Circular 188 1982

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by Edward W. Smith

New Mexico Bureau of Mines & Mineral Resources

A DIVISION OF
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COVER SKETCH-TAOS PUEBLO; five-story, oldest (900 yrs) continuously occupied adobe structure in the United States is shown here in a tribal drawing by Richard Sandoval of Santa Fe used with the permission of Tribal Governor Patricio Romero and Tribal Secretary Donald Espinosa.

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Preface

This report is the result of many years of working as a geologist and planner for the Eight Northern Indian Pueblos Council of New Mexico which is composed of the Pueblos of Tesuque, Nambé, Pojoaque, San Ildefonso, Santa Clara, San Juan, Picuris, and Taos. During this period the Council was able to initiate the large-scale manufacturing of adobe bricks at San Juan Pueblo which has resulted in a reliable source of adobes for public and private construction projects.

In reviewing and studying the various techniques of commercial adobe operators throughout the southwest United States, Australia, and Central and South America, I noted that very few publications had been written on the modem production techniques of adobes. An extensive number of articles had been published on adobe designs and architecture, but very limited information was available on the location of commercial adobe producers, production totals, classification of adobe bricks, geology and mineralogy of adobe soils, important manufacturing techniques, and the physical properties of adobes.

The pueblo Governors and staff of the Council encouraged me to locate and study the commercial adobe operations throughout the state. In carrying out the field work for the New Mexico Bureau of Mines and Mineral Resources, an extensive number of photographs were taken of each adobe operation. Unless otherwise noted all photographs used in the report were taken by the author.

ACKNOWLEDGMENTS--I am indebted to George S. Austin, Deputy Director of the New Mexico Bureau of Mines and Mineral Resources for his support of this project and for his laboratory investigation identifying the various minerals associated with adobe clays. Grateful acknowledgment is also made to Tibor Rozgonyi and Kalman Oravecz of the New Mexico Institute of Mining and Technology, Rock Mechanics Laboratory, for their excellent work and assistance in the testing of the various physical properties of adobes and to Sharon Murray and Florence Maestas of the Eight Northern Indian Pueblos Council, who assisted in the preparation of the manuscript and in drafting the many illustrations in the text.

Special thanks are given to architects William Lumpkins, Allen McNown, Dale Zinn, and Bill Haney for their assistance in reviewing the manuscript. Also of great help were geologists Bill Clary and Arlon Lovelace, archaeologist Charlie Steen, adobe author and contractor P. G. McHenry, and Joe Tibbetts of *Adobe Today.* The writer extends his sincere thanks to the more than 75 adobe producers contacted or visited during the study. They were most cooperative in providing information on their adobe operations and extended many kindnesses during the field investigations. New Mexico's adobe producers represent the best of the old west and are responsible for keeping the adobe-brick industry alive within the state. Recognition is given to the following adobe producers who manufacture the majority of the state's adobe bricks and furnished the information on the major adobe-production techniques: Richard Levine of New Mexico Earth, Alameda; Ernest Sanchez of Adobe Enterprises, Inc., Albuquerque; Dennis Duran of the Eight Northern Indian Pueblos Council, San Juan Pueblo; Robert Godby and Howard Scoggins of The Adobe Patch, La Luz; Ralph Rivera of the Adobe Farms, Española; Victor and Eloy Montaño of Santa Fe; Dean Leach of Western Adobe, Albuquerque; Manuel Ruiz of Corrales; and Jerry Sanchez of Rio Abajo Adobe Works, Belen. Special recognition is also given to Tom Harley, Vice President of the Hans Sumpf Company in Madera, California, who also reviewed the manuscript and gave his permission for the writer to reprint certain items related to their adobe operation.

Sincere appreciation is extended to the New Mexico Bureau of Mines and Mineral Resources for their financial assistance and to the Governors and staff of the Eight Northern Indian Pueblos for providing the additional support needed to complete the project. Major credit and appreciation is also given to Joe Garcia, Executive Director, and Walter Dasheno, Director of Planning, of the Eight Northern Indian Pueblos Council, who provided me with time and continued support for the project.

