Technical Series

Indigenous Building Materials: An Overview

enter for Resourceful Building Technology

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Indigenous Building Materials: An Overview

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Center for Resourceful Building Technology

Fostering Efficient Resource Use.

The Center for Resourceful Building Technology

The Center for Resourceful Building Technology (CRBT) is a non-profit organization whose purpose is to educate the public on a variety of issues relating to housing and the environment, with particular emphasis on innovative building materials and technologies which place less stress on regional and global ecosystems.

CRBT strives to identify and encourage the use of resource efficient building materials and design elements that exemplify:

- Efficient use of limited resources
- Demonstrated recyclability or reusability
- Energy efficiency in manufacture and use

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Introduction to Indigenous Building

Building with Indigenous Materials

Homes built from indigenous materials are unique dwellings, not cookie cutter productions. They are individual representations of a region, climate, and culture. At the same time they have the potential to be comfortable, functional, durable, and energy efficient and to satisfy modern standards of living. They can make use of common materials that people formerly considered scrap or waste, or didn't think of as building materials at all. Indigenous building promotes creativity and experimentation on the part of builders while helping to reduce the demand on scarce natural resources.

Using indigenous materials can aid in the production of housing that is both monetarily and environmentally affordable. Indigenous materials not only have the potential to save the owner or builder money through reduced materials costs, but can also create jobs for under-employed or under-skilled workers. One of the attractions of indigenous methods of building is that they afford the owners an opportunity to actively participate in the construction of their own building, even if those owners have limited construction experience.

Remember to objectively explore all of the possible materials and construction methods for your project. Choose a building method that will well represent your financial, functional and aesthetic needs, as well as your timeline. Seek to build not a mere shelter, but an architectural example to educate and inspire all those who experience your creation.

Why build with indigenous materials?

Millions of people worldwide live in houses made from minimally processed local construction materials such as earth, straw, and native wood. Indigenous materials are those native to a building site or its surrounding region, and indigenous methods are the particular applications of those materials, as developed to suit a specific climate and culture. Indigenous materials are generally relatively expensive, due to their abundance and the minimal costs incurred in transporting them to the building site. More and more people throughout the United States are considering the use of indigenous building materials in home construction because of their potential to reduce the materials costs and environmental impact of building.

Most homes built in North America today, regardless of local material availability and climate, utilize a "stick-frame" construction method, comprised of wood stud-wall and wood roof and floor framing. As dimensional lumber prices are rising and the dependability of wood quality is declining, however, alternatives to wood framing are becoming increasingly desirable for both home buyers and builders. Metal framing members are increasingly used as a substitute for wood studs, joists and rafters in residential construction. Some builders have turned to types of construction that don't depend on dimensional lumber framing, such as structural insulated panels. Not only stick framed dwellings, but also other wood structures such as timber frame and log homes are dramatically rising in cost as the supply of straight, large-diameter trees is declining.

The continued use of wood-intensive construction methods is becoming more and more impractical and costly. Large trees from mature forests are now scarce and small, fast growing trees, although plentiful in supply, do not provide the type of lumber to which builders have become accustomed. Engineered wood products such as wood I-joists, plywood and glue laminated beams provide some construction substitutes for large dimension lumber. Though these engineered wood products use wood fiber efficiently and so extend the timber resource, their manufacture consumes significantly more energy than the production of traditional building materials.

Indigenous materials, then, offer builders a means of constructing a dwelling that is of less energy and resource impact on the earth, that is affordable, and that allows even the owner with minimal construction skills to be an active participant in the building process.

Why doesn't everyone build with indigenous materials?

Indigenous building materials aren't ideal for everyone in every situation. Owners considering the use of indigenous methods should be aware that most construction with indigenous materials is highly labor intensive. This makes necessary either a large construction crew with high labor expenses or, for the independent do-it-yourselfer, a long span of time. Also, the knowledge base for some of the unfamiliar techniques and materials has been largely unpublished, requiring research and experimentation on the part of the builder. Adapting the building techniques to specific sites and materials also takes some time and patience. It can be difficult to find architects, engineers and contractors willing to work with unfamiliar materials. In addition, finding lending institutions willing to finance an unconventional structure can be a challenge, as can winning approval from building inspectors.

Indigenous material structures may require more maintenance than conventional buildings. Indigenous buildings, particularly those with an adobe finish, must be protected from the effects of weather and may need annual repair or refinishing of the surfacing material. If properly cared for, however, indigenous buildings can outlast typical stick-frame buildings. Straw bale buildings almost 100 years old are still standing and in use.

Earthen buildings can last hundreds, and even thousands, of years as demonstrated by buildings in the Middle East and the pueblo dwellings of the American Southwest.

Since indigenous construction methods evolved to suit particular regions and conditions, they may not adapt well to other locations and climates. Some methods have inherent design limitations that may make them unsuitable for desired applications. Some sites simply don't have suitable building material, and importing it from elsewhere negates many of the advantages of this type of building. Indigenous construction isn't the perfect solution for every owner and builder, but there are many indigenous materials and techniques, and one or another will be appropriate for a variety of climates and locations, if not for all projects.

Types of indigenous materials

The same materials are not indigenous to every geographic area. The semi-arid woodlands of Montana provide different building opportunities than the deserts of Arizona, the palmetto plains of Florida or downtown Chicago. Some examples of indigenous building techniques that are currently or have been historically used in parts of the temperate United States include:

- adobe walls
- sod walls and roofs
- strawbale walls and ceilings
- cob walls
- straw/clay walls and roof insulation
- rammed earth walls and foundations
- cordwood masonry walls
- stone walls and foundations
- log frames and walls
- salvaged used building materials

These techniques are sometimes applied as well in interior walls, floors, decorative or landscaping applications.

Many people choose to build outbuildings, barns, storage sheds, or workshops from indigenous materials. Such trial structures give builders a chance to experiment with new techniques before constructing a house or other large structure. In addition, outbuildings can be especially inexpensive owner-built applications of indigenous building methods. Since outbuildings usually don't have to meet the rigid building codes of residential structures, they are also a means of demonstrating indigenous techniques in code-governed areas.

