Chapter 1

Introduction

EARTH: OUR HOME OF HOMES. For thousands of generations it has also been our building material of choice: raw, local, and reflective of people, place, and a logical human scale. Extravagance was saved for structures and buildings with profound cultural significance: large timbers for a sacred house in a scrub brush desert; stones the size of school buses dragged 12 miles and up a mountain to build a temple; miles and miles of monolithic earthen walls to keep out invaders. Extreme structures like these required a concentration of human population and centralized power to make them happen. The vast majority of human dwellings have seamlessly ebbed and flowed from and back into the landscape over the centuries. In the last 200 years we have seen a radical transformation of human habitation, in location, building size, and material choices. Even in this era of industrialized and commodified building systems, it has been estimated that over 50% of the earth's population still build with and reside in houses made of earth. (Ronald Real, *Earth Architecture*, 2009). From the adobe pueblos of the North American Southwest to the 13-story cob towers of Yemen, people around the world inhabit earthen structures — and they've been doing so for thousands of years.

Most people living in the Western World live in cities; many more will soon move to sprawling cities; and millions are experiencing the urbanization of rural areas. Most North American homes are relatively recently constructed; the materials used to build them came from the lumber yard, hardware store, or giant box store. Only a few generations ago, these homes would have been built with indigenous materials from the forest, field, or directly under foot. The curse of Western civilization is that, despite its vast quantity of available conveniences, it fosters a profound and insidious culture of disconnection. The commercialization of all needs has created a social architecture that divorces people from place, from planet, and from each other.

In the last 50 years there has been a resurgence of interest in rehabilitating severed connections on multiple levels — from social reconnection (charity, co-housing, neighborhood involvement, community-creating) to material reconnection with the items of daily life (where food and fuel come from, where wastes go, where building materials are sourced, and how all of the above is transported and transformed from raw materials).

The need for these types of connections drives a culture on a conscious and subconscious level. The empowerment and purpose someone feels when they feel and understand the history and meaning of the materials of their daily life is profoundly different from the probable dullness and hollowness of someone's experience who does not. In Polynesia, the construction of a dwelling involves the entire community. All materials are sourced locally and are assembled with songs and meaning assigned to each facet of the process and each part of the building. In essence, the whole home resonates with symbol and meaning. In the Western World, the essence of the home is its value as an investment — a commodity described in cost-per-square-foot terms; songs ascribed to any facet of these buildings are likely to be the curses and frustrations expressed by those who have built them more for money than any love of any "craft."

For those who are longing for spiritual connection, to experience a deeper sense of the sacred, or — on the most basic level — begging to feel some sense of meaning in their lives, one positive action to take is starting a collection of things made by hand by people they know. A carved spoon, a clay bowl, a knitted scarf: all these items carry with them a significance that cannot be purchased. Consciously seeking to incorporate items with significant stories into one's life can be a powerful experience. They become landmarks of connection throughout a routine existence. This might sound like a mundane exercise, but just as small reminders in daily life can horribly trigger a sufferer of PTSD, these objects with history and meaning can be the positive opposite.

In this rising tide of connection and resiliency, certain notions and movements have been playing major and convergent roles. The local and organic food movement is reconnecting people with food and sustainable systems of production. The environmental movement is reconnecting people with our place in the natural world in a holistic and reparative way. The social justice movement is reconnecting people with their own power and with each other. The sustainability movement is connecting and educating people with the multifaceted knowledge required to inhabit and sustain one's self and greater community in a particular place and climate. For many, this is known as *permaculture.* A major part of permaculture is *whole-systems design.* This is looking at the design of a garden, home, community, and or other system through a long-term lens that takes all factors into consideration: location, geology, climate, soil type, aspect, natural resources, people, etc. The facet of a whole-systems design process that takes shelter into consideration (whether you are a permaculturalist or not) is most commonly referred to as *natural building.*

Natural building, in its most basic definition, is a method of construction that uses minimally processed and locally sourced "natural" materials. In its most embodied form, it represents a whole-systems approach to construction that incorporates a worldview into a structure. It wholeheartedly takes into consideration the grand global implications and footprint (in every sense of the word) of materials, including acquisition, processing, transport, intended use, and post-use. For some, it's just an earth-friendly and breathable wall system, for some, it's the structural implementation of permaculture; and for others it is a means to healthy and nontoxic living or a method to exit the industrialized capitalist banking system. For whatever reason it draws people, natural building as a movement marks a shift away from industrialized, commodified building systems toward more place-based, ecological, and human-scaled building.