Edward W. Smith
Geologist and Planner
Eight Northern Indian Pueblos Council

San Juan Pueblo,
October 23, 1981

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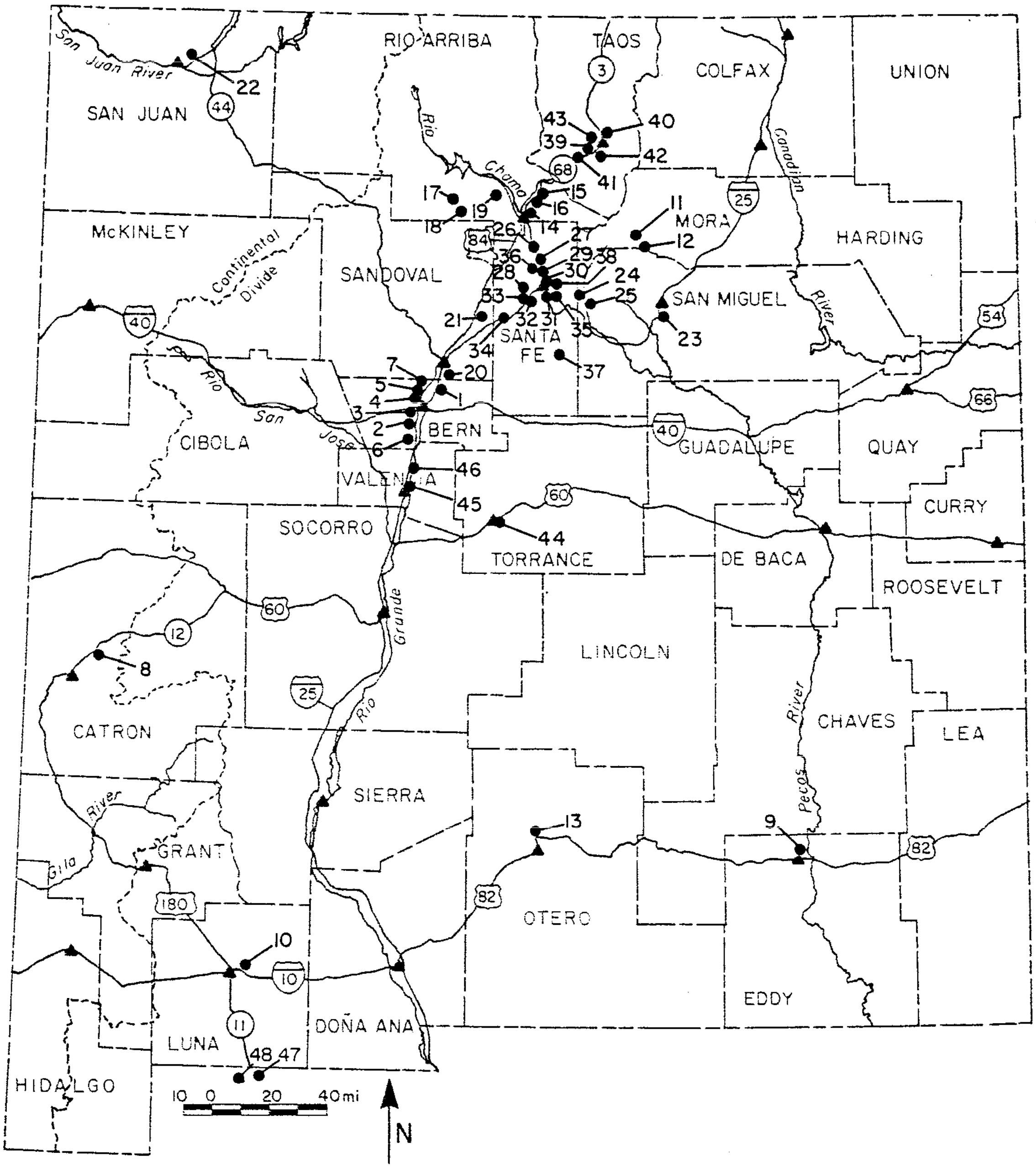


FIGURE 1-INDEX MAP SHOWING LOCATIONS OF COMMERCIAL ADOBE-BRICK PRODUCERS ACTIVE IN NEW MEXICO IN 1980.