Mining the built environment

Some of the indigenous building types mentioned here are most appropriate for rural settings where raw materials such as agricultural byproducts or scrap wood are plentiful. On the other hand, earthen constructions can frequently use the earth of excavation from the building site, whether that site is rural or urban.

For many Americans, the surrounding environment consists largely of buildings. These should not be ruled out as a source of construction materials. These buildings are plentiful and accessible, providing a local source of structural and finish components that can be salvaged and reused. Remodeling and demolition projects can supply the urban or suburban builder with building elements including windows, doors, insulation, roofing materials, lighting and plumbing fixtures, structural steel, dimensional and finish lumber, wood or tile flooring, stone, brick, block and broken concrete. Reusing these materials has many of the advantages of using indigenous materials: processing and transportation costs are low, supplies are abundant, and purchase costs can be affordable. In addition, reuse prevents these valuable resources from becoming problem waste in landfills.

Resource Efficiency

The relative resource efficiency of indigenous construction methods must be evaluated before selecting materials to complete a building project. "Resource efficient" materials and methods exemplify:

- efficient use of limited natural resources
- demonstrated recyclability and/or renewability
- reduction of the energy used to build and operate buildings

The use of indigenous building methods has the potential to cause less air, water and land pollution than the use of industrially processed building materials. Some applications of earth, mineral, and agricultural waste involve little additional processing energy. If local sources are used, transportation energy and resulting pollution are kept to a minimum.

Many indigenous building materials are minimally processed and do not contain chemical additives such as adhesives. This promotes good indoor air quality and safe and easy disposal of the building materials at the end of a building's lifetime. These resource efficient qualities of indigenous materials can be compromised, however, by the finishes, binders and additives combined with the indigenous materials in application. For example, cementitious stucco or mortar is not indigenous to most areas and finishes such as paints, varnishes and sealants can be detrimental to indoor air quality, particularly if the structure does not have an adequate ventilation system.

For some building techniques, such as adobe or cordwood construction, the building site itself can provide much of the material needed. This allows the owner to directly correlate the environmental costs of building with the benefits. Seeing the immediate effects of resource extraction in their own yard helps owners recognize more of the consequences of construction.

When evaluating a material for resource efficiency, it is essential to consider the powers that can affect the site: fires, floods, hurricanes, tornadoes, earthquakes, rain, snow, freeze-thaw cycles, groundwater capillary action, mildew and rot, insects and soil movement. Another vital consideration is the local climate. Some types of indigenous building cannot provide the insulation value desired and required of today's housing without modification of the building method and the addition of supplemental insulation. Earthen techniques, for example, are indigenous to almost any region, but designing an earth wall with an R-value suitable for a northern climate can be a challenge. Furthermore, if the site is susceptible to flooding or seismic action, an unreinforced earthen structure can collapse. Building a house with one- fourth the environmental impact of a conventional dwelling does little good if the structure has less than one-fourth the lifespan due to poor design considerations and failure to adapt the building to its site.

For some applications and climates the strategic use of non-indigenous material can complement indigenous components to extend the lifetime or reduce the maintenance of a structure. Cement, for example, is extremely durable and provides stability to a structure. Many building codes require the use of cement within the foundation or structure of a building to provide protection against lateral loads and ground instability. Cementitious stucco can also protect an indigenous structure from the effects of weather, and cementitious mortar can bind the components of a stone, cordwood or even strawbale wall.

Builders should be careful to scrutinize the contribution of non-indigenous components to the overall resource and energy cost of the structure. As non-indigenous materials are added to a structure, the resource efficiency of the structure can be subtly but seriously compromised. Cement, for example, embodies almost 8,000,000 BTUs per ton consumed in manufacturing as compared to the negligible quantity of energy embodied the native rock or wood that it binds or supports. The fuels burned in the production of cement account for approximately 8% of all carbon dioxide emissions worldwide.

Traditional Indigenous Building

Many indigenous building methods of today were inspired by architecture used by native Americans since prehistory. Both nomadic shelter and monumental pre-Columbian architecture reveal ingenious solutions to shelter and social needs that evolved with the technology level and comfort expectations of society. In most cases these traditional ways of building demonstrate minimal energy and material inputs. There are a number of historical references available that document these fascinating ancient ways of building.

Other indigenous building methods used today are refinements of centuries-old technologies from Europe, Asia, Africa and the Middle East. Traditional building methods from any locale can offer inspiration and instruction to indigenous builders of today.

Indigenous Wall Systems

Adobe

This well-known construction technique uses sun-dried blocks of mixed clay, sand, gravel and straw to build thick masonry walls. Although in the United States adobe building is most often used in the Southwest, soils in many areas are suitable for use in adobe brick. Often soil from the building site itself can be used, and tempered with the addition of other materials as necessary. Because of the use of highly available earth and the use of solar energy (sunshine) to cure the blocks, adobe construction epitomizes resource efficiency in construction, if not in operation.

Adobe buildings need a relatively high foundation to protect them from soil and ground-level moisture. Likewise, a good roof with overhangs can help protect the finished wall from weather — a necessity in less-arid climate zones. Adobe finishes require vigilant yearly maintenance to counteract the effects of weathering, although an asphalt emulsion or other additives can be used in the stucco finish to reduce the amount of weathering and general wear that adobe walls experience.

In addition to surface weatherproofing, adobe walls require additional insulation or design modifications for cold climates. Although adobe walls are massive, with a 12" minimum thickness for load bearing walls, their R-value is low. The thermal mass will help to moderate the building's temperature swings, but in cold climates a high R-value (resistance to heat flow) is a necessary complement to thermal mass in order to provide comfort and energy efficiency. Deeper adobe blocks or double block walls afford somewhat greater thermal efficiency. With design for maximum utilization of passive solar gain and thermal storage, adobe alone may be able to withstand cold weather conditions in zones with moderate winter sunshine, but it is often necessary to supplement the adobe wall with a form of insulation to meet the minimum R-value requirements of individual states.

