Adobe as a building material

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Introduction

Adobes are dried mud or unburned bricks that have been used for thousands of years in the construction of dwellings and other structures. Even today the majority of the people in the world use mud-brick construction. The term adobe generally is used to describe various building materials made of earth and the techniques for using these materials. Most often it refers to sun-dried brick, currently the most widely used in the United States, but puddled earth material, mud-plastered logs or branches, cut soil horizons, and even rammed-earth construction also can be identified as adobe. Generally, any structure that has been made with soil or mud as a primary building material is considered to be adobe.

Types of adobe

Smith (1982) divided adobe bricks into six types: 1) traditional, 2) semi-stabilized, 3) stabilized, 4) terrón (cut sod), 5) pressed adobe, and 6) burnt adobe (quemados). Each type of brick is made somewhat differently.

Traditional adobe brick is made with poorly sorted soil composed of a more or less uniform mixture of sand, silt, and clay. Straw is usually added to the bricks to prevent cracking when they are cured. Traditional adobes have been used for centuries in the southwest United States. The majority of these structures were and are built on field stone or river-rock foundations to prevent undercutting of the walls at ground level. This undercutting during weathering is the most common cause of structural failure. Mud mortar is used between bricks, and plaster or cement stucco covers the walls to prevent erosion of the adobe by water. Annual applications of a wall covering are often used.

Semi-stabilized bricks are a new class of adobe production developed by large-scale adobe producers. A small amount of stabilizing material such as portland cement or asphaltic or bituminous emulsion is added to the adobe in order to obtain a partially water-resistant brick. The brick is made in essentially the same way as a traditional adobe brick, but with, for example, 2–3% (by weight) asphaltic emulsion added to the mix.

Stabilized adobe bricks contain enough stabilizer to limit water absorption of the bricks after seven days of immersion in water to less than 2.5% by weight. A fully stabilized, commercial adobe brick contains between 5 and 12% asphaltic emulsion.

Terrón is Spanish for a brick made from cut sod or turf. In parts of the southwest U.S. terrónes are still used widely; they usually measure 7 × 7 × 14 inches or 4 × 7 × 14 inches. An ordinary garden spade with a flattened blade cut down to measure 7 × 8 inches commonly is used to cut the sod. Terrónes are used in the same manner as traditional adobe bricks.

Pressed adobe brick is manufactured from traditional or stabilized adobe materials that are pressed into a dense brick with a hydraulically operated machine or a hand-operated press. The advantage of pressed adobe bricks is that generally they have a higher compressive strength and cure more rapidly than traditional ones. However, without a stabilizer, the pressed adobe bricks distintegrate rapidly when wet.

Burnt adobe, or quemado, is a traditional sun-dried adobe brick that has undergone modification by low temperature firing. Combustible materials, usually wood, kerosene, or old tires, are burned in a stacked-brick kiln, which is built to allow air circulation within. Combustibles are fed through small doors at the end of the kiln, and smoke escapes through holes in the top. It takes from two to four days of firing to produce 300 to 500 quemados.

Thermal properties

Building materials are evaluated for thermal performance based on conductivity measurements known as R- and U-values. The R-value indicates the ability of a wall to insulate effectively—the higher the resistance to the conductive transfer of heat, the higher the R-value and the better the insulator. The R-value is calculated by dividing the thickness of the wall by the wall's thermal conductivity, which is the amount of heat per square foot per hour flowing from the hotter to the cooler side of the wall. The U-value, or conductance, is represented by the reciprocal of the R-value and reflects the rate at which heat is conducted through a material.

R- and U-values, however, do not tell the full story of what constitutes thermally efficient walls (Smith, 1982). Both of these values reflect the rate at which heat passes through the wall only after it has achieved a steady-state condition. Steady state is when heat passes uninterruptedly from one side of the wall to the other at a constant rate. The heat capacity of a wall is not considered in these calculations but is determined by the length of time that passes before a steady state of heat flow is achieved. In practice, external temperature changes constantly during the day, so a true steady-state condition is rarely achieved.

The net result of the thermal properties of adobe bricks is the preservation of cooler night temperatures into the next day and of warmer afternoon temperatures into the following evening. Thus, there is a "flywheel effect" that moderates temperatures within adobe buildings.

