Adobe: A Present from the Past

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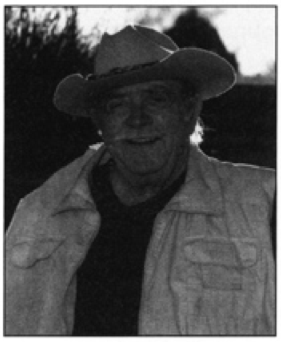

Paul McHenry, Jr., is a registered architect who has been planning and building adobe homes since 1961. He teaches classes in adobe architecture at the University of New Mexico, has authored several books on the subject, and is recognized as a world authority on adobe architecture and technology. He has been a member of the New Mexico Construction Industries Division Committee for approval of the Uniform Building Code™ *(UBC) since 1982. Mr. McHenry established the Earth Architecture Center International in 1994 to collect and disseminate information on building with earth worldwide. (For further information, see www.earthbuilding.com.)*

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.

THE PAST

Man has used earth since time began. First, there may have been caves, then brush shelter, which was covered with mud to make it windproof and waterproof. Then man's ingenuity created solid walls of earth that were stronger and lasted longer. Finally, came preformed, sun-dried brick. This started with hand-shaped lumps and evolved to molded forms of a particular size.

The particular forms that developed in each location were in response to the climate, available resources and culture. Different areas developed at different speeds, so there is no universal time line, but all followed the same pattern. Identical examples can be found from the arid regions of the Far East and Africa to the humid climates of South America. Each location developed in a manner that was appropriate to its own climate and culture.

The earliest habitations of earth-wall buildings have been found in the Indus River Valley in India and in the Tigris and Euphrates valleys in Mesopotamia, which is present-day Iraq. Some examples date to 7000 B.C.

Migration and cultural transference affected the use of any area. Materials used were those that were at hand. The systems tended to stay with the familiar forms and technology that had been satisfactory in the past. The arid lands of the Middle and Far East provided a setting that had very little timber or structural members. So man, in his ingenuity, developed the arch and vaulted domes, where large areas could be roofed over with small bricks. This is a tribute to the creativity of the human mind. Make the best use of what is at hand.

An example of this theory at work is the difference between the Middle East and the Western Hemisphere. The arid portions of the Middle East made wide use of domes and vaults because they had no wood for structures. The Western Hemisphere, on the other hand, did not discover the vault principle until after Pre-Columbian times. They didn't have to. There were plenty of trees for roof structures. There are a few minor exceptions, but the need was missing.

As late as 1940, adobe was recognized as a viable solution to economic problems. It has historically reappeared in the United States in times of economic hardship, where needed buildings could be constructed with local materials and labor. An elementary school in Anthony, New Mexico, and a high school in Carmel, California, used adobe.

THE PRESENT

At this time, in spite of the long history of earth-wall building, the technology and its benefits are unknown or misunderstood in most of the modern nations of the world. Moreover, adobe buildings have a poverty image in most parts of the world, making adobe less desirable to people who can afford better (more modern) materials. Furthermore, the 50-year lack of exposure to professional architects and engineers who write the building codes has resulted in codes that are unrealistically severe with respect to adobe.

In the state of New Mexico, adobe has a split image, relegated to the rich or the poor. One must be affluent to afford the labor-intensive higher cost of building with adobe, or so poor you cannot afford any better. However, it is not the cost of the adobe itself that is the culprit, but the careful re-creating of the past with other labor-intensive, hand-wrought materials that adds much of the cost to a contemporary adobe. Still, it is possible for a poor person to build shelter with the materials underfoot, without having to buy anything.

CLIMATE FACTORS

Climate dictates humans' shelter requirements, and the materials at hand, in turn, dictate to some extent how those shelter requirements are met. In drier areas, like the arid lands of the Middle East, adobe brick masonry reached incredible heights of innovation and skill. In Europe and most of the Western Hemisphere, there were many humid areas lacking enough continuous dry weather to dry mud bricks. In these areas, they used rammed earth. (From a global perspective, rammed earth is as popular as adobe.) Again, there are exceptions. In New York State, more than 25 examples of adobe brick homes can be found.