Ideal soil for adobe building contains both coarse and fine sand for strength, as well as silt and clay for binders. Although a wide range of soils can be used successfully in the manufacture of adobe, soil that is too high in clay can cause the bricks to crack, and may require the addition of sand, straw or other "tempering" materials in order to ensure strong bricks. Soils that contain types of clay that swell excessively in the presence of moisture can be unsuitable for use in adobes or may be usable with the addition of more sand and another variety of clay. Soil with too high of a sand content won't bond well and the bricks crumble easily.

Individual components of the soil at a site can be measured by mixing a soil sample into a glass jar of water, and letting it soak for an hour. After this time the jar should be shaken, and then allowed to sit while the soil settles out. The proportions of the settled layers can then be analyzed. Gravel settles to the bottom first, followed by sand. The next layer will be silt, and the top layer of sediment is clay. Organic material remains suspended in the water, or floats on top. An ideal adobe soil contains approximately: 55% of a fine and coarse sand mixture, 30% silt and 15% clay. After evaluating the soil components, test bricks should be made, so that soil performance can be assessed. There are a number of other tests to determine soil properties, and local agricultural extension offices or Soil Conservation Service offices will be able to assist in identifying soil types.

In order to fashion bricks, adobe soil is first mixed with water on site, and sand or straw added as necessary. A very wet mix will be easier to combine thoroughly, but will also take longer to dry, and is more susceptible to cracking. The wet adobe mixture is transferred into wooden forms or molds lying on level ground. Bricks can be formed in a number of shapes and sizes, depending on their intended use, available forms and the dictates of local builder traditions. Common sizes made in the Southwest are 4"x 8"x12" for single story building, and 4"x10"x14" for two story structure, both of which comply with the minimum standard depth for load bearing walls.

Brick forms can be created in a number of different styles, from single-brick forms filled with a shovel to large multiple-brick formworks designed to be filled by a front-end loader. Molds are removed when the brick is dry enough to support itself, and the bricks are left spread out to air dry, or cure. When bricks have dried enough to handle, they are turned on edge. Later, bricks are stacked and protected from rain to complete the curing and drying process. Adobe bricks can also be kiln fired, but this produces bricks susceptible to freeze-thaw degradation, while adding another step and expense to the process. Adobe firing is not recommended for most North American climates.

The cured adobe bricks are set onto a wall using about 3/4" adobe mud mortar made of the same materials as the bricks, or a lime mortar, or gypsum mortar. Interior walls are usually one brick wide. Multiple brick configurations are often used for external load-bearing walls. Reinforcing rod is frequently used in load bearing walls to tie the roof and foundation systems together, and may run the full height of the wall. A wooden top plate or reinforced concrete bond beam can be added to spread the roof load and stabilize the wall, and is usually required to meet code specifications. The finished wall is then covered with a smooth coat of adobe that functions as a stucco.

Adobe building is a proven success, as demonstrated by buildings hundreds of years old that are still in use today, both in the southwestern United States and around the world. Proper maintenance is necessary to ensure the longevity of adobe structures, particularly when building in regions that do not have a hot and arid climate. Alterations to standard designs and upkeep schedules may be needed to ensure the building's longevity and comfort in wetter climates. Check with local building codes to determine regulations governing adobe building in individual communities and counties.

Sod

Another type of earthen block used for walls is the sod block. This style of building dates from the homesteading era on the Great Plains, although it shows influences of both the Native American earth lodges and the earth buildings of the plains immigrants' European homelands.

On the nearly treeless prairies, sod made a logical building material. Sod strips were cut from the prairie with a special cutting plow, and these strips were then divided into blocks for building. The dense mat of prairie grass roots held the uncured block together. Sod blocks were stacked to form thick walls. In some cases the walls were then plastered, adding to their weather-resistance and durability. In many cases sod walls were built above and around an excavation or partial "dug-out," in order to take advantage of earth sheltering, a very significant contributor to thermal stability.

Although sod building techniques are little used today, some sod houses built over 50 years ago are still inhabited, illustrating the worth of good designs and careful maintenance. The early sod houses may well have inspired the development of another type of indigenous building, the strawbale house, as the later bale houses are almost identical in design, with a straightforward substitution of bales for sod.

If sod houses were to be built today, they would probably be stuccoed and plastered structures with an additional insulation supplementing the sod wall to meet modern expectations of appearance and thermal performance. In deep soils, limited amounts of sod could be extracted from the land in a manner that would not necessarily increase erosion or deplete soils. Anyone wishing to build a sod house today can study available historical accounts of sod houses and reference modern straw bale building texts.

Strawbale

Although they may sound unusual, walls built from bales are not a new idea. Strawbale houses have been standing in Nebraska for nearly 100 years. Early pioneers in that nearly treeless area could not easily build conventional log or wood-framed houses, and sandy soil made sod houses impractical. The "Nebraska-style" strawbale wall that evolved in that region is a load-bearing wall in which staggered courses of bales, rather than wood framing members, provide structural strength and bear the weight of the roof, as well as comprise the insulation of the wall.

Today strawbale construction often utilizes bales as insulative infill in a post and beam or timberframe structural wall. The framing members bear the weight of the roof and provide wall structure, while straw bales constitute the insulation and eliminate the need for exterior wall sheathing. In small and simple structures load-bearing walls without a wood frame are still used frequently.

The use of straw to reduce the consumption of wood in construction demonstrates several potential advantages. Straw is an annually renewable waste product of grain production. Using straw for insulation avoids the resource and energy consumption that the production of most modern insulations demands. Often, baling straw avoids disposal by burning in the field, a common practice which adds CO_2 and particulates to the atmosphere. Returning straw to the soil by plowing it under is not often practiced, as the direct economic costs to the farmer of doing so generally outweigh the immediate fertilization benefits.