Burch et al. (1982), in a seminar held on thermal-mass effects in buildings, observed that the most significant reductions in energy during heating or cooling were found in the summer cooling season. During these times the buildings "floated" during a portion of the day (i.e., no heating or cooling load was used during a part of the day, and outdoor temperatures both rose above and fell below the indoor temperature). The tests they conducted were performed at Gaithersburg, Maryland, and involved uninsulated masonry, insulated masonry, log, and wood frame (both insulated and noninsulated) construction.

Tests conducted in New Mexico with adobe confirm the general results of Burch et al. (Gustinis and Robertson, 1983). However, these latter tests did not result in large savings in power during the summer because the principal cooling devices in New Mexico

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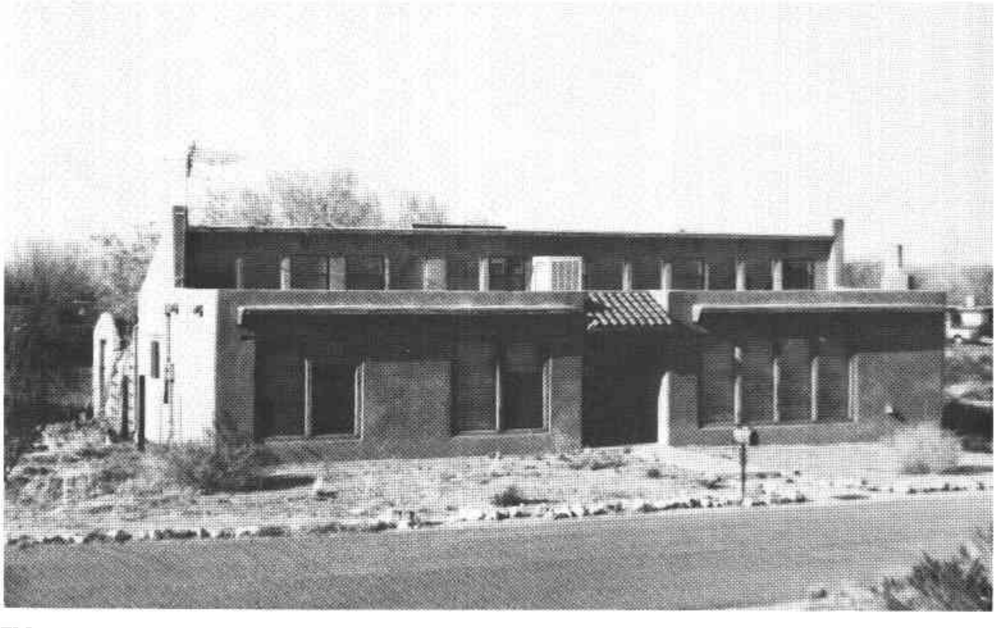

FIGURE 1—South-facing home in Socorro, New Mexico, with exterior, lightweight, conventional insulation covering adobe walls. Winter heating is provided by windows on upper level and fireplace on southeast (right) corner of home.

are evaporative coolers. These coolers use only a fraction of the energy needed to operate the refrigerated coolers used in moister climates.

The thermal efficiency of heating adobe buildings in the winter is not significantly better than for conventional wood frame houses with adequate insulation because the indoor temperature is commonly held above both the day and night outside temperature. Also, the thermal mass pulls the interior heat into the wall, causing greater use of generated heat. As can be seen from many excellent examples in the southwest U.S., past adobe builders responded to this problem by increasing the thickness of walls. The majority of adobe producers today manufacture 10 × 4 × 14-inch bricks that weigh 30 lbs each. Many older buildings contain adobe bricks with dimensions up to 6 × 12 × 24 inches that weigh up to 100 lbs each. In some cases these bricks were used to construct walls up to 2 ft thick. Even with the typical R-value of 2 for adobe, thick walls can preserve moderate indoor temperatures in all but the coldest parts of the year.

Burch et al. (1982) also reported that a wall mass (such as that of adobe) has a larger effect when placed inside conventional wall insulation as opposed to outside the same wall insulation. The result of a combination of adobe and conventional light-weight insulation can be especially effective (Fig. 1).