Abstract

The use of adobe by the pueblo Indians, the Spanish. and, later, the Anglo-Americans has resulted in a native architecture that is a unique aspect of New Mexico. Historically and up to the present day, New Mexico has remained the largest manufacturer and user of adobe bricks in the United States. Results of a field investigation and sampling program identified 75 adobe producers in the state, 48 of which were active during 1980. Production in 1980 totaled 4,133,000 adobe bricks valued at $1,174,598. A total of 30 adobe-brick producers, representing 87% of the active manufacturers, are located in the Albuquerque and Española Basin areas of the Rio Grande valley where a total of 3,448,000 bricks were produced in 1980. Of all producers, the 10 largest scale adobe-brick manufacturers (150,000—1,000,000 adobes/yr) produced 81% (3,361,000) of the state's total adobe-brick production. Engineering tests on the bricks were performed by the New Mexico Institute of Mining and Technology, Rock Mechanics Laboratory, in Socorro. Tests were performed on adobes from 56 locations, with the majority of adobe bricks meeting the specifications of the Uniform Building Code and the New Mexico State Building Code adopted in 1977 (Construction Industries Division, 1979). Full physical-property information on all types of bricks has been included here, as well as descriptions of the geology of the major adobe-soil locations. The mineralogy of the adobe clays was analyzed by the New Mexico Bureau of Mines and Mineral Resources as belonging in four clay-mineral groups. The terminology of the adobe-brick industry, general characteristics, economic factors, and techniques of production are also detailed in the report. In addition, examples of buildings representing the four architectural periods in New Mexico covering a span of 900 yrs are outlined and illustrated. Finally, in the appendices, adobe-building construction details and specifications as well as unique uses of adobe are included.

Introduction

This report includes the results of various adobe-yard and field investigations carried out in the state of New Mexico during 1980. The area covered by this report and the names and locations of the commercial adobe-brick producers active in the state in 1980 are shown in fig. 1 and table 1. The purpose of this investigation was to obtain the basic information necessary to establish an inventory of all the commercial adobe operations within the state of New Mexico. The study included the locations and distribution of adobe yards as well as soil types, geology and mineralogy. physical-property tests, techniques of production, transportation, market trends, and other economic factors. The locations of the adobe operations were also plotted on various state and local geologic maps and on the U.S. Department of Agriculture county soils maps where available.

Adobe samples were collected from 56 locations and represent six types of adobe bricks produced or sold in New Mexico. The types of adobes (shown in table 2 with their average prices) are identified as: 1) traditional, 2) semistabilized, 3) stabilized, 4) terrón, 5) pressed adobe, and 6) burnt adobe (quemado).

Approximately 20 adobe bricks from each adobe producer were randomly collected for testing and delivered to the Rock Mechanics Laboratory at the New Mexico Institute of Mining and Technology in Socorro. The physical-property tests carried out at the laboratory included the compressive-strength and modulus-of-rupture tests on all six types of adobe bricks. The semistabilized and stabilized bricks were further tested for their percentage of water absorption and moisture content. They were also subjected to a 24-hr water-spray erosion test.

Information obtained from adobe producers, various architects, builders, and others confirmed that wide acceptance of adobe bricks exists in the state; the total production of all adobe yards is usually sold out by the end of November of each year. The 1980 summer market value for the three major types of adobes averaged $266.00 per thousand for the traditional adobe bricks, $278.00 per thousand for the semistabilized adobes, and $369.00 per thousand for the stabilized adobes. Transportation costs averaged an additional $100–$200 per thousand for delivery within a 100-mi radius of the adobe yard. The present market for all types of adobe bricks produced in New Mexico is primarily in the construction of adobe houses, greenhouses, walls, hornos, and room additions. Extensive use of adobes in the Indian pueblos and Spanish communities continues throughout the state.

Analyses of the clay-size fraction of New Mexico adobe-clay material, the New Mexico Uniform Building Code amendment on unburned clay masonry, and drawings of adobe-construction details and specifications for adobe materials have been included in the appendices of this report. The mineralogical studies on the majority of adobe-clay material collected were completed by the New Mexico Bureau of Mines and Mineral Resources in Socorro. The four clay-mineral groups that were identified include the high-aluminum kaolinite group, high-potassium illite group, calcium- or sodium-rich smectite group, and the mixed-layer illite-smectite group.