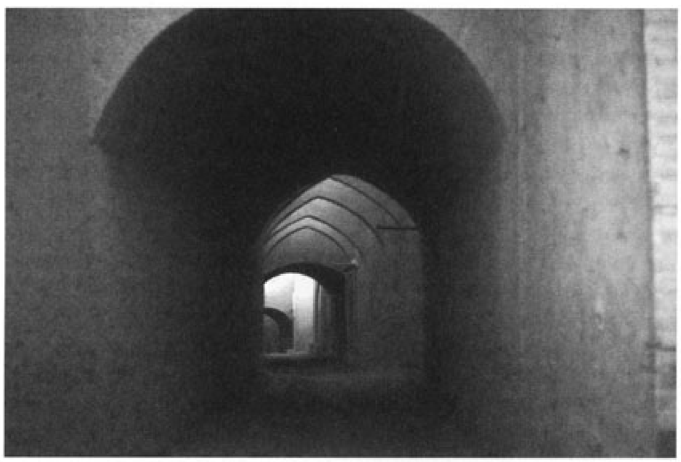

Photo: Paul McHenry, Jr.

Adobe barrel vault and arches in Iran, age unknown. In this part of the Middle East, mud brick vaulted arches have been found dating to 7000 B.C.

Photo: Paul McHenry, Jr.

Carmel High School in Carmel, California, circa 1939, was built of adobe. It has since been in continuous use.

Many other buildings still stand in unlikely places, like the Church of the Holy Cross in Sumpter, South Carolina, which was built of rammed earth around 1850. In County Devon, England, it is estimated that there are more than 40,000 "cob" houses, which were built with globs of mud and straw.

ADOBE TECHNOLOGY

The following recommendations and standards are only a minimum outline of each subject, and are intended as a guide for further study and detailing.

Soils

The physical properties of soil for adobe bricks are simple. It is common soil mixed with water. Most common soil in its natural state has adequate quantities and proportions of the four main elements: aggregate, sand, silt and clay. The type of clay may be expansive or inert without substantially affecting the quality of the brick. When the brick is dry, all expansion or shrinkage will have taken place. The proportion of the four ingredients can vary widely. Sample testing of many historic structures demonstrates this clearly.

A series of more than 60 tests at Tumacacori Mission in Arizona (around 1820) indicated that the percentage of clay varied from as high as 32 percent to as low as 0 percent. While some bricks had no clay at all, most samples indicated approximately 50 percent aggregate and sand, and 50 percent clay and silt. This leads one to the conclusion that the percentage of coarse material (aggregate and sand) should be approximately half, and the finer materials (silt and clay) a similar percentage.

In many areas, straw is traditionally added to the mud mixture. The reason for this is that most natural soil normally has too much clay, which can cause shrinkage cracks as the brick dries. The addition of straw reduces shrinkage cracks to suitable levels, thus creating the myth that straw is essential. The most important test to determine the adequacy of a soil for making bricks is to make some bricks and dry them in the sun.

Adobe bricks dry will weigh approximately 100 pounds per cubic foot (15.7 kN/m^3) ± 10 percent.

Bricks

Adobe bricks can be any size. The most common size in the Southwestern United States is 10 inches by 4 inches by 14 inches (254 mm by 102 mm by 356 mm) and weighs 35 to 40 pounds

(15.9 to 18 kg). In Latin America, the bricks tend to be larger, and in the Middle East they are smaller, perhaps for easy handling in building tall vaulted and domed structures. The New Mexico Institute of Mining and Technology at Socorro conducted extensive tests of the adobe bricks from more than 80 brickmakers in New Mexico. The following specification values were common to nearly all the bricks tested. These figures are reflected in the standard requirements by the New Mexico Building Codes. The testing procedure is contained in the *New Mexico Building Code.*

Compressive Strength. A large group of samples indicates that most bricks have a compressive strength of 250 to 300 pounds per square inch (psi) (1724 to 2069 kPa). The actual loading at the bottom of most adobe walls is less than 10 psi (69 kPa), including roof structure and dead and live loads.

Modulus of Rupture. This measure of a brick's flexural strength, although not of particular value in masonry calculations, provides a measure of the brick's toughness. The same samples above show an average of 50 pounds (22.7 kg) or more.

Water Resistance. There are two measures of a brick's water resistance. One is absorption and the other is erosion. Bricks made with unamended soil will self-destruct if subjected to standing water, such as during a flood, without the support of waterproof plaster. They will also erode rapidly if subjected to a concentrated steady stream of water. They are seldom affected by freeze-thaw conditions. Vertical surfaces of unamended mud are minimally affected by rainfall, averaging less than 1 inch (25.4 mm) of erosion in 20 years in areas receiving 10 inches (254 mm) of rain per year. Horizontal surfaces (such as tops of walls), however, will erode at the rate of 2 to 3 inches (51 to 76 mm) per year.

Moisture-resistant, or "stabilized," bricks can be made by adding a sufficient quantity (10 to 15 percent by volume of mixing water) of a waterproofing agent, such as asphalt emulsion or portland cement to the mix as it is being prepared. A totally waterproof brick will absorb less than 4 percent moisture in one standard test. Many brick manufacturers add a small quantity of asphalt emulsion stabilizer (3 to 5 percent) to the mix and designate these as "semistabilized." This is to cut rain losses during the early drying stages, when the bricks are most vulnerable, but does not make the dry brick waterproof.

