Rammed Earth: Developing New Guidelines for an Old Material

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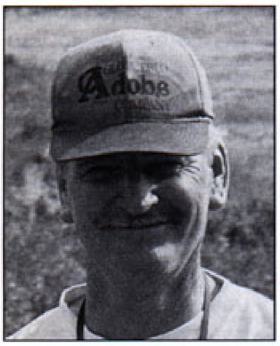

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The views expressed here are those of the author and do not necessarily reflect the opinion or agreement of the International Conference of Building Officials.

Today, we are seeing a revival of interest in earth-wall systems not witnessed since the years after the oil embargo of 1973. Some of these old methods, dressed up in new suits, may hold the key for meeting shelter challenges in the years ahead, when the combination of population increase and anticipated energy problems arrives in full force. Therefore, it behooves the building official to become familiar with them.

The Current Scene

Many Southwest United States builders have some exposure to adobe, but few are familiar with rammed earth. The practice has enjoyed modest growth in the Southwest, around Tucson, Arizona, and Las Cruces and Albuquerque, New Mexico, where roughly a half dozen contractors ply the trade. Additionally, a few other contractors build in California and Colorado. Thus, the industry is still small enough for an easy identification of the builders and their contributions to the trade. About half of the builders are booked up to two years in advance with high-end custom projects and each builds about four homes a year. The other half work with lower cost passive solar designs and are not so commercially oriented. Each averages perhaps two homes per year. A few are more concerned with low-cost, energy-efficient structures and keeping costs low. This mix of builders working at both the high and low ends is a healthy one for the industry. Additionally, communication and technology exchanged between the rammed earth professionals is somewhat better than that between their counterparts in Adobeland.

It is of note that the "hot spot" for contemporary rammed earth is Australia and, in particular, the Perth area of Southwestern Australia, where the government, lending institutions and code departments work to encourage its use. The standard of work is high and a number of larger, commercial structures have been accomplished. This scenario has been stimulated by the high cost of quality lumber in Australia and, as a result, a conscious turn to masonry. It would not be unwise to observe that a similar situation could develop within the United States over the next few decades.

The Current Code Situation

The earth-building codes currently on the U.S. books were written with only adobe in mind, at a time when other earth-wall systems received little attention or study. As a result, some states and code jurisdictions have modified their codes to recognize other established methods. In New Mexico, besides adobe, the code embraces *terrón* (a traditional sod brick), pressed adobe (a machine-compressed earth block), burnt or fired adobe [kiln-fired at 1200°F (649°C) for 24 hours], and rammed earth. Currently, the language in the New Mexico code for the above-wall constructions, including rammed earth, is sketchy. However, in some jurisdictions, the building official has worked with local rammed earth contractors to accept guidelines that have proven themselves. Such a relationship exits in Doña Ana County and the City of Las Cruces, where rammed earth has emerged as the most popular earth-wall system (see sidebar).

Several years ago, an accident occurred on a rammed earth building site in the Albuquerque area. As might be expected, interest in a specific code for rammed earth, as different from adobe, became a priority item—for awhile. The mistakes made by the contractor in part involved incorrect technology transfer from adobe to rammed earth. In other words, just because a contractor is well-versed in adobe does not mean that he or she can transfer common adobe wall techniques to rammed earth. A 38-page guideline for a rammed earth code, replete with illustrations, was compiled by the Rammed Earth Code Committee, consisting of the author, Stan Huston of Huston Rammed Earth and Mario Bellestri of Soledad Canyon Earthbuilders. We included seismic charts for rammed earth walls in Seismic Zone 2B, which represents roughly one third of New Mexico's land area. These charts were prepared by Dr. Fred Webster, seismic engineer, of Menlo Park, California. This document was submitted to the state for review. After receiving Code Change Committee input and the thumbs-up from the New Mexico Home Builders' Association, it was condensed to an eight-page, words-only document written in code language. Now, with the accident a fading memory, this much needed code update is stalled in Santa Fe. Passage of a more specific code for each wall-building system is needed to ensure that accidents are prevented in the future.

The European Connection

While U.S. government awareness of rammed earth has been low since the 1940s, such was not always the case. In August, 1926, the U.S. Department of Agriculture issued Bulletin 1500, entitled *Rammed Earth Walls for Buildings,* authored by M.C. Betts, architect, and T.A.H. Miller, associate agricultural engineer. Key comments include:

> Earth has been used for buildings from time immemorial. One method of use, superior to others, and which was known to the Romans, has been preserved by tradition to modern times. This method consists of ramming slightly moist, specially selected earth, without the addition of straw or other material, between movable forms, and is known by its French name, "pisé de terre," which means "rammed earth."
>
> *Pisé de terre* is a reliable building material when properly handled and is admirably adapted to structures on farms distant from transport routes.