Geology of adobe materials

Usable adobe materials are found over large areas of the southwest U.S., and they constitute a virtually inexhaustible supply (Fig. 2). The adobe materials are obtained principally from stream-deposited sediments, particularly young river-terrace deposits and weathered, older geologic formations. Typical adobe bricks made in New Mexico consist primarily of silt-sized particles, with 15 to 25% clay material plus a remainder of sand and coarser particles. Many of the larger particles are as large as cobble size (2.5–10 inches) with no apparent deleterious effect on the adobe brick. Clay minerals act as a binder in adobes and must be present in moderate amounts for the bricks to have adequate strength. The actual amount of clay-sized material may vary greatly.

Smith (1982) reports that the mineralogy of the clay fraction is variable for most adobe clays. In general, it consists of about equal parts of expandable clay minerals (smectite and mixed-layer illite–smectite) and nonexpandable clay minerals (illite and kaolinite). Chlorite and vermiculite are uncommon. Clay mineralogy is important in adobe manufacture because excessive amounts of expandable clay minerals result in undesirable shrinkage and cracking. Excessive amounts of nonexpandable clay minerals may produce bricks without the shrinkage and cracking problems but may also result in bricks without the necessary strength for use in construction. A balance of both expandable and nonexpandable clay minerals allows the clay material to act as a binder rather than as a framework or structural element and appears to be the best combination.

Adobe walls do have a tendency to crack with time. However, repair work is quite easy because the same mud materials and plaster that were used in the original wall can be used for repairs. The resulting repaired structure is as strong as the original if the repairs are made carefully, provided that the original cracking was not a result of undercutting. Adobe structures at Indian pueblos in New Mexico that received proper annual care have stood for centuries.

Building codes and tests

Building codes govern the construction of new buildings. The New Mexico building code requires that adobe bricks have a compressive strength averaging 300 lbs per square inch. The importance of this test for a heavy material such as adobe brick is apparent when the great amount of weight a typical wall unit must bear is considered. In addition to the weight of the roof, each layer of brick in a load-bearing wall must support the column of bricks above it and it depends upon the compressive strength of the underlying brick layers for support. Another test required for all types of adobe brick is the modulus of rupture. This test measures the relative cohesion of the materials that make up the bricks and the resistance to tension or shear forces that might result from the settling of a foundation or from wind action.

Other tests, used only for semi-stabilized or stabilized adobe bricks, determine the water-resistant qualities of the bricks. The water-absorption and erosion tests are done only if the bricks are left unplastered or if they are required by the architect or the Federal Housing Agency.

Energy usage

McHenry (1983) described a study done by the energy research group at the University of Illinois and the architectural firm of Richard G. Stein and Associates, New York, that compares the energy costs of manufacturing nearly all common building materials. The total energy investment must include mining, shipping, processing, storing, handling, shipping to the point of use, and installing the materials. Some of the common items reported in this study include common brick, with an invested energy rating of 13,570 Btu per brick; concrete block, with 29,018 Btu per block; and portland cement, lime, and paving brick, all with large Btu values. Although traditional Southwest adobe brick has not been evaluated, McHenry indicates that the value would be approximately 2,500 Btu per brick.

Utilization

Smith (1982) chiefly discussed adobe producers in New Mexico, but commercial operations also exist in the southwest U.S. from Texas to California. Hubbell (1943) extends the area suitable for adobe construction northward into Oregon, Idaho, Wyoming, and even Montana (Fig. 2). Long and Neubauer (1946) mention modern earth-wall construction in Washington, D.C., Michigan, and Arkansas, as well as in all of the southwestern states, and Smith (1982) notes examples of earth-wall construction from New England to South Carolina.