Most available baled straw is a product of industrial agriculture, and its categorization as a "waste" product is an outgrowth of the economic and cultural assumptions that drive present agricultural practice. Unceasing yearly extraction of straw from the field has a destructive cumulative impact on the soil; reducing its tilth, resistance to erosion and general health. Furthermore, almost all straw produced today comes from grain crop monocultures which require infusions of fossil fuels, pesticides and fertilizers. The impact of extracting straw from the field for use in building can be reduced by choosing producers who practice crop rotation and organic pest control.

In strawbale construction, a platform or foundation at least as wide as the bale is needed. The bales are tied to the foundation by a series of rebar or steel rod stakes or pins embedded in the foundation, or a continuous allthread rod that spans from the foundation to the wall top plate. If the design has or needs a basement, the foundation can be built at a standard 8" or 6" thickness to save materials, and the bales will then rest on the floor platform which spans the foundation. In this configuration it is more difficult to tie the bales securely to the foundation, but it is absolutely essential to devise a system for ensuring the structural stability of the wall.

Standard size 18" to 24" wide bales act as building blocks. The 60- to 100- pound densely-compacted tight bales are dry stacked to form a wall. The wall is generally stabilized against lateral movement by placing the bottom course of bales over pins projecting up from the foundation. Load bearing walls use short bamboo, wood or rebar pins driven downward through the bales as the wall is being raised to tie the courses together and ensure stability. Each bale needs at least two pins driven in at an angle securing it to the courses below, to provide a structurally sound wall.

A wooden top plate or concrete bond beam is used to span the top of load bearing walls. This creates a more stable monolithic wall structure and ties the roofing system into the bales. The load-bearing wall is often secured to the foundation by the compression of a cable and turnbuckle system that passes over the top plate of the wall and attaches to both sides of the foundation. The top plate and foundation may also be joined by a continuous allthread rod that can be tightened to keep the bale wall under compression as the bales settle.

Bale infill wall systems usually depend on an exterior layer of tightly stretched expanded metal lath or chicken wire to guide construction and keep walls straight and plumb. These smooth, straight walls oftentimes produce a tidier appearance than the load bearing walls. Since post and beam structures utilize bales primarily for their insulative value, extensive pinning and a bale-wide top plate are not necessary. although securing the bales to the foundation for lateral stability is still essential. When bale infill is combined with a wood or metal structural system there is also a lessened need for heavy framing of load-bearing windows and doors. Consequently, a post and beam structure can actually use less lumber than the "woodless" load bearing wall filled with framed window and door openings and capped by a wood top plate.

A percentage of bales will need to be notched and trimmed to fit within framing dimensions and around window and door openings. Chainsaws provide a useful bale cutting tool, but hand saws work also. Caution must be taken to avoid cutting the bale ties, which will result in the decompression of the bale. When less-than-full-length bales are required, a bale is "stitched" with a specially made bale needle to allow retying of the baling twine, and the bale is then split to the needed length.

Dense, dry bales are important for a strong, well-insulated wall. Loose bales are hard to handle and can result in substantial and uneven amounts of settling. If the wall is load-bearing, the structure must be allowed to settle under the completed roof weight before the stucco is applied. This settling process may take weeks, depending on climatic conditions and bale density. Excessive settling can cause problems with window and door installation, and can complicate the construction of interior partition walls. Dense bales should be selected to reduce the potential for settling. In a framed wall with strawbale infill, the settling time is virtually eliminated, since the strawbales bear only their own weight.

Strawbale buildings can be functional, economical, and resource efficient. A finished wall of tightly stacked strawbales covered with stucco can achieve insulative values as high as R-50. Strawbale can be an economical construction method and can create a thermally efficient house. The high R-values will help to keep a building warm in the winter and cool in the summer, reducing energy costs.

In addition, plastered walls are very fire resistant. The plaster enhances the natural fire resistance of bales provided by the high density of straw within the wall and the silica content of the straw. The finished wall is also pest resistant, and if protected from moisture can retain its structural integrity for decades.

Straw bale buildings have been built with non-professional labor for a fraction of the building cost of conventional professional stick framing. Custom straw bale buildings can also be more costly than average conventional construction. As with all indigenous building, total costs will depend on labor skill level and the amount of outside labor employed, specifications and detailing, materials choices and design variations. The wall system generally comprises only 20% of the overall cost of a structure, so to achieve substantial cost savings strawbale walls must be complemented by cost effective roofing, foundation, interior and exterior finishes, and mechanical systems.

Cob and related systems

Certain old European methods of building, cob, leichtembau and bourrine, use loose straw and clay mixtures. The clay-coated straw mix is hand-molded to shape free form walls or rammed within temporary or slip forms. These straw and clay walls have been used for centuries to infill post and beam structures or to make massive monolithic load bearing walls.

Cob construction, refined in the western counties of England, combines a large proportion of clay soil with a smaller amount of straw which functions as fiber reinforcement and stabilizes the undried mass. Soil for cob walls should contain from 10 to 30% clay, but not more, as shrinking of drying clay will cause the wall to crack excessively. Straw fibers are left long to add body and to distribute hairline drying cracks in the clay. The heavy clay/straw mixture is rolled into bundles (cobs). These clumps act as a means of transporting and supporting the earth until it dries. The mud-dipped bundles are stacked alongside or on top of one another to form layers that can be up to 2.5' thick and 2' high, tapering in towards the top of the wall. Each course of cob is allowed to dry before the next layer of material is added. Cob construction is slow and labor intensive, but can produce a rustically beautiful and sturdy product.

Other straw/clay methods such as leichtembau use a formwork to guide wall formation and commonly depend on a post and beam structural system. The forms produce straight walls but require additional material and equipment during the construction process. Formwork is temporarily fastened with clamps to the structural uprights. Forms similar to concrete formwork, up to 12" deep, are filled with straw that has been coated with clay slip or slurry. The coated straw is then tamped down within the forms using wooden mallets or pneumatic equipment. Once a layer has been tamped, the formwork is moved up or along the wall and another "lift" is tamped into place. The resulting mostly-straw wall is much more insulative than the walls that are mostly clay.