A New Mexico crewman uses a spray attachment to water down a pile of prepared soil, as it is turned by the Bobcat. Prior to adding the water, the dirt is dry-mixed with a premeasured amount of portland cement. The pile represents the amount of work that must be done (rammed) within 90 minutes of mixing. The objective is to bring the mix to roughly a 10 percent moisture content, with a uniform color and texture.

Bulletin 1500 goes on to describe the process, including illustrations of the old "shuttering," or wooden form systems, and the many shapes of hand tampers. In 1926, the direct influence between historical European usage and U.S. rammed earth could be easily traced. Most references are to structures in France, Germany and England, where rammed earth buildings dating to the 1500s are still occupied.

Prior to the establishment of sawmills, American colonists built stout rammed earth homes in rural New York and Pennsylvania. Many are still in place today, the earth walls hidden behind plaster or ship-lap coverings.

In Washington, DC, a formidable two-story rammed earth building, with walls 2 feet (610 mm) thick, was constructed in 1773. It stood at 1300 Rhode Island Avenue for two centuries, serving for a period as an embassy, and was demolished only when the land became more valuable for other real estate. It is said that the wrecking ball used in this effort was ineffective, the thick earth walls absorbing the shock.

The Church of the Holy Cross in Sumter, South Carolina, was constructed in 1850 of rammed earth and is still in use today. This impressive public structure, with its steeple and steeply pitched gable roof, has required relatively little maintenance over its 148 years.

Foundations, Earth Mixes and Moisture Protection

All of the older, pre-code work was unstabilized soil, rammed on a masonry stem, set well above grade, and the earth wall protected both by plasters and adequate roof overhangs. Today, a concrete stem must project at least 6 inches (152 mm) above grade. Foundations are of a standard "inverted-T" shape, although a number of builders have successfully utilized packed rubble-filled trenches, with a reinforced concrete grade beam (three continuous No. 4 steel rebar) poured above this. These are usually 10 inches (254 mm) thick and a little wider than the wall in width to leave a ledge for the forms to sit on.

Today, the earth material is generally stabilized using portland cement. This means that certain styles popular in Southwestern architecture, where roof overhangs do not exist, can be constructed without the concern of moisture damage. In fact, totally exposed work, both inside and out of the structure, can be attractive and cost saving, due to the elimination—or reduction—of expensive stuccos. Plasters in such homes are limited to tiled areas, such as in bathrooms and kitchens, and to some frame walls, utilized in closets, plumbing walls, etc.

Unstabilized rammed earth, like unstabilized adobe, is allowed as long as the exterior walls are adequately protected from moisture damage. That usually means a hard plaster or stucco that can resist abrasion from hail. Softer earth plasters, stabilized with asphaltic emulsions or other means, do well on unstabilized vertical walls under roof overhangs.

Stabilization using portland cement occurs in most soils at around 5 percent of portland cement to weight of dry soil. New Mexico guidelines call for 6 percent, as a safety net, but even so, the builder must submit a lab report on the soil with the building permit application. Essentially, the builder provides the lab with several cured cylinders of stabilized soil, which are subjected to an American Society for Testing and Materials procedure. This sequence involves submerging the sample under water for a prescribed time, after which it is pulled out and immediately given a compression test. If the sample comes in at 300 pounds per square inch (2069 kPa) or better, it is deemed to be stabilized. Most labs are familiar with these tests, as they commonly conduct them for highway construction projects.

The soil to be used should be stockpiled near the site. It will be wetted to maintain a moisture content of about 10 percent. When ramming is ready to begin, only a portion that can be used in the next 90 minutes is pulled away from the main stockpile and mixed with the portland cement. Once the cement is added, the pile is turned from all directions thoroughly, until the entire mass is the same texture and color. Any unwanted debris or organic matter is spotted and tossed out by the crew.

This mixing procedure works at various levels of technology, ranging from low-tech shovels and rototillers to scoop loaders, such as smaller Bobcats. Possibly the most advanced tool for this part of the work is a towable machine developed by Mr. Huston. It has two hoppers, one for the basic earth mix and the other for portland cement. These two hoppers feed down to a conveyor belt that takes the materials to a pug mill, where the proper amount of water is added. The resulting mix is fed to a loading tray (somewhat like a giant dustpan), where the scoop on the Bobcat can easily gather it. Or the mix can be delivered to a conveyor that takes it directly up to the wall system and dumps it into the forms for tamping. This last advance means that walls go up quicker, but code officials must realize that lower-tech methods can produce just as good a wall.