Smith (1982) found 48 active commercial New Mexico producers in 1980 with 10 large-scale operations (150,000 to 1,000,000 adobe bricks per year) responsible for 81% of New Mexico's total production (4,133,000 bricks). He estimated that individual homeowners

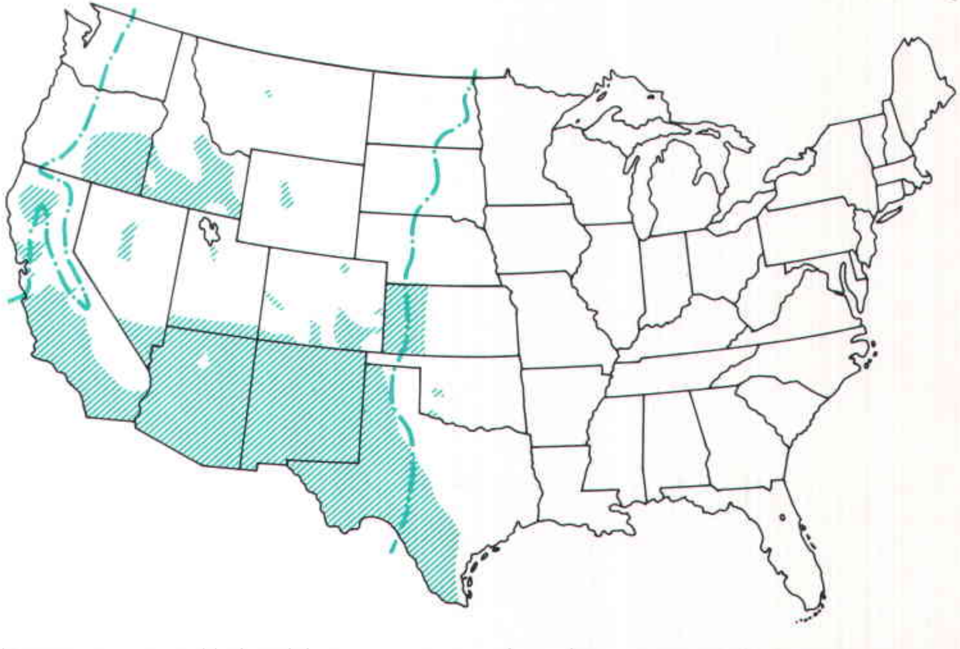

FIGURE 2—Areas suitable for adobe construction are shown between the dashed–dotted lines. Exceptions are the mountainous regions having a normal annual precipitation of more than 20 inches. Shaded areas show where soil is amenable for adobe production (after Hubbell, 1943).

produced an additional three or four million adobe bricks for their own use. A market study for 1981 through 1983 (Robert L. Allgood, written comm. 1983) of the principal adobe producers in New Mexico indicated that, although production by these operations was down 14% in 1981 and 24% in 1982, the 1983 production should be only 3% lower than production in 1980. Many producers stated that they could not make enough adobe bricks to meet the current market demands.

Summary

Adobe bricks, far from being an obsolete construction material with poor insulating properties, are now recognized as very contemporary because of their unique abilities to store heat and moderate extremes of temperature inside a structure. Properly constructed adobe homes, taking full advantage of the sun in either active or passive solar systems, are extremely energy efficient, at least in areas with a suitably high percentage of sunny days. With the development of stabilized and semi-stabilized adobe brick and proper care of walls, new adobe structures can last many years, perhaps rivaling the life of the ancient adobe pueblos of the southwest U.S. that have survived for hundreds of years.

References

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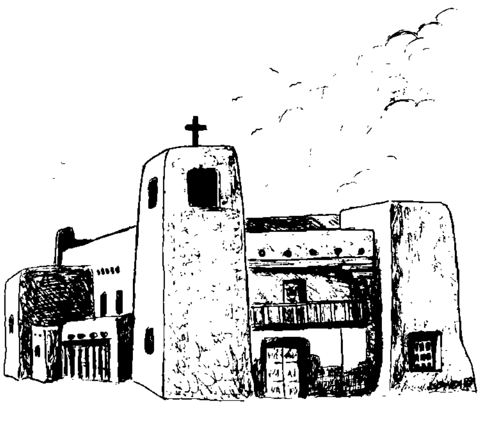

Geographic names

U.S. Board on Geographic Names

Agua Fria, Rito de la—stream, 4 km (2.5 mi) long, heads at 36°37'40" N., 106°23'35" W., flows northwest to Rito de Tierra Amarilla 13.5 km (8.4 mi) northeast of Cebolla; Rio Arriba County, NM; 36°38'53" N., 106°25'15" W.; *not*: Rio de Agua Fria.