On the various styles of natural building, there are a wide variety of written materials detailing how to build using straw bales, adobe bricks, cob, rammed earth, earth bags, and pressed blocks, to name a few. This book is intended to fill a particular void: there is little literature published on *Light Straw Clay*. LSC is versatile, can be implemented in nearly any building project, and is compatible with nearly any superstructure. You could think of it as the "duct tape" of the natural building world. Much like flour and water can create a cornucopia of baked goods, straw and clay can be combined in myriad ratios and for a plethora of applications: floors, walls, ceilings, sculptures, new construction, renovation, interior walls, and exterior walls. It's insulative, fire resistant, durable, insect-resistant, it provides thermal mass; and the list goes on. The sky is the limit with LSC, and my hope is that this book inspires you to incorporate it into your project, building repertoire, and/or your own home.

Chapter 2

Rationale

WHAT IS LIGHT STRAW CLAY? It is an infill system of loose straw lightly coated in clay that is packed into forms (temporary or permanent) to insulate and enclose a building. It is not load bearing, but it can be mixed to a variety of densities. The "light" in light straw clay refers to two things: the amount of clay (less than in traditional daub in wattle and daub) and the material's weight (it is very light). Light straw clay is the English translation of the German word "leichtlehmbau."

Light straw clay was developed in Europe as an evolution of the wattle-and-daub infill system that filled in the spaces between structural members in half-timbered houses from the 12th century, on. According to Robert and Paula Laporte, North America's preeminent light straw clay experts:

> 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 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.

There are a few other frequently used names for light straw clay: *light clay, straw clay* and *slip straw* are commonly used, and it has also been referred to as *rammed straw* (akin to rammed earth wall systems that have little-to-no fiber

Daub is a mud mixture applied to wattle *— a network of woven sticks in the wall.* PHOTO CREDIT: MICHAEL G. SMITH

14th-century building uses wattle-and-daub infill. Wattle and daub is "heavy straw clay" — a predecessor to LSC. PHOTO CREDIT: ROBERT LAPORTE in them). For the sake of consistency, all of the above will be referred to in this book as *light straw clay,* or *LSC*.

Advantages of Light Straw Clay

As a light straw clay wall system is composed of more fiber (straw) than binder (clay), it is much lighter and much less dense than other natural wall systems like cob, adobe, or rammed earth.

Nontoxic

LSC is essentially nontoxic. Clay is known for its ability to absorb toxins due to its relatively large surface area and negative ionic charge. Because of this negative ionic charge, it absorbs positively charged ions which most bacteria, viruses, fungi, and toxic chemicals have an abundance of. (From "Living Clay," livingclayco.com) Combined with straw (which has minimal pesticides and herbicides applied to it as a crop, with only two applications being applied per year and not near harvest), it creates a nearly nontoxic wall insulation and enclosure. Being made mostly of cellulose, it is a relatively benign material and, like clay, it does not off-gas any volatile organic compounds (VOCs), unlike many other manufactured types of wall insulation.

Low-Tech Method and Materials

In addition to being a building material that is not hazardous to your health (although working with straw and dry clay can be very dusty, so it is best to wear a respirator), it is also very "low tech." The mixing and manufacture of light straw clay can be done without electricity: either manually or with a tumbler. Because the material is very lightweight, you don't have to be a muscled construction worker to participate in the installation. It can quite literally be fun for the whole family — including grandchildren and grandparents. It can be pleasant work; the job site can be quiet, the tools are very simple, and the material is all lightweight, nontoxic, and easy to install.