Forms

Today, the most common rammed earth system is based on the typical concrete forming panel. Makers such as Symons, Burke and Universal supply the trade. All of the associated hardware—wedges, whaler straps, cross-ties, inside/outside corners, etc.—are rented to the contractor or purchased. The concrete forming panel, with its sturdy steel frame and special plywood inset, is well suited for rammed earth, being strong enough to withstand the ramming pressures. Some contractors make up their own systems or modify existing ones. This includes larger panels that eliminate the cross-ties within the forms, which can be a nuisance during ramming. From the code inspector's viewpoint, any forming system should be sturdy, and it is considered that plywood under ¾ inch (19 mm) in thickness may not be adequate to avoid deflection, even with a good whaler system bracing the forms on both sides.

Forms are being removed from a section of 16-inch-thick (406 mm) rammed earth wall, just completed in central New Mexico. In this case, extra thick sheets of oversized plywood serve as forms, with whalers of 2-inch by 10-inch (51 mm by 254 mm) lumber, and pipe clamps to tighten the assembly. These walls become hard enough to bend a No. 16 nail within two days of exposure to the air.

Lifts and Tamping

The historical approach to rammed earth is to place the raw material in the forms via a "lift." In rammed earth parlance, a lift is the equivalent of a "course" in ordinary masonry. Eight inches (203 mm) of material is dumped into the forms, usually by a tractor with a scoop or a Bobcat-type loader. The crew quickly grades out the moist mix, using square shovels. It is then tamped. In the "old days," this was done by hand. Today, it's accomplished via pneumatic tampers, with a tamping head ranging from 2½ to 4½ inches (63.5 to 114 mm) in diameter. A wall correctly tamped by hand will attain the same density as one tamped by machine.

An 8-inch-deep (203 mm) lift will tamp out to about 5 inches (127 mm), a reduction in volume of about 37 percent. The resulting density is in the 100 to 110 pounds per cubic foot (15.7 to 17.3 kN/m^3) range, similar to adobe. Lifts of material deeper than 8 inches (203 mm) stand the risk of "bridging over" untamped material below and should be avoided. The work proceeds upward, lift after lift, until it arrives at a point approximately 6 inches (152 mm) under the top of the forms. Because the form panels are made in 2-foot (610 mm) sizes, most forming assemblies will top out at 8 or 10 feet (2438 or 3048 mm). Then, with top forms still in place, the contractor places the steel and a concrete bond beam is poured. I have purposely kept this explanation simple, but as the wall ascends, everything from electrical conduit and steel ladder reinforcement to window boxes, plumbing vents and uplift anchors can be rammed into the wall. Uplift anchors may start with their base plates set on top of the last lift rammed, 18 inches (457 mm) or so below the bond beam void. The bolt then projects into the bond beam pour and may be turned to tie into the horizontal rebar of the bond beam. Also, any ties or straps for roof attachments will be set before pouring the bond beam.

When a wall section has been rammed, forms may be removed immediately. The 10 percent moisture content is not enough to create an unstable wall, and new work can be exposed, as it will cure quickly when exposed to the air. Where a bond beam is to be poured, the lower generations of forms may be removed, with the top forms still in place. Safety around forms must be observed constantly. Freshly exposed walls utilizing portland cement should be "wet-cured" using a water spray, as is done on freshly stuccoed walls.

Attachments

The inspector should be advised that today, the more advanced earth-building contractors have become quite versatile and proficient in a "mixed-media" approach. That is, a structure may have straight, exterior walls of rammed earth, interior walls of exposed adobe, and some frame walls for closets, plumbing walls, etc. Therefore, you have to be familiar not only with each wall system but also with good attachment systems to connect the different walls. This often begins with common foundations and bond beams, but extends to hardware. Specifying particular brand name products to attain good attachments is to be avoided (but often only a certain brand will do the job "off the shelf"). Effective attachments tend to be oversized, compared to regular masonry. Remember, you are dealing with very massive walls. Look for wide galvanized straps of a sturdy gauge, long screws and deep anchors welded to flat plate bases, and good plan details that clarify how attachment is to be achieved. Isometric sketches that everyone can understand can help at this stage.

Rammed Earth versus Adobe

Perhaps the most obvious advantage is that ramming the material directly into forms eliminates the entire molding and curing process necessary for adobe blocks. Rather than making many small blocks, which require up to a 30-day dry spell to cure, the rammed earth wall is like one monolithic adobe block that cures *in situ.* The material going into an adobe is moved from eight to 12 times during its manufacture. With rammed earth, the material is moved one to four times. Additionally, the whole craft of preparing a suitable mud mortar (up to 20 percent of the wall mass for adobe) can be avoided. However, in fairness to adobe, rammed earth lends itself only to very straight, often plain and boxy layouts, while adobe can be deployed in all sorts of curves, steps and the like. In short, adobe is more "artistic."

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Rammed Earth: A Code Official's Perspective

Doña Ana County is located in Southwestern New Mexico, about 45 miles north of El Paso, Texas. A large county of some 3,804 square miles (9852 k^2), it is bordered on the east by the 9,000-foot-high (2743 m) Organ Mountains and on the south by the Texas state line and extends west across the Rio Grande. About four months of winter conditions (snow is rare) and eight months of summer conditions prevail. At an elevation just under 4,000 feet (1219 m), there are more cooling days than heating days. Many of the homes in the area are built in a Southwestern architectural style with a solar orientation.