Straw/clay building methods can produce strong and stable walls. A roofing system can be set directly into the top layer without any additional support. Modern building codes often require structural reinforcement within a wall, either with rebar or cement, and at the very least call for a top bond beam to ensure structural stability. In a post and beam system, the straw/clay infill can be reinforced with a horizontal bar or tension cable that stretches between structural members, reducing the amount of deflection from lateral loads. Load bearing methods are not recommended for use on unstable ground, as structural cracking can occur. Although well-built straw/clay buildings have been standing for hundreds of years, without proper construction and maintenance straw/clay structures can weaken and potentially collapse.

Cob and other straw/clay construction methods can be suitable for almost any region. To ensure longevity, straw/clay walls require a high foundation to protect them from soil moisture, and large overhangs to protect them from the effects of weather. Stucco treatments can also improve the exterior weather resistance. The building's interior is kept comfortable by the thick walls, providing adequate insulation and temperature moderation through thermal storage mass, ideal for passive solar designs.

Rammed Earth

Rammed earth walls utilize soil containing sand, clay, silt and small gravel, similar to the soil used in adobe. To create a rammed earth wall, six- to eight-inch thick layers of slightly dampened soil are tamped, or rammed, inside a form in place on the wall. Once a layer has been tamped, another layer can be added and tamped. The elimination of a drying or curing period allows individual walls and entire small structures to be raised in a matter of days using pneumatic tampers. Once the formwork is removed, the wall cures for several months and a protective finish coat is added. The end product is something like soft sedimentary rock.

Rammed earth walls have been left without a finish in arid climates, and can survive with little maintenance; however, structural and weathering concerns are valid. The site must be well drained and stable, and the roof and foundation systems must be protective. Most climates will require at least one protective cementitious layer of stucco. Installing windows and doors requires careful consideration as difficulties may occur due to the wall thickness and surface vulnerability to flowing water. Exterior rammed earth walls are massive, usually with a 2-3 foot thickness that provides thermal mass and stability. Bond or collar beams and reinforcing rods are required to provide reinforcement and stability to the wall.

Rammed earth is labor intensive but if the tamping process is mechanized can take less time to erect than blocks. Some builders provide a skilled crew to erect rammed earth buildings. The cost of labor for the crew, or the cost of the equipment used in mechanized rammed earth processes, can make this method of building one of the most expensive of the indigenous technologies.

New twists on rammed earth construction involve the addition of additives such as cement, to further stabilize the soil used. Mechanical applicators are also being used by Rammed Earth Works in California to spray an earth and cement mix onto one-sided forms.

Similar to the rammed earth buildings "Earthships", developed in New Mexico, utilize salvaged tires as permanent wall formwork, eliminating the use of temporary forms. The tires ensure that the wall will not shift or crack because each tire is filled with earth and tamped as an individual unit. The filled tires are staggered like blocks to form a wall reinforced with rebar and a bond beam. The Earthship method of construction utilizes a stucco-type finish. Additional amounts of stucco, along with crushed aluminum cans or rocks as fill, are used to smooth out the niches between tires.

The Earthship method utilizes cast-off tires, which have historically been a problematic waste. It also uses aluminum cans set in adobe mortar as blocks in interior walls. Both tires and cans are extremely high in resource and energy value and can be recycled from their present form, which reduces the overall resource efficiency of this building method.

Earth can also be rammed into blocks using a mechanical press. Compressed block presses can be either hand-powered or motorized. There are several companies that rent or sell large block machines that can turn out as many as 600 blocks per hour. Larger machines can be expensive, but require only one person to operate them, saving on labor costs and time expenditure. Some builders will rent earth block machines by the hour, to produce block for individual projects. Smaller hand presses and simple machines are less expensive and more accessible for single home endeavors, but will require more block pressing time and some curing time.

Compressed earth blocks are similar to adobe blocks in appearance, use, and performance. Unlike adobe, the rammed earth blocks contain only soil and possibly a cement stabilizer. On-site soils are often suitable for making block, although a high organic content can be problematic and proportions of sand and clay should be evaluated. Different machines or presses require different soil moisture levels, and accordingly the curing time for the blocks produced can range from literally no time to as long as it takes adobe blocks to cure.

Stucco Finishes

Adobe, strawbale, straw/clay, and rammed earth walls can all be finished inside and out with plaster or stucco coatings. Finishes can range from an interior gypsum plaster to a stable cementitious stucco to an earthen adobe stucco. Indigenous builders should be aware that plaster and stucco are expensive finishes that can add considerable cost to indigenous construction. Although an unstabilized mud adobe finish requires substantially more maintenance than stabilized alternatives, it uses only natural materials and costs less than cement-based finishes. Adobe stucco can be stabilized with small percentages of asphalt emulsion or portland cement.

Most stucco finishes consist of three coats; an initial "scratch coat" that can be applied thickly to the uneven wall surface and allowed to crack, a smoother "brown coat" which is used to float out surface variations, and a thin smooth "finish coat". Stucco of any kind is generally applied onto a lath or reinforcing chicken wire mesh for ease of application, surface durability, and longevity. The scratch and brown coats of non-cementitious adobe stuccos generally need to be reinforced with fibers; straw, hair, sawdust, or ashes can be used. The finish coat, if not sealed with an additive such as asphalt, will require yearly maintenance.

Cementitious stucco finishes are durable and often can be applied with unskilled labor, inexpensive tools, and indigenous materials. A new generation of acrylic stuccos offers extremely low maintenance. The prime advantage of stucco finishes for some, though, is their aesthetic versatility. Curved walls and connections, reliefs, and insets make for interesting, personalized wall surfaces. Marbles, tiles, glass pieces, bones, and stones can be set into the surface to form colorful mosaics. Many stuccos have an integral color pigment that eliminates the need for surface painting.

