. The links below will help you to recycle your electronic devices responsibly.

- Electronics Take Back
- Canada - Recycle My Electronics
- United States - E-cycling central

Of course, the greenest option is to keep your device going as long as possible. If you decide to upgrade, please give some thought to passing your old one along for someone else to use.