Mortar. The mortar to be used for adobe construction is ideally the same soil used to make the bricks, but screened to eliminate small stones that would interfere with bedding in the mortar. Using similar soil provides a homogenous mass that is stronger than its separate parts. Bricks are laid in a full slush mortar bed. Care must be used not to lay too many courses in one day, dependent on the weather, or the wall will not be stable. The normal number of courses laid in New Mexico in hot dry weather is seven to eight. The water in the mortar can migrate into the bricks, reducing their strength.

If the wall surface is to be plastered, it is desirable not to fill the head joints completely, so the void will serve as a key for the plaster. Lime or cement mortar is allowed in place of mud mortar, the use of which will speed construction, particularly in cold weather, when mortar dries more slowly.

Walls

Walls are laid as normal masonry, using leads and string lines, as single brick walls. One must make sure that there is a minimum of 4 inches (102 mm) of bond (overlap) between courses of brick. It is not normally necessary to modularize the opening to the brick size to avoid cuts, as you might with concrete masonry units; adobe bricks can easily be cut with a trowel or hatchet. In multiple brick walls, where two walls are built, cross bonding of header courses or other ties must be included to provide stability. Because adobe dries very slowly, caution should be used in the speed with which multiple brick wall courses are laid. Make sure that the wall and mortar are dry enough to support the additional courses and bricks.

Bond Beams

All adobe walls should be secured at the top with a bond beam of steel-reinforced concrete or wood. This serves to tie the structure together and provide a broader, strong surface for point loads. Concrete bond beams require a minimum depth of 6 inches (152 mm), and include two ½-inch (12.7 mm) diameter steel reinforcing rods (continuous). Wood bond beams should also be a minimum of 6 inches (152 mm) thick and must be secured at the joints and corners to function properly.

Photo: Paul McHenry, Jr.

A man makes adobes in Sasabe, Sonora, Mexico.

Foundations

The foundations for adobe walls are the same as for any other type of construction. Frost-line depth should be observed, and the full wall thickness should be supported by the foundation wall or slab. An allowed exception provides that 2 inches (51 mm) of perimeter insulation will serve for a full 2-inch (51 mm) width of the foundation wall. Monolithic foundation/slab construction is also allowed, with the first layer of adobe on the slab to be stabilized.

Insulation and Thermal Values

The thermal conductivity of an adobe wall is poor. Partially compensating for this is its thermal storage properties, which dampen the highs and lows of the exterior ambient temperatures. The sun's warmth and heat, supplied on the interior, is stored in the wall, which will be the average of the exterior high and low temperatures and reflect the temperatures of several days past.

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Adobe: A Code Official's Perspective

We have been living in adobe homes here in New Mexico for more than 400 years. The Taos Indian Pueblo, the Santa Cruz Church and the Santuario de Chimayo are popular and significant examples of adobe construction that are still in continuous use.

The Material

The adobe is a simple mixture of clay, sand and water with a small amount of straw. The mixture of mud is typically placed into a wooden form, the *adobeda,* then removed from the form and allowed to dry outdoors in the Southwest sun. The drying of the adobe causes it to shrink and become hard. Drying also causes shrinkage cracks. However, no unit may have more than three cracks, and no crack may exceed 2 inches (51 mm) in length or 1/8 inch (3.2 mm) in width. The adobe must have an average compressive strength of 300 pounds per square inch (psi) (2069 kPa) when tested. One sample out of five is required to have a compressive strength of not less than 250 psi (1724 kPa).

It is ironic that the contemporary use of adobe as a construction material has been for "high-end" residential construction and, alternatively, for construction on budgets of very meager means. This "split personality" is caused by the labor-intensive nature of both the manufacturing of the brick and the building of the adobe wall. The enormous amount of labor involved drives up the cost of construction. However, if the homeowner has plenty of time, and is so inclined, the owner may construct the building walls by his or her own hand. Such a situation is not uncommon, thanks to the simple tools and skills required. Laying adobe is not a high-tech endeavor. With very few changes, the adobes are still set in a bed of mortar in much the same way as the Native Americans of Taos Pueblo and the colonial settlers of Chimayo, New Mexico, did many years ago.