High Vapor Permeability

Light straw clay walls are highly vapor permeable. This is a benefit because vapor permeable walls allow moisture to exit a building instead of being trapped in wall cavities. Breathing, showering, cooking, etc., all generate water vapor in a building. Naturally "breathable" (aka vapor permeable) wall systems allow moisture, in the form of vapor, to move through the walls without the need for mechanical ventilation. Combined with clay-based binders and a clay-based plaster, an LSC wall system can help regulate humidity in a building, creating a much healthier environment in terms of air quality.

Vapor barriers are discouraged for LSC wall systems because they trap moisture moving through the natural wall system, where it can condense and be trapped. If water in a wall system can't escape, mold can form, which can be toxic for inhabitants. Clay's hygroscopic capacity allows it to absorb high volumes of water vapor and then release it — "breathing" it out — without compromising the straw or wood that it is in contact with. So, LSC in general, thanks to clay's properties, will regulate dampness, which also helps maintain its insulative qualities.

Place-based Architecture

The reason travelers find many types of vernacular architecture so appealing is partially due to their unique expression of people in a place. A building can be a reflection of place, and light straw clay buildings can embody place-based architecture by using materials from a structure's own site. One of the most common materials to use from a site (besides wood from harvested trees) is the earth excavated to make room for the foundation of a building. The amount of excavated earth may provide an adequate amount of clay for both wall infill and plaster skins. What better way for a building to fit into its environment than being built from materials found on the site?

Carbon Sequestration

Light straw clay being predominantly made of straw has the capacity to sequester carbon. Straw is made of cellulose; the chemical formula for cellulose is $C_6H_{10}O_5$, making straw approximately 45% carbon. If a building uses 100 2-string bales and each bale contains approximately 19 pounds (8.6 kg) of carbon, that is about 1 ton (860 kg) of stored, or sequestered, carbon.* This, in conjunction with earthen plasters, energy efficient design, and low impact living can substantially lower the carbon impacts of building a new residence. (**Calculations from Stuart Staniford, "Carbon Off-Set Values of Straw Bale Buildings," Aug 2010, earlywarn.blogspot.com*)

Chapter 3

Appropriate Use

Of the many natural wall systems to choose from, there are many reasons to choose a light straw clay wall system. Straw clay is highly compatible with framed wall systems because it is a non-load bearing material. Light straw clay can be infilled in nearly every wall framing system, be it timber framing, pole framing, conventional lumber framing, or framing specifically designed for straw clay infill.

LSC is also excellent retrofit insulation because preexisting walls can be furred out to any thickness. Furring out a wall simply involves adding stud material to the desired depth of wall (see "Larsen Truss System" in Chapter 6 for more on this). This can be done to the interior of a building or to the exterior. Using staggered studs or Larsen trusses also improves the insulation's performance because it allows the creation of a continuous thermal envelope, virtually eliminating the thermal bridging that occurs in a conventionally framed building (where solid studs create breaks between insulated stud cavities).

Interior walls can be infilled with straw clay in buildings that have exterior wall systems of other materials. Interior walls can benefit from the soundproofing and thermal mass that straw clay provides, and they provide a seamless look because they take plaster as well as other natural wall systems. If done with good and consistent formwork and with attention to detail, the walls can be very flat, lending themselves to very smooth finish plaster, which leads to less "dusting" through the life of the wall.

LSC's compatibility with conventional framing systems makes it easier to find contractors who can provide straightforward estimates for a project.

2×4 interior walls are infilled with LSC to aid in sound dampening and creating a sense of privacy for this small 800-square foot three-bedroom home. Photo credit: Lydia Doleman

Wall systems or walls with lots of openings, like the south side of a passive solar building in the Northern Hemisphere, are highly compatible with straw clay, whereas cob, adobe, and straw bale are hard to work with around windows, doors, and other openings. It's a somewhat common practice to design a building that takes advantage of the high R-value of straw bales for the north, west, and east walls of a building, but use LSC in the south wall, which has the bulk of the glazing (windows).

One of the advantages light straw clay has over cob and adobe and other natural wall systems is that it slumps and sags very little while being installed, allowing an entire wall cavity to be filled in one work session. As long as tamping is consistent and there are not long periods of drying time between installations in the same wall/stud cavity, there is also very little shrinkage.