During the field work, only the adobe-brick producers that were actively manufacturing and selling commercially were sampled in detail. A total of 48 active producers were identified and were classified according to their 1980 production totals as 1) small-scale adobe producers (1,000–30,000 adobes), 2) medium-scale adobe producers (30,000–150,000 adobes), or 3) large-scale adobe producers (150,000–1,000,000 adobes). A total of 10 large-scale manufacturers of adobes produced 81% of New Mexico's total production. Not included in the state's adobe-production totals are the values for the thousands of adobe bricks pro-

TABLE 1-LIST OF COMMERCIAL ADOBE-BRICK PRODUCERS ACTIVE IN NEW MEXICO IN 1980 (for locations, see fig. 1).

Map no.	County	Name and mailing address	Telephone	Approximate production annual	Type production equipment
1	Bernalillo	New Mexico Earth P.O. Box 10506 Alameda, NM Richard Levine. Owner	898-1271	700.000	Front-end loaders. pugmill. wooden forms. and delivery trucks
2	Bernalillo	Western Adobe 7800 Tower Road. SW Albuquerque. NM Dean Leach. Owner	836-1839	250.000	Front-end loader. pugmill. Hans Sumpf type mechanical adobe layer. and delivery trucks
3	Bernalillo	Manuel Ruiz P.O. Box 104 Corrales. NM	898-22I8	175.000	Front-end loader. wooden forms, and delivery trucks
4	Bernalillo	Frank Gutierrez N.S. Rt. Box 595 Corrales. NM	898-1913	20.000	Front-end loader. wooden forms, and delivery truck
5	Bernalillo	Pete Garcia Box 46 Corrales. NM	898-2780	45.000	Front-end loader. wooden forms, and delivery truck
6	Bernalillo	Adobe Enterprises. Inc. 6000 Powersway. SW Albuquerque. NM Ernest Sanchez. Owner	877-4315	500.000	Front-end loader. wooden forms. and delivery trucks
7	Bernalillo	Lawrence Tenorio P.O. Box 555 Corrales. NM	898-8792	10.000	Front-end loader. plaster mixer. wooden forms. and delivery truck
8	Catron	Aragon/Garcia Adobes %General Delivery Aragon. NM	533-6411 533-6313	15.000	Front-end loader. wooden forms. and delivery truck
9	Eddy	Adobeworks 1204 Dallas Ave. Artesia. NM Jerry and Gladys Holt. Owners	No phone	30.000	Front-end loader. ready-mix truck. mechanical adobe layer. and delivery truck
10	Luna	Hachita Adobe 100 E. Peach St. Deming. NM Gordon Garland. Owner	546-6646	45.000	Front-end loader. cement mixer on tractor. wooden forms. and delivery truck
11	Mora	David Griego P.O. Box 66 Ledoux. NM	387-5183	7.000	Porta Press adobe machine
12	Mora	Robert Garcia %General Delivery Ledoux. NM	No phone	18.000	Hoe. shovel. wheelbarrow, and wooden forms
13	Otero	The Adobe Patch Rt. I. Box 240 Alamogordo. NM Robert Godby and Howard Scoggins. Owners	437-9932	350.000	Front-end loader, ready-mix truck. mechanical adobe layer. and delivery truck
14	Rio Arriba	Eight Northern Indian Pueblos Council P.O. Box 969 San Juan Pueblo. NM Dennis Duran. Mgr.	753-4846	436.000	Front-end loader. pugmill. Hans Sumpf mechanical adobe layer. and delivery trucks
15	Rio Arriba	Robert Ortega % General Delivery Dixon. NM	579-4261	30.000	Hoe. shovel. wheelbarrow, and wooden forms
16	Rio Arriba	Medina's Adobe Factory P.O. Box 44 Alcalde. NM Joe and Mel Medina. Owners	852-2467	50.000	Front-end loader. ready-mix truck. mechanical adobe layer, and delivery truck
17	Rio Arriba	Antonio Serrano P.O. Box 64 Cañones, NM	638-5530	1,000	Hoe. shovel, wheelbarrow. and wooden forms
18	Rio Arriba	Felix Valdez %General Delivery Cañones. NM	638-5446	5,000	Front-end loader. wooden forms. and delivery truck
19	Rio Arriba	Andy Trujillo %General Delivery Abiquiu. NM	No phone	6.000	Hoe. shovel. wheelbarrow, and wooden forms
20	Sandoval	Big "M" Sand & Cinder P.O. Box 33 Bernalillo. NM Tim Montoya, Mgr.	867-5498	9.000	Front-end loader, wooden forms, and delivery trucks
21	Sandoval	D. Sandoval/E. Trujillo P.O. Box 1283 Pena Blanca, NM	465-2972	2.000	Hoe. shovel, wheelbarrow, and wooden forms
22	San Juan	D. T. Wiley P.O. Box 879 Aztec, NM	334-6751	12.000	Front-end loader. wooden forms. and delivery truck