Cordwood masonry

A different type of indigenous building technique, cordwood masonry or stackwood construction, uses cut-to-length pieces of unmilled wood similar to firewood as building blocks. The small logs are set into a masonry mortar with cut ends facing the interior and exterior of the building. Cordwood walls can be highly decorative, and offer an opportunity to use logs too short, small or irregular to be milled into traditional lumber. Cordwood buildings in Europe have existed for nearly 1000 years, and the building style was commonly used in Eastern Canada and northern Wisconsin at the end of the 19th century.

Cordwood walls can be used in a post and beam framework in seismic areas, and elsewhere as a load-supporting straight or curved wall, or within a log-end framework featuring structurally built up corners. Log ends 6"-24" long can be used in cordwood masonry, creating walls as wide as the length of the wood used. Wider walls are more thermally efficient but use more material. Mortar can be laid only at the ends of each wood piece, leaving an airspace within the wall which increases the insulative capabilities of the wall by reducing thermal bridging, and saves mortar as well. The airspace can be filled with sawdust, straw, or other insulative materials, or simply left open. It is also possible to achieve greater thermal efficiency in an exterior stackwood wall by modifying the building design to create a double-wall system that sandwiches insulation between two thinner cordwood walls. The double walls are tied together by incorporating pieces of wood that span both walls at periodic intervals in the construction. The double wall system is most appropriate for locations where an abundance of wood is available. Other, more insulative construction methods are at to be more resource and energy efficient in extreme climates.

Mixing wood and cement is generally avoided in the construction business because of their different moisture content, but taking proper precautions can help to prevent problems bonding the two materials. The wood used should be dry, so that is does not shrink away from the set masonry as it ages. The wood should not be too dry, however, or it will draw moisture from the mortar, causing it to crack or fail to set up, thereby weakening the wall. Including wet sawdust in the mortar helps equalize the moisture content across the wall, promoting slow, even drying that prevents the mortar from cracking. Wood used in cordwood construction should be sound. Within the wall wood is protected from rot by lime in the mortar that separates each piece. A damp course to separate the wall from groundwater capillary action is extremely important.

Cordwood masonry normally uses a cement-based, non-indigenous mortar, but it is possible to utilize locally available materials in the mortar mix. Sand, sawdust, lime and Portland cement create a durable, and weather resistant surface. Adobe may also serve as a suitable mortar, yet should be used with caution on exterior walls. The smaller the amount of cement in the mortar, the greater the need for large overhangs, thick walls and a high foundation.

Cordwood is well-suited to non-load bearing interior walls. Cement mortar can have an undesirable gray appearance, but is easily covered with an interior finish coat of adobe or gypsum stucco. The addition of bones, rocks or bottles within the wall creates unique and decorative variations for interior partitions.

Stone

Although not very insulative, native stone can provide extreme structural capabilities and longevity of materials and finished structure. Most stone used for construction is set in cementitious mortar. Stone can provide foundations and structural elements such as arches for infill walls of indigenous material, thus reducing the need for concrete and wood.

Like adobe, stone has a passive solar gain capacity due to its thermal mass which allows a stone structure to moderate interior temperatures. Stone itself has a low R-value and high conductivity, so should be used judiciously on exterior walls where insulation is desirable.

Depending on the desired effect, stone can be collected or cut. Collected native stone is economical and requires no processing— perfect for use in landscaping, for retaining walls and durable patios. Small, river washed stone, set in a base mortar, provides a wonderfully textured wall or floor surface. Cut stone, even when locally produced, requires a significant amount of processing which increases the cost and the amount of energy spent. In many areas permits to quarry or gather stone must be obtained.

Log

One of the most familiar types of indigenous building is log construction. Much information is available in libraries and bookstores on building techniques. Although the log housing market is now dominated by companies that build custom homes from large logs, it is possible to create an affordable house using native logs.

Through careful management of forest land, it is possible that enough trees can be sustainably harvested on a site for building. The builder should keep in mind that some tree species are better suited to log home construction than others. In general, log walls have a lower R-value than conventional stick-framed walls (depending upon the diameter of the logs used), are not fire resistant, and are subject to decay. As with other types of indigenous building, the longevity of a log structure can be increased by covering it with a good roof that has long overhangs to protect walls from weathering, periodically treating the wood with sealant, and using a high foundation that prevents moisture wicking and runoff damage.

Roofing Systems

Some of the indigenous materials used in wall systems, with a few alterations, can also be used overhead. Many applications employ indigenous materials as insulative infill for a traditionally structured roof, much like infilling a post and beam wall. While they do not necessarily conserve lumber, infill systems can eliminate, or lessen, the need for more highly processed materials, and may reduce the need for other types of roof insulation.

Poles

The indigenous, minimally processed substitute for dimensional lumber is poles or logs. If available, poles can be an economical and environmentally responsible use of wood. Poles usually require less labor and energy consumption than sawn lumber for production, but generally require more for installation. The potential savings is in wood fiber and transportation energy.

By leaving the cross section round, the wood is stronger and able to compensate for knots and holes. The retention of strength and elimination of dimensional waste allows the use of smaller diameter logs, often from less vigorous trees which are a common product of timber thinning operations.

Poles can be used to frame almost any conventional roofing system and can virtually eliminate the need for dimensionally sawn lumber in a post and beam structure. Typical joint connectors must be altered to compensate for the round pole. Otherwise the pole will have to be sawn flat at each connection which can decrease the structural integrity of the wood. Steel connector systems with round sockets are available for

90-degree, 45-degree and other angles of connection. Reference books on pole construction are readily available.

Earthen Roofing Systems

Beautiful domes and vaults can be built out of adobe block, compressed earth block and stone, although traditional sloped roofs are difficult to fabricate without utilizing spanning members. More detailed information is contained in some of the reference resources listed at the end of this paper. It should be noted that domes generally do not lend themselves to application of common roofing finishes and great attention needs to be given to the structural detail needed to create a water-proof layer on an earthen dome roof.