Straw bales are load bearing in this building that uses LSC for the south wall.
Photo credit: Lydia Doleman

Even with the intense heat application of a blow torch, LSC only smolders.
Photo credit: Lydia Doleman

Many projects, particularly in urban areas, have to be carried out in limited space. When there is limited square footage to work with, the 18″ to 24″ width of straw bales or cob may rule these wall systems out because they eat into usable space. In urban areas and sites with limited space, straw clay can be an excellent choice to create thinner wall systems that are still highly insulative. LSC can be made to fill any wall width that can reasonably dry within the timeframe of most building seasons. Most LSC walls do not exceed a 12″ thickness.

Straw clay is very fire resistant. Tests conducted by Joshua Thorton and John Straube found that, based on ASTM standards E 111 and E 84, LSC would very likely meet the conditions required for a fire-resistant period of four hours. They also reported that LSC is a "highly ductile material with the potential to absorb a fair amount of energy in the event of seismic activity." (Thornton, *Initial Material Characterization of Straw Light Clay,* Canada Mortgage and Housing Corporation, 2005.)

As each piece of straw has been coated in clay and packed in the wall, there is very little that can actually combust. Although, the walls are breathable to vapor, the continuous wall envelope should not have open channels for sufficient quantities of oxygen to be present, which also helps LSC resist combustion. Like a lot of dense materials, it may only smolder.

According to architect Franz Volhard, one of the European leaders of earthen construction methods, his own fire tests of LSC demonstrated:

- Light earth responds passively to the effects of flames, i.e. it does not contribute to the spread of fire.
- The formation of an "insulating" charred layer protects the surface of

underlaying materials from direct exposure to the flame, which increases with flame duration.

- Neither smoke, nor fumes nor perceptible combustion gases were produced.
- No particles fell from the specimens which could have contributed to the spread of the fire.
- Compared with wood-wool magnesite-bonded panel, the fire behaviour was better with less charring and no smoke development.

These results suggest that straw light earth could be classed as B1 "Not easily flammable."

(Franz Volhard, *Light Earth Building: A Handbook for Building with Wood and Earth,* 2016, p. 225.)

Given that the required formwork for LSC is usually very flat and rigid and resists bending under pressure (plywood with "strongback" reinforcement), it is easy to form flat walls into very rectilinear structures, be it craftsman-style bungalows or modernist buildings. Light straw clay can also be made into bricks. Once dry, they can be placed directly in wall cavities, stacked to insulate thick walls in wetter climates (where there wouldn't be enough time in a building season for LSC infill to dry), or cut and fit in to odd spaces that need insulation. Curved walls and window openings can also be made with light straw clay, although they require more detailed planning and curved formwork.

Rounded corners are achievable with LSC wall systems by using rounded forms.

PHOTO CREDIT: LYDIA DOLEMAN

Rounded corners in the making.

PHOTO CREDIT: JIM RIELAND

Due to the nonstructural aspect of light straw clay, a superstructure must be erected prior to installing the wall insulation. Therefore, you need a dry work space, in most situations. There are various methods of infill, some of which leave the roof framing until after the walls are filled in. In wet climates, having a roof structure up allows more time for installing the LSC and is added insurance should a storm happen during an anticipated dry season. However, having a roofless building allows for significantly more airflow to help facilitate drying.

Other applications of light straw clay are ceilings and floors. LSC can be used between floor joists if permanent formwork is used, or by implementing what is referred to as "light earth reels" (Volhard) or "chorizo style" (they look like sausage rolls), where the straw clay is wrapped around a stick or bamboo rod and suspended between the floor joists. Adequate airflow must be provided, as it requires a much heavier clay slip to wind the straw and clay around a stick that will adhere while being suspended overhead. In addition to all the other advantages of LSC, the advantage of this method is that it takes plaster very well; plus, it can be very artistic.

If you live in an area with wind-driven rains, you might want to consider a rainscreen to protect your finished walls. Wind-driven rain does not rule out building with LSC, but it is best to plan for worst-case scenarios. This is also true for areas of high snow. A snow drift next to an earthen plaster or lime-plastered wall will cause problems. A rainscreen (even for a half wall) can be a smart choice to mitigate climatic issues.