Map no.	County	Name and mailing address	Telephone	Approximate annual production	Type production equipment
23	San Miguel	Mariano Romero [illegible]	425-8202	10.000	Front-end loader and wooden forms
24	San Miguel	Danny Porter P.O. Box 18. Rt. 1 Pecos. NM	757-6422	14.000	Front-end loader and wooden forms
25	San Miguel	Robert Leyba P.O. Box 13 Pecos. NM	757-6234	8.000	Hoe. shovel. wheelbarrow. and wooden forms
26	Santa Fe	Adobe Farms Rt. 1. Box 193B Espanola. NM Ralph Rivera. Owner	753-4628	300.000	Front-end loader. ready-mix truck. wooden forms, and delivery trucks
27	Santa Fe	Oliver Trujillo Rt. 1. Box 187C Santa Fe. NM	455-2414	60.000	Hoe. shovels. wheelbarrow. and wooden forms
28	Santa Fe	Charles C de Baca Rt. 2. Box 246 La Cienega. NM	471-7949	4.000	Hoe. shovels. wheelbarrows. and wooden forms
29	Santa Fe	Edward Sandoval Rt. I. Box 834 Santa Fe. NM	455-744'	5.000	Hoe. shovels. wheelbarrows. and wooden forms
30	Santa Fe	Roman Valdez/James Lujan Rt. 1. Box 104-D Santa Fe. NM	455-2803	12.000	Hoe. shovels. wheelbarrows. and wooden forms
31	Santa Fe	Adrian Madrid 1580 Cerro Gordo Santa Fe. NM	No phone	20.000	Hoe. shovels. wheelbarrow. and wooden forms
32	Santa Fe	Victor Montano Rt. 6. Box 79A Santa Fe. NM	471-2038 983-1532	265.000	Front-end loader. wooden forms. and delivery trucks
33	Santa Fe	Eloy Montano 523 Barela Lane Santa Fe. NM	983-2172	235.000	Front-end loader. hoe and shovels. wooden forms. and delivery trucks
34	Santa Fe	Al Montano Rt. 2. Box 224 Santa Fe. NM	471-4227	2.000	Hoe. shovels. front-end loader. and wooden forms
35	Santa Fe	Albert E. Baca Rt. I. Box 99 Santa Fe. NM	455-7542	3.000	Hoe. shovels. and wooden forms
36	Santa Fe	Rodriguez Brothers Rt. 6. Box 22 Santa Fe. NM	471-7570	100.000	Hoe. shovels. front-end loader. wooden forms. and delivery trucks
37	Santa Fe	Tod Brown General Delivery Cerrillos. NM	No phone	3.000	Hoe. shovel. and wooden forms
38	Santa Fe	Montoya Adobes 420 Arroyo Tenorio Santa Fe. NM	No phone	10.000	Hoe. shovel. and wooden forms
39	Taos	Emilio Abeyta P.O. Box 177 Ranchos de Taos. NM	758-3022	12.000	Hoe. shovels. wheelbarrow. and wooden forms
40	Taos	Taos Pueblo Native Products P.O. Box 1846 Taos. NM Marrion Threehawks. Mgr.	758-8761	47.000	Backhoe. hoe. shovels. wheelbarrow. and wooden forms
41	Taos	Joe Trujillo P.O. Box 633 Ranchos de Taos. NM	758-9768	60.000	Front-end loader. ready-mix mounted on ground. wooden forms. and delivery truck
42	Taos	Ralph Mondragon P.O. Box 199 Ranchos de Taos. NM	758-3644	15.000	Pugmill, mud vehicle. and wooden forms
43	Taos	Joe Pacheco P.O. Box 174 Taos. NM	No phone	2.000	Hoe, shovel. wheelbarrow, and wooden forms
44	Torrance	Humberto Camacho P.O. Box 631 Mountainair. NM	No phone	5.000	Hoe. shovels. wheelbarrow. and wooden forms
45	Valencia	Rio Abajo Adobe Works 105 W. Aragon Been. NM Jerry Sanchez. Owner	864-6191	150.000	Front-end loader, wooden forms, and delivery truck
46	Valencia	Otero Brothers Rt. 2. Box 774 Los Lunas. NM	864-4054	40.000	Front-end loader. wooden forms. and delivery truck
47	State of Chihuahua. Mexico	Alfonso Carrillo Las Palomas. Mexico	No phone	30.000	Hoe. shovels. and wooden forms
48	State of Chihuahua. Mexico	Leonardo Duran Las Palomas. Mexico	No phone	5,00	Hoe. shovel. and wooden forms