Regulations for rammed earth are not found in the *Uniform Building Code*™ (UBC), which New Mexico has adopted. Regulations for this method of construction have been adopted by the state of New Mexico in its own building code supplement, which replaces the first four chapters of the UBC.

The permitting process is the same as with a conventional dwelling. No architectural stamp is required, since this type of construction is not considered an alternative method. The plans go through plan review first, then the flood commissioner, and finally planning and zoning, before the issuance of a building permit.

The county executes required foundation, framing, insulation and final inspections. The electrical, plumbing, heating, ventilation and air conditioning are inspected by the state of New Mexico. The foundation inspection usually involves a spread footing, followed by a slab inspection. During the construction of the walls, a random core sample may be sent to the lab for testing.

When the walls are completed, the bond beam or tie beam will be inspected. The framing inspection consists of any interior walls and roof framing, while the insulation inspection covers required exterior perimeter insulation and roof insulation. The final inspection is performed after those for electrical, plumbing, heating, ventilation and air conditioning. Finals are passed, the structural final is performed and then the certificate of occupancy is issued.

The massive rammed earth walls—especially noticeable at doors and window sills—provide excellent thermal storage to maintain coolness in the summer and warmth in the winter. With the addition of exterior insulation, the walls are even more effective.

There are three contractors in Doña Ana County who build with rammed earth. The rammed earth buildings in Doña Ana County range from homes 1,000 to 5,000 square feet (93 to 465 m^2) in size, to a few commercial structures.

—Tommy Garcia
Head Building Official
Doña Ana County Community
Development Department
Las Cruces, New Mexico

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There is much to be said for the aesthetic of a nicely finished, exposed adobe wall.

Another advantage of rammed earth versus adobe is the fact that the forming, already in place, creates a natural void for the concrete bond beam. Adobe builders typically set up a lumber or plywood form system on the top of the adobe wall to contain the concrete pour, an awkward and time-consuming process. With rammed earth, the forming is already there.

Yet another advantage of the rammed earth process is its efficiency in constructing very thick walls. It is said that for up to 16 inches (406 mm) in thickness, adobe is a more efficient system than rammed earth; beyond 16 inches (406 mm), rammed earth becomes more efficient. Anyone who has constructed a 24-inch-thick (610 mm) adobe wall knows that the rules of masonry must be followed—mixing the mud to specs; barrowing it to the work; setting speed leads, line blocks and string; lifting and laying the block; striking the joints, etc. A massive 24-inch (610 mm) wall in small units uses up mortar and adobes faster than most masons would like. Additionally, double adobe walls require attention to proper overlaps. Cutting and fitting is required, at least occasionally.

However, with forming panels up and properly leveled, it is almost as quick to ram a 24-inch (610 mm) wall as it is an 18-inch (457 mm) one. Once the tamper is working, a sweeping, side-to-side motion is set up. Swinging the tamper over to pack that extra 6 inches (152 mm) of width is not that much more work; the crew members have room to stand inside the formed void as they ram. The same crew members will tell you that ramming a skinny wall [such as 12 inches (305 mm) in width] is a difficult void to work in. Additionally, it can be difficult to set convenience outlets, plumbing or other in-wall items within a narrow, formed void.

The other advantage connected with thicker walls is seismic. Builders in Seismic Zones 3 and 4 will appreciate the idea that rammed earth walls 24 inches (610 mm) thick (and not too high) typically withstand the anticipated ground accelerations for projected earthquakes. In other words, it's difficult to tip such walls over.

There is some validity in the argument that a rammed earth wall can accept a more diverse range of material sizes, due to its very wide nature. For example, in pressed adobe, large aggregates are avoided, since they can set up fracture lines in the block. There is an old German saying that any stone up to the size of a walnut is acceptable in a rammed earth wall. Of course, the basic soil must be good, containing sufficient clay as a binder and sufficient sharp, coarse sand for strength. An approximation for a basic mix might be 15- to 25-percent clay fines and 75- to 85-percent sharp sands and small gravels.

A disadvantage to rammed earth is its somewhat "machine intensive" profile as compared to adobe. While one could legally build a quality rammed earth wall using the hand tools of Beethoven's time, it requires a physical tenacity reserved for Marine Corps personnel and football players in training. It tends to scare away the less hardy builders who are not familiar with the operation of loaders, air compressors, tampers and heavy forming. Therein lies the paradox inherent in some appropriate technology solutions: Today, we use energy-intensive methods for a short span of time to construct buildings that save energy over long spans of time. Perhaps that is not such a bad trade-off. ■