A board-and-batten rainscreen keeps the wind-driven rain from saturating the LSC on the south side of this handsome brewery. Photo credit: Dean Hawn, Burning Daylight Construction

A half rainscreen keeps the bottom portion of this tiny timber frame LSC from being damaged by splashback from the roof. Photo credit: Lydia Doleman

Other Important Considerations

If you are considering building a full-sized residence or something over 800 square feet, consider building a small shed or outbuilding first. It's much more cost effective to work the kinks out on a small building than on a big one. There are so many little details in an LSC building. Things will be much more streamlined if you are familiar with its idiosyncrasies, so it's best to start with a smaller project rather than jumping right into a big one. You may even discover that you don't want to use LSC on the larger structure, or that you may want to use it in only particular parts of your building. Starting small will be much less stressful, too; you won't feel the same time pressure about the myriad daily decisions you have to make on a construction project if you have gone through them once on a smaller project. Plus, you will have the added bonus of having the smaller structure as a place to put all your tools (or yourself!) while you work on the bigger one.

(Due to code constraints and permit costs, a lot of people choose to build smaller structures under inspectors' radar. But be careful with this.

Small "outbuildings" are often characterized by code as sheds, or non-inhabited agricultural buildings; often they are not required to meet code, but different municipalities have different requirements, so it is important to thoroughly look into your local building codes.)

Disadvantages of Light Straw Clay Wall Systems

Labor

Light straw clay is labor intensive. Even with a tumbler (more on that later), you will need a group of people to pack the straw into the wall cavities and move forms. It takes a minimum of five people to mix slip, mix straw clay, and pack it into walls. You could do this all solo; but it would take you several seasons for a whole house. But try turning this disadvantage into an advantage. Take the more-the-merrier approach, and turn your worksite into a work party! Remember that the labor can be done by practically anybody, and it's relatively quiet and pleasant. (See Chapter 8 for more on work parties).

Dry Times

The rule of thumb with straw clay is that you need approximately one week per inch for dry time. For the average 12-inch-thick wall, that's 12 weeks (more incentive to get the walls done quickly). During that time there are a lot of other parts of a project to complete, but especially in locales that have short building seasons and extreme weather, you must plan ahead for adequate drying time. With longer dry times, mold can be an issue. Little white fuzzy spots of mold sometimes appear, especially in areas with low air circulation or where an LSC mix with a higher proportion of clay was used, e.g., tops of stud cavities and repairs. (This light white mold is harmless.) If using a water thinner, like borax, in your slip, it can cause efflorescence, which is a buildup of salts that crystallize on the surface as they dry. These are harmless, and can be gently scraped off.

The amount of moisture dissipating from a straw clay wall system can sometimes overload an interior and cause surface molds to appear on wood, especially if the wood wasn't completely dry, or it wasn't treated/sealed. The use of fans and dehumidifiers is highly encouraged. Propane heaters are *not* recommended; they produce a fair amount of moisture in their heat production.

In systems where the formwork is permanent, there is less exposed surface area for the LSC. In situations like this, or when dry time is short and/or humidity is high, care must be taken not to make too heavy a clay mix; you want to allow the LSC to dry well in the closed wall cavity. The use of water thinners to limit the amount of moisture in the slip is advised. For more information on what, when, and why to use water thinners, see Chapter 5, "Water." Once again, the use of fans and dehumidifiers is key to facilitating the drying of an LSC wall system.

Specific Exclusions

There are some situations that are *not* right for straw clay. You should consider other options if you:

- live in an area with an excessively short building season (one where wet weather is followed closely by freezing weather)
- have no access to materials for building the supporting structure
- have limited access to straw or clay
- have no labor pool
- live in a building with preexisting termite or mold issues
- have a major straw allergy.

These are some of the reasons you might want to explore a different wall system. Note, however, that some innovative builders have implemented the use of straw clay *bricks* for short-season building. The increase in surface area greatly decreases dry times, and the bricks are light and stackable.