TABLE 2--AVERAGE 1980 PRICES FOR VARIOUS TYPES AND SIZES OF ADOBE BRICKS PRODUCED IN NEW MEXICO. * indicates summer adobe-brick price averages for 38 traditional adobe producers, eight semistabilized, and six stabilized adobe-brick producers. ┼ indicates average price per terrón at Isleta Pueblo.

Type of adobe	Size of adobe (inches)	Average price/adobe
Traditional	10x4 x 14	26.6¢ *
Semistabilized	10 x4 x 14	27.8¢ *
Stabilized	10 x4 x 1[4]	36.9¢ *
Terrón	7 x 7 x 1 4	12¢ ┼
Pressed adobe (Porta Press)	10 x 3 x 14	35¢
Burnt adobe (quemado)	8 x 3½ x 16	25¢

duced by individual homeowners for their own construction projects, representing perhaps an additional 3—4 million adobe bricks per year.

As the adobe operations and their yards were visited, studies were carried out on production methods. Three major production techniques in use in the adobe industry were identified and are detailed in this report as 1) the traditional handcrafted method used by 17 adobe operators who produced 215,000 bricks, 2) the semimechanized method used by the majority of operators (23) who produced 1,742,000 adobe bricks, and 3) the mechanized method used by eight large-scale adobe manufacturers who produced a total of 2,176,000 adobe bricks.

History

A study of the earliest awakenings of human civilization reveals that the use of soil as a building material is among the oldest of technologies mastered by prehistoric man. The use of mud in construction evolved in several of the arid and semiarid regions of the world as early as 7000 B.C.; to this day, mud and soil remain the primary building materials in the housing of at least 50% of the world's population.

The word "adobe” has its roots in an Egyptian hieroglyph (fig. 2) denoting brick. The etymological chain of events ultimately yielded the Arabic "at-tob" or "al-tob" (sun-dried brick), which then spread to Spain in the form of the verb "adobar," meaning to daub or to plaster. Through Spanish conquests of the New World, the word adobe was brought to the Americas, where it still exists.

FIGURE 2-REPRODUCTION OF EGYPTIAN HIEROGLYPH OF QUEEN HATSHEPSUT MAKING A MUD BRICK (Fathy, 1973).

Today, adobe is generally used to describe various earth-building materials and techniques or the structures resulting from these methods. Most often the term has come to refer to the sun-dried adobe brick, the earth-building material now most widely used in the United States, but adobe can also be applied to puddled structures, adobe-plastered logs or branches, and even to rammed-earth ("pisé") construction. Generally any building that employs soil or mud as a primary material can be considered adobe.