Bond Beams

Our generation has seen reinforced concrete footings replace the mortarless stone footings. The top of the walls are now being capped with bond beam for the purpose of distributing the concentrated loads of the roof beams. Without the distribution of the concentrated loading, it is likely that the adobes at the bearing points of the concentrated load would fatigue or fail in compression. The bond beam supporting the roof structure may be constructed as a 6-inch-thick (152 mm) concrete beam with two No. 4 rebars, solid heavy timber or 1-inch (25.4 mm) nominal lumber centered over the middle two thirds of the wall. The bond beam must be 10 inches (254 mm) wide for the exterior walls or 8 inches (203 mm) for the interior walls.

Stabilized Adobe

Historically, deterioration and failure of adobe structures was most commonly caused by moisture migration into the structural adobe. The damage caused by the moisture becomes more significant during the winter months because of the freeze-thaw cycles, which cause the surface of the mud plaster or the adobe to flake off. During the seasons when freezing is not a problem, wind and rain become an issue. Wind and rain cause damage by eroding the surface of the adobe. Stabilized adobe has essentially eliminated all the problems caused by the freeze-thaw cycle. The use of cementitious three-coat stucco coating has become the exterior finish system of choice to protect nonstabilized adobe.

Thermal-resistive Properties

Adobe works very well for storing radiated heat because of its thermal mass properties. However, it has low thermal resistive properties. A 10-inch-thick (254 mm) adobe has a U-value of 0.36 (R-2.78); a 14-inch-thick (356 mm) adobe has a U-value of 0.26 (R-3.89). In many cases, this requires insulation to be added to the wall, which is typically done by furring out the inside surface, then filling in the cavities with insulation, or the outside surface may be insulated by adding a layer of polystyrene or polyurethane prior to applying the exterior coating.

Electrical and Plumbing

Electrical mechanics are required to channel a notch into the adobe to embed the electrical wiring. Type UF electrical cable is allowed to be in contact with the adobe and the gypsum plaster. However, it must be protected from the concrete plaster [1996 *National Electrical Code®* Section 339-1 (a)]. Type CI-2 wire is required to be protected from concrete plaster and gypsum plaster. This protection may be provided by running it through a conduit, embedding it in a layer of mud mortar or covering it with building paper. Plumbing mechanics must provide protection for acrolynitrile butadiene styrene (ABS) plastic and polyvinyl chloride (PVC) piping (1991 *Uniform Plumbing Code™* Section 315-b), which can be done in the same manner as for electrical wiring. The channeling and protection of the electrical and plumbing add significantly to the cost of adobe buildings.

House of Style

Although labor intensive and more expensive than conventional frame construction, adobe is still a popular choice as a building material. One reason is that adobe is very forgiving, lending itself to visual softening of the corners and the walls of a building. Variations from the straight and flat surfaces are not only tolerated, they are encouraged. These variations are what add to the character and the personality of the adobe home. ■

—Raymond Quintana, AIA
Chief Building Official
County of Bernalillo, New Mexico

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This is also subject to thermal lag and reflects the temperatures of several days past.

Mechanical Accommodation

Adobe walls can be channeled for the placement of pipes and electrical wiring and then filled with plaster or mortar. If a series of outlets are at the same height, the cable can be laid with the wall. In areas where multiple pipe assemblies are close together, it may be desirable to build a frame wall to accommodate them. Most plumbing lines should be placed below the floor, and main electrical lines should run in the roofing assembly, with drops channeled down to the outlets. This cable is of the direct burial type.

Attachments

Door and window frames may be attached to adobe walls by the use of "gringo blocks" (wood adobes) laid in the wall as it is constructed. These are normally made from scrap 2 by 4 lumber and are hollow and filled with mortar to provide solid connections. For lighter use, such as the attachment of wall cabinets, deck screws of at least 3 inches (76 mm) in length have been effective.

Seismic Factors and Precautions

Adobe walls are no more prone to seismic damage than other unreinforced masonry buildings of stone or brick. Protective measures can be incorporated into the original construction by the use of counterforts at the corners and continuous horizontal reinforcement at several levels between courses of the bricks. Shake-table tests indicate that the application of wire mesh on the interior and exterior of the walls will reduce the danger of collapse. This may be the simplest and most practical method for retrofitting older buildings. Additional study is needed.

THE FUTURE

Building material supplies in the United States are declining. The demand for lumber by domestic markets and Japanese interests, the use of metal studs instead of wood by builders and the quality of today's lumber compared to 15 years ago are evidence of a serious problem. The availability and high costs of building materials in the 21st century will increase shortages in housing, especially as the world's population increases. For some this is merely a problem, for others it is a matter of life or death.

Adobe can be a viable solution for many types of buildings: Material for adobe building is available locally, it is processed by solar energy, only semiskilled labor is required, minimum transportation is involved and adobe meets every ecological principle. Adobe has served us well in past times of need, and, if we do not lose these building arts by attrition, it can serve us again. ■