Some regions in North America do not have a code for the use of straw clay as an insulating wall system (See Chapter 11 – Building Codes). This could make a permitted project challenging because you would have to work with the local building department for permission to build this way. Also, some banks may not grant a loan for an unconventional wall system; and some insurance companies will not insure an unconventional project.

Properties

The most obvious property of LSC is its insulative ability. Insulation levels are rated by their "R-value," which is the measure of a material's resistance to heat flow. A higher R-value means better thermal performance. The R-value of LSC walls is mostly contingent on the density to which it is packed and the amount of clay used. Good tests have been done on the R-value of LSC by the Design Coalition, Douglas Piltingsrud, Franz Volhard, and others.

Note that in the testing done to produce Tables 3.1 and 3.2, the amount of straw in each mix remained consistent; only a change in the amount of subsoil in the mix impacted density and, therefore, the thermal resistance (R-value) of the LSC. In short, less subsoil equals a lighter LSC mix and a higher R-value per inch, while more subsoil equals a heavier LSC mix and a lower R-value per inch.

The R-value of a wall assembly will also depend to some extent on what type of wall system is in place. If building a structure and not using split stud or Larsen trusses, the thermal envelope will not be continuous; the insulating quality of the entire wall system is diminished because there will be thermal bridging through the studs.

Optimal Density

Given the broad range of densities achievable with LSC, it is important to achieve the correct one to meet the desired R-value for a wall system. Field experiments are required to find the ratios that will yield your desired density.

The following is a guideline recipe by Douglas Piltingsrud (designcoalition.org):

Following is a basic formula for making a wall density of 13 lbs/ft^3 (pcf) with a thermal

Table 3.1: Thermal resistance of straw-clay at different densities

Specimen	Density (#/ft^3)	Density (kg/m^3)	Conductivity (W/m°K)	Delta Temp. (deg. C)	Temp–median (deg. C)	R/inch (hr°F*ft^2/BTU/inch)
Low Dens. I	10.2	164	0.08	4.54	23.21	1.80
Low Dens. II	13.0	209	0.09	approx 4.5	approx 23	1.69
So. Dakota I	15.8	254	0.09	4.51	23.40	1.55
So Dakota II	13.3	213	0.09	4.54	23.39	1.67
Reg I	13.3	213	0.08	4.55	21.30	1.72
Reg II	13.7	220	0.09	4.54	23.59	1.66
NM I	38.1	612	0.13	4.58	23.21	1.11
NM II	43.9	705	0.16	4.19	23.40	0.90

Credit: Design Coalition

Table 3.2: Properties of light straw clay mixtures (1)

	Density pcf (kg/m^3)	Straw pcf (kg/m^3)	Subsoil pcf (kg/m^3)	Water gal/cf (l/m^3) (2)	Min. % Clay in Subsoil	Min. Clay Salt Ratio	Subsoil Testing Method (3) (4)	Subsoil Volume % (5)	Max. Wall Thickness Inches (mm)	Straw Volume % (6)	Air Volume %	Straw + Air Volume %	R-value (hr•°F•ft^3 • BTU per Inch Thick)	Conductivity (W/m°K)
Lighter	10 (160)	6.7 (107)	3.3 (53)	1.55 (208)	70	3.5 : 1	A	2.0	15 (381)	7.4	90.6	98.0	1.80	0.079
	12 (192)	6.7 (107)	5.3 (85)	1.63 (218)	46	1.7 : 1	A	3.1	15 (381)	7.4	89.4	96.9	1.72	0.084
	13 (208)	6.7 (107)	6.3 (101)	1.67 (224)	40	1.33 : 1	A	3.7	15 (381)	7.4	88.9	96.3	1.69	0.086
	15 (240)	6.7 (107)	8.3 (133)	1.74 (233)	35	0.95 : 1	A	4.9	15 (381)	7.4	87.7	95.1	1.63	0.090
	20 (320)	6.7 (107)	13.3 (213)	1.93 (258)	30	0.60 : 1	A	7.9	12 (305)	7.4	84.7	92.1	1.48	0.101
	30 (481)	6.7 (107)	23.3 (373)	2.31 (285)	N/A	N/A	B	13.8	12 (305)	7.4	78.8	86.2	1.22	0.122
	40 (641)	6.7 (107)	33.3 (533)	2.70 (362)	N/A	N/A	B	19.9	12 (305)	7.4	72.8	80.2	1.01	0.143
Heavier	50 (801)	6.7 (107)	43.3 (694)	3.08 (412)	N/A	N/A	B	25.7	12 (305)	7.4	66.9	74.3	0.84	0.163