Sod earth finishes produce an unconventional looking roof, often flourishing with vegetation and blending the house into the landscape. Using earth as a roof finish provides only moderate insulation at the cost of considerable weight. An earth roof requires a waterproofing layer placed on top of the roof decking, underneath the sod. Next a rigid insulation layer is needed for most climates, and can be doubled for colder climates. After the insulation is cut to fit, straw is laid down to protect the insulation from a 2" layer of crushed stone, and then laid again on top of the stone. A 6"-12" layer of topsoil is then placed, planted, and allowed to develop naturally.

The soil layer provides a natural finish and eliminates the need for shingles. The soil carries moderate insulative value that reduces the amount of processed insulation needed, although some supplementary insulation is normally added. The earth roof holds snow in the winter, providing slight extra insulative advantages. Vegetated soil also acts as a sponge for rainfall, reducing the amount of backsplash and water flow.

Edge detailing is crucial for all earthen roofs, to avoid excessive weather damage and leakage. In addition, earthen roof systems are so heavy, particularly with a dead load of show, that they require massive structural roof reinforcement. This roof framing reinforcement can virtually negate any resource efficiency gains made by using an earthen roof in place of a processed finish roofing material.

Straw/Clay

Insulative straw/clay mixtures, as previously described, can be tamped between roof framing members with the ceiling decking serving as formwork. Extra caution should be taken to only lightly coat the straw with slurry. A heavy mixture can put excessive weight on the decking and may require so much drying time that decay may begin. Also, using a wet-applied material over drywall or other interior finishes that can be harmed by water can be problematic.

The straw/clay insulation is protected from outside water by a moisture barrier. The straw/clay must also be vented so that trapped moisture can escape to prevent mildew and decay. For thermal efficiency, it is important to completely fill all of the space between the rafters, leaving only the air channel above. The roof is then finished with conventional treatments.

Thatch

Where straw or reed are available, in the marshlands of Britain and North America, thatch provides a natural alternative to wood or metal roofing finishes. Reed and straw are both annually renewable and biodegradable. In tropical climates, palmetto leaves can also be used, but require different (often simpler) application techniques than traditional thatch.

Reed is applied in large bundles and held on by bars that run the perimeter of the roof. The thickness of thatch works doubly as a water barrier and a thermal insulator. Rainfall will not seep past the first 3-4" of reed. The thick layers of tiny air-filled tubes act as an insulative thermal mass, usually requiring no additional insulation.

The main drawbacks of thatch are its susceptibility to fire, insects, rodents and rot. Thatch distributors have developed fire retardant products that can be applied on the decking to prevent flame spread into the house. Fire retardant chemicals can also be used to impregnate the reed, but the treated reed will only be suitable for a landfill when discarded, and cannot be left to biodegrade.

Thatch offers beautiful aesthetic advantages, giving a sort of golden rolling hills effect to any structure. Thatch, unfortunately, is fairly expensive; a labor intensive process requiring experienced artisans and specialized tools.

Flooring Systems

Earth Floors

Stabilized earth floors provide an economical surface that can be used in conjunction with shallow foundations. The material used in earth floors consists of gravel, soil (sand, silt, and clay), and a finishing sealant such as linseed oil. If not on the building site, ingredients apart from the sealant can be found locally and transported without much energy or expenditure. The installation process requires only simple tools which can easily be made on site.

To effectively utilize an earthen floor, the building site must be well drained and stable to prevent water seepage, freeze/thaw, and cracking. With good drainage the floor should be resistant to freezing; however, if water does seep into the first layer of the floor, interior heat can moderate the ground temperature enough to prevent freezing. In cold moist climates a gravel base is needed for water protection, but can be reduced or eliminated in warm arid climates. An additional capillary break is strongly recommended.

Earthen floors lack the insulation desirable in cold climates, and can conduct heat out of the house. The most serious problem with this type of earthen floor construction is the lack of a radon venting mechanism, which can pose a particular threat in areas where radon occurrence is probable.

In order to construct an earth floor the topsoil and all organic matter must first be removed. The base is laid in a 6"-12" deep layer made up of 1"-3" diameter tamped stone, providing a bulk moisture barrier and a stable foundation. A screen of straw is then placed and tamped over the rock to prevent the soil from filling the air spaces. The soil makes up a 2" thick tamped subfloor that consists of 50% sand, clay and silt. A 2"-3" thick earth layer is then made of a clay slip and sand, spread over the subfloor and allowed to dry for 3-6 weeks. The earth layer can also be made of tamped earth, with no water added, but a higher clay content. The finish coat, consisting of a soil slurry, sand and oil, is then applied in a thin layer to smooth out the cracks in the rough earth floor. Expansion joints should be inlaid to guide cracks. To further prevent sporadic cracking, a lath grid or pattern can be made for the rough coat and finish coats, allowing small separation joints. The finish coat can be inset with wood, stone, or tile, or left by itself.

Stone Floors

Many regions have readily available stone that is suitable for flooring. Traditionally this stone is set in a cementitious mortar, but other methods are suitable for setting stone, that can reduce or eliminate the amount of cement normally required.

The earth floor mentioned above can serve as a base for a stone floor. Flat stone is laid as it is with mortar but is grouted with a clay slurry and sand mixture. The floor is then sealed with beeswax to protect the mortar and allow for easy maintenance.

Stone can also be laid without mortar, using only gravity to hold it in place. Large stone pieces, cut flat on one or both sides, are laid in a deep sandy soil layer. (Broken concrete pieces, or "urbanite," can also be used.) The gaps are then filled with pea gravel, which is plentiful in many river and creek beds.

Pea gravel used alone in a 3"-6" deep layer has been used to create an unusual yet comfortable flooring.

Foundations

Due to wet soil conditions, earthquakes, and insects, many areas of North America demand cement-based foundations. Not many indigenous materials can compare to the strength, longevity or stability offered by cement., whether it be in concrete block, poured concrete, or stone foundations with cementitious mortar.