Amargo Creek—stream, 41 km (25.5 mi) long, heads on the west slope of the Continental Divide at 36°57'10" N., 106°43'12" W., flows west to the Navajo River, 6.4 km (4 mi) west–northwest of Dulce; Rio Arriba County, NM; sec. 32, T. 32 N., R. 2 W., NMPM; 36°56'53" N., 107°03'35" W.; 1966 description revised; *not*: Amargo River, Rio Amargo.

American Spring—spring, in the Fernando Mountains, 1.6 km (1 mi) east–northeast of View Point and 8.9 km (5.5 mi) east of Ranchos de Taos; Taos County, NM; sec. 36, T. 25 N., R. 13 E., NMPM; 36°21'15" N., 105°30'22" W.; *not*: Bear Spring.

Archuleta Arroyo—stream, 8 km (5 mi) long, heads 6.4 km (4 mi) west–southwest of Gallina Peak at 36°28'15" N., 106°50'17" W., flows northeast to Arroyo del Puerto Chiquito 9.7 km (6 mi) southwest of El Vado; Rio Arriba County, NM; sec. 26, T. 27 N., R. 1 E., NMPM; 36°31'28" N., 106°48'18" W.; *not*: Arroyo Archuleta.

Aspen Spring—spring, on the northwest slope of Chosa Mesa, 0.32 km (0.2 mi) north–northeast of Horn Spring and 14.5 km (9 mi) southeast of Gobernador; Rio Arriba County, NM; sec. 26, T. 28 N., R. 4 W., NMPM; 36°37'50" N., 107°13'33" W.; *not*: Horn Spring.

Bear Spring—spring, in Bear Wallow Canyon, 2.4 km (1.5 mi) south–southeast of Tetillas Peak and 11.3 km (7 mi) southeast of Ranchos de Taos; Taos County, NM; 36°17'15" N., 105°31'18" W.

Brokeoff Mountains—mountains, 38 km (24 mi) long, highest elevation 2,119 m (6,953 ft) at Cutoff Mountain; extend northwest from the Guadalupe Mountains in Texas, into New Mexico, 80 km (50 mi) southwest of Carlsbad; bound on the north by Salt Flat and Box Canyon, on the east by Big Dog Canyon, Valley Canyon, and Middle Dog Canyon and on the west by Crow Flats; Otero County, NM, and Hudspeth and Culbertson Counties, TX; 32° 17'00" N., 104°58'30" W. (north end), 31°57'00" N., 104°52'45" W. (south end); 1907 decision revised; *not*: Guadalupe Mountains, Sacramento Mountains (BGN 1907).

Cañada Escondida Tank—reservoir, in Cañada Escondida, 12.1 km (7.5 mi) northwest of Cañon Plaza; Rio Arriba County, NM; sec. 5, T. 27 N., R. 7 E., NMPM; 36°35'55" N., 106°13'03" W.; *not*: Escondido Canyon Tank.

Chavez Creek—stream, 19.8 km (12.3 mi) long, heads at an unnamed spring on the southwest slope of Grouse Mesa at 36°49'32" N., 106°25'02" W., flows southwest to Rio Brazos 1.8 km (1.1 mi) northeast of Ensenada; Rio Arriba County, NM; 36°44'22" N., 106°31'15" W.; *not*: Chaves Creek.

Chicosa Ridge—ridge, 6.4 km (4 mi) long, highest elevation 2,219 m (7,281 ft), extends east from Cabresto Canyon between Ulibarri Canyon on the north and Cañon Chicosa on the south, 19.3 km (12 mi) northeast of Gobernador; Rio Arriba County, NM; T. 31 N., R. 4 W., NMPM; 36°52'05" N., 107°11'50" W. (east end), 36°51'20" N., 107°15'30" W. (west end); *not*: Chicoso Ridge.

Chicosa Tank—tank, on the south slope of Chicosa Ridge, 20.9 km (13 mi) northeast of Gobernador; Rio Arriba County, NM; sec. 36, T. 31 N., R. 4 W., NMPM; 36°51'36" N., 107°12'30" W.