(1) Values in the table may be interpolated

(2) Water mixed with subsoil equals clay slip

(3) Subsoil Testing Methods per 2015 IRC Appendix R Commentary (also upcoming in 2018 version...)

A. Lab test for percent of clay, sand and silt via hydrometer method

B. Ribbon test or the Figure 3 Ball Test in the Appendix of ASTM E2392/E2392M

(4) Trace amounts of organic materials are acceptable

(5) Uses 168 pcf for subsoil specific gravity (2.7 g/cc)

(6) Uses 90 pcf for straw specific 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.

CREDIT: DOUGLAS PITINGSRUD AND STRAWCLAY.ORG

resistance of R-1.69 per inch. A 12-inch (30 cm) thick wall with this density will yield an insulation value of R-20. At a 15-inch (38 cm) wall thickness, the R-value would be 25.4.

More information on R-value is provided in Chapter 4, Building Science Notes.

Prior to commencing the LSC wall infill, it is important to figure out what quantities of clay are needed to achieve the wall density you are looking for.

Example: 13 pcf/R-1.69 per inch Wall Density Formula

- 30 lbs of straw (13.6 kg)
- 28 lbs of subsoil (12.7 kg) with minimum 40% clay content
- 58.4 lbs of water (7 gallons or 26.5 liters)

Creating Test Blocks to Assess LSC Mix Density

Build a minimum of three boxes that have one cubic foot in their interior. Use screws to put it together on at least one side, so you can remove a side of the box to assess compaction and remove the sample.

Using gallon buckets or a similar scalable vessel, and starting with the slip formula above for an optimal mix of 13 lbs/ft^3, make some test batches. If you are using site subsoil with an unknown percentage of clay instead of bagged clay, then make a number of batches using different amounts of subsoil and ranging from a heavy slip to very light slip, then mix each of the slips with 6.7 pounds of straw, and tamp the LSC into the forms. Three forms can give a very good range.

Label your forms, so you'll remember which mix has which amount of subsoil. Remove one side of the form after tamping to make sure compaction is suitable. Remove the straw clay sample and let dry. Expedite this process with heat and air movement (sun is great too, but protect from rain) to dry the samples. Once dry, you can weigh the samples to find the achieved densities.

You can then evaluate both the variability of the density of the mix based on the amount of subsoil in each sample and the variability of the density of the sample related to the level of tamping.

An optimal mix will yield a dry sample of 13 lbs/ft^3, which is R-1.69 per inch. If you have a lighter sample, you will have a higher R-value, but you may be losing the necessary binder by having too little subsoil in your slip or insufficient tamping. If you have a heavier sample, then you will have a lower R-value, which means that the subsoil quantity is higher than optimal and/or you are compacting the mixture too much. With testing and practice, it is possible to achieve an optimal density of mix and to get a feel for the correct level of tamping. Other desired densities and R-values can be achieved using the same process and varying the amount of slip and compaction.

Soundproofing

No testing has been done yet on the acoustic qualities of an LSC wall system. However, Franz Volhard calculates sound reduction by "using the values of other massive building elements with a corresponding mass per unit area." He adds: "Earth building materials add mass to a timber frame structure and it is possible to achieve good sound insulation using a simple, single-skin construction. Compared with other massive wall infill materials — all earth materials and light earth in particular are softer and more elastic. Sound vibrations are softened and attenuated. As a heavy but soft building material, earth therefore offers excellent sound insulating properties." (Franz Volhard, *Light Earth Building*, 2016, pg. 227–228)

Given the variability in density, the potential for split-stud construction and the variety of skins that are compatible with light straw clay, the potential for sound absorption is high.