Stone or rubble

Stone is the one indigenous foundation alternative that reduces the amount of cement used without compromising weatherproofing and longevity. Stone foundations may not be suitable for seismic zones but can be reinforced with steel bar for additional strength. Stones of almost any shape and size can be used, stacked like bricks, to create foundation walls or bond beams. Extremely flaky or crumbly stone should not be used. If stone is not locally available, old brick or urbanite can be used instead. Stone foundations, like concrete foundations, have a very low R-value.

Rammed Earth

Rammed earth and compressed earth block can only be used for foundations on extremely dry, stable ground, and are only suitable for earthen buildings. The foundation is constructed as an above-grade wall would be, but needs water proofing on the exterior surface. Concrete can be sprayed or applied by hand to the inside of the form, providing a protective layer. Rammed earth foundations are unstable alone and should be reinforced with rebar and small concrete footings.

Wooden Post/Pier

Wooden posts can be used in spot and pile foundations, usually proving an economical and resource efficient system in areas where wood is readily available. Treated post foundations are suitable for most soils, excluding the extremely wet and the termite infested. Posts can be buried alone in arid climates, but elsewhere are generally set into a tamped gravel or sand pit to protect the wood from constant water exposure.

In warmer climates, posts can be mechanically joined to a concrete footing, raising the entire structure above ground. Without ground contact, the posts are less vulnerable to rot, but any wooden foundation would have greater longevity if it were built from treated poles able to resist rot and insects.

Notes on Indigenous Building

A Word of Caution

Some indigenous building methods are very well understood and documented. For others, testing is still incomplete. Where testing does exist, code descriptions may not. It is important for engineers and architects and owner /builders to properly execute designs in order to provide for safe and durable indigenous buildings.

Indigenous buildings have a certain simplicity in their design and construction that seems to lead owner/ builders to rush into projects underprepared. No building project should be embarked upon without careful planning and structural engineering. The deceptive ease of application of indigenous building methods can result in dangerous under-engineering or sloppy construction of buildings. While properly constructed buildings may survive earthquakes, storms and years of general wear, poor design and careless construction can lead to unsound buildings that are candidates for structural catastrophe that could cause physical, as well as financial harm to the owners. Careful attention to principles of engineering as well as professional planning assistance, are highly advisable.

Codes, Insurance and Financing

Building code officials and banks in many areas are reluctant to approve unconventional types of construction. Adobe use in New Mexico and Arizona is a notable exception to this rule. Involving architects, engineers, and building code officials in a project from the beginning is a good way to cultivate a relationship that leads to approval for an indigenous building. In some locations, groups have scheduled tours of exemplary indigenous buildings for bank, insurance, and code officials, in order to tangibly demonstrate the practicality and durability of indigenous building. Becoming familiar with the codes and officials who enforce them in your area before starting a project can help to prevent stress, confusion and expense in the long run.

Disclaimer: The above information is intended for informational purposes only. All methods described herein should be evaluated by an engineer before their application.

Additional Information Sources

Adobe and Rammed Earth Buildings
by Paul G. McHenry
The University of Arizona Press
1230 N. Park Ave., Suite 102
Tucson, AZ 85719

Appropriate Building Materials:
A Catalog of Potential Solutions
by Roland Stulz and Kiran Mukerji
SKAT Publications
Vadianstrasse 42
Ch-9000 St. Gallen, Switzerland

"At Home With Mother Earth" (Video)
Feat of Clay
507 N. Plymouth Blvd.
Los Angeles, CA 90004

Cal-Earth
Geltaftan Foundation Inc.
10225 Baldy Ln.
Hesperia, CA 92345

Center for Resourceful Building Technology
P.O. Box 100
Missoula, MT 59806

Cob Cottage Company
Box 123
Cottage Grove, OR 97424

Cordwood Masonry Housebuilding
Earthwood
366 Murtagh Hill Rd.
West Chazy, NY 12992

Dwelling on Earth
Rammed Earth Works
1350 Elm St.
Napa, CA 94559

Earthbuilders' Encyclopedia
—and—
Adobe Codes
Southwest Solaradobe School
P.O. Box 153
Bosque, NM 87006

Earthen Building Materials:
A Bibliography
Center for Maximum Potential Building Systems, Inc.
8604 F.M. 969
Austin, TX 78724

Earthship, Vols. I, II, III
Solar Survival Architecture
Michael Reynolds
P.O. Box 1041
Taos, NM 87571

Earthword Issue Number 5
"Sustainable and Indigenous Architecture"
The EOS Institute
580 Broadway, Suite 200
Laguna Beach, CA 92651

The Efficient House Sourcebook
Rocky Mountain Institute
1739 Snowmass Cr. Rd.
Snowmass, CO 81654-9199

Indigenous Architecture Worldwide:
A Guide to Information Sources
L. Wodehouse
Gale Research Company, Detroit

"The Last Straw"
Out on Bale (un) Ltd.
1037 East Linden St.
Tucson, AZ 85719

"The Mudslinger"
Adobe/Solar Associates
847 E. Palace Ave.
Santa Fe, NM 87501

MoosePrints (Straw/clay building)
by Robert Laporte
Natural House Building Co. Inc.
RR1, Box 115F
Fairfield, IA 52556

Native American Architecture
Robert Easton, Peter Nabokov
Oxford University Press
200 Madison Ave.
New York, NY 10016

Plastered Straw Bale Construction
The Canelo Project
HCR Box 324
Canelo, AZ 85611

Sod Walls
by Roger Welsch
J&L Lee Co.
P.O. Box 5575
Lincoln, NE 68505

Solar Energy International
(workshops)
P.O. Box 715
Carbondale, CO 81623

The Straw Bale House
by Steen, et al.
Chelsea Green Publishing Co.
P.O. Box 428
White River Junction, VT 05001

Center for Resourceful Building Technology

Fostering Efficient Resource Use.

The Center for Resourceful Building Technology (CRBT), founded in 1990, is a non-profit organization whose purpose is to educate the public on a variety of issues relating to housing and the environment, with particular emphasis on innovative building materials and technologies which place less stress on regional and global ecosystems.