Chuska Mountains—mountains, 113 km (70 mi) long and 16 km (10 mi) wide, separated from Defiance Plateau on the west by Black Creek Valley and Black Salt Valley; extends north from Tse Bonita Trading Post in New Mexico to a point 11.3 km (7 mi) east of Los Gigantes Buttes in Arizona; Navajo Indian name chosga'i, means white spruce or fir; first reported by Captain Alexander W. Doniphan's 1846–47 expedition; McKinley and San Juan Counties, NM, and Apache County, AZ; 36°35'00" N., 109°17'00" W. (north end), 35°39'30" N., 109°02'00" W. (south end); 1963 description revised; *not*: Boundary Mountains, Chusca Mountains, Choiskai Mountains.

Colorada, Laguna—lake, 0.48 km (0.3 mi) long, 5.6 km (3.5 mi) northwest of Gallina; Rio Arriba County, NM; sec. 2, T. 23 N., R. 1 W., NMPM; 36°15'00" N., 106°54'50" W.; *not*: Laguna Colorado, Red Lake.

Crescent Tank—reservoir, in the Guadalupe Mountains, 51 km (32 mi) east of Douglas; Hidalgo County, NM; sec. 33, T. 33 S., R. 21 W., NMPM; 31°23'05" N., 108°58'33" W.; *not*: Crecent Tank.

Crowther Cow Camp—locality, on the west side of Gavilan Creek, 7.5 km (4.7 mi) west–southwest of Jawbone Mountain and 23.0 km (14.3 mi) northeast of Cebolla; Rio Arriba County, NM; 36°43'22" N., 106°20'30" W.; *not*: Crawthner Cow Camp.

Deer Park—meadow, 0.32 km (0.2 mi) long, 3.5 km (2.2 mi) south–southeast of Tetillas Peak and 12.1 km (7.5 mi) southeast of Ranchos de Taos; Taos County, NM; 36°16'48" N., 105°30'52" W.

Ensenada Ditch—ditch, 4.7 km (2.9 mi) long, in the flood plain of Rio Brazo 0.64 km (0.4 mi) southeast of Ensenada and 3.4 km (2.1 mi) northeast of Tierra Amarilla; Rio Arriba County, NM; 36°43'28" N., 106°31'50" W. (west end), 36°44'08" N., 106°29'06" W. (east end); *not*: Encinado Ditch.

Escondida, Cañada—canyon, 8 km (5 mi) long, heads at 36°35'18" N., 106°16'45" W., trends east to Rio Vallecitos 1.9 km (1.2 mi) south of Ensenada Lake and 7.4 km (4.6 mi) northwest of Cañon Plaza; Rio Arriba County, NM; sec. 4, T. 27 N., R. 7 E., NMPM; 36°36'12" N., 106°11'42" W.

Estufa Creek—stream, 1.6 km (1 mi) long, heads on the west slope of the Continental Divide at 36°58'15" N., 106°43'30" W., flows northwest to join Las Cuatas Creek to form Spring Creek 17 km (10.5 mi) northwest of Chama; Rio Arriba County, NM; 36°58'35" N., 106°44'20" W.

Falling Iron Cliffs—cliffs, 3.7 km (2.3 mi) long, in the Chuska Mountains 7.2 km (4.5 mi) southeast of Upper Wheatfields community, Arizona; Apache County, AZ, and San Juan County, NM; 36°10'40" N., 109°01'07" W. (northeast end), 36°09'40" N., 109°03'00" W. (southwest end); *not*: Beshnalthdas Cliffs.

Fuertes Spring—spring, on the southeast side of the Cañada Fuertes, 7.4 km (4.6 mi) east–southeast of Cebolla and 6.9 km (4.3 mi) southwest of Canjilon Mountain; Rio Arriba County, NM; sec. 4, T. 26 N., R. 5 E., NMPM; 36°31'20" N., 106°24'20" W.

Gavilan Creek—stream, 11.2 km (6.9 mi) long, heads at 36°41'52" N., 106°21'20" W., flows northwest to Rio Brazos 6.1 km (3.8 mi) south–southeast of Brazos Peak and 27 km (16.8 mi) north–northeast of Cebolla; Rio Arriba County, NM; 36°45'26" N., 106°21'34" W.

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