Outlining a clearcut chronology of the development and spread of the use of adobe in ancient times is difficult, because such use probably emerged in many forms throughout the world as an independently contrived answer to one of man's most basic needs. Given the relative abundance of the material, understanding why experimentation with mud buildings was attempted by many ancient peoples is not difficult; probably the most accurate description of the origin of adobe is that of having many distinct yet overlapping roots. However, the development of the use of mud as a building material roughly parallels the birth and spread of the great ancient civilizations of the world. The Neolithic Period (10,000-3000 B.C.) marks the gradual replacement of the nomadic existence of the hunter-forager with that of primitive agriculture and the domestication of animals. Stable, nonmigratory existence began, and this early civilization brought with it efforts at building the first relatively permanent structures.

Among the earliest remains of adobe structures are those discovered in the ruins of Neolithic farming villages in Mesopotamia dating as far back as 7000 B.C. (Steen, 1972). Hand- and form-molded bricks from this era are also seen in the ruins of structures throughout Mesopotamia, Crete, Egypt, and India. The use of mud construction spread rapidly eastward through Asia and westward through North Africa and the Mediterranean Basin and, as the glaciers of the ice age receded in northern Europe, these peoples also began to use adobe in the construction of shelters. Meanwhile, the New World was undergoing a similar development. Although not used as early as in the great civilizations of the opposite hemisphere, use of adobe can be seen dating from as early as 3000 B.C. at the Chicama Valley in Peru (Steen, 1972).

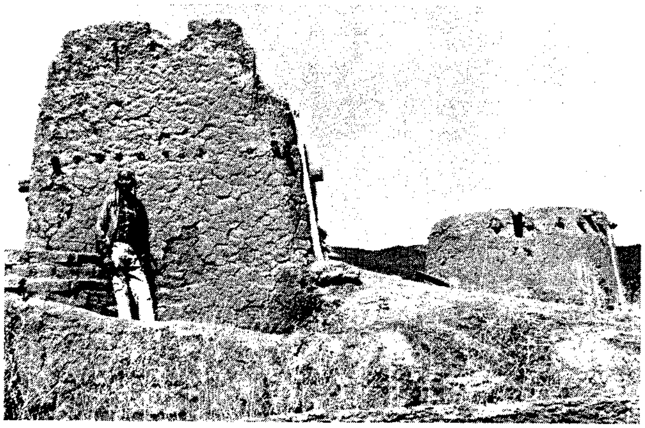


FIGURE 3-JESUS MERMEJO OF PICURIS PUEBLO STANDING NEXT TO THE OLD PUEBLO STRUCTURE BUILT OF PUDDLED ADOBE BETWEEN 1250 AND 1300 A.D.

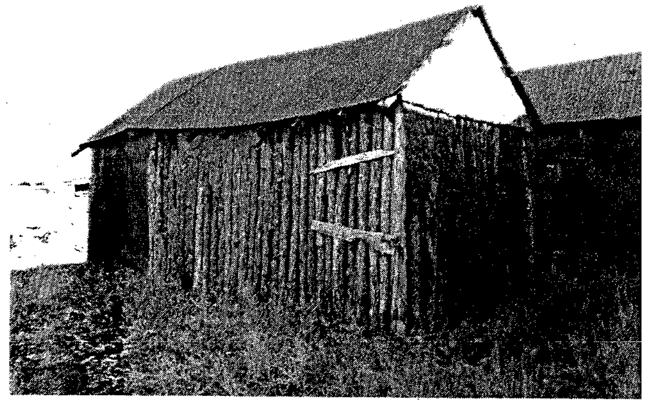


FIGURE 5-JACAL SHED COMBINED WITH TIN ROOF.

The first adobe construction in what is now the United States, however, probably does not predate the 10th or 11th century A.D. Since that time the region that now includes the state of New Mexico has undergone much development in its adobe architectural styles, incorporating contributions from the Indian, Spanish, and Anglo residents of the area to produce a distinct native New Mexican architectural landscape. The evolution of architectural styles in New Mexico can be roughly broken down into four periods—Indian, Spanish Colonial, Territorial, and later American (Bunting, 1976); but, regardless of period or style, construction of buildings has always revolved around adobe as a primary construction material.

What is known as the Indian period actually includes all architecture previous to the 1598 arrival of Spanish settlers in the area and can be broken down along archaeological lines into several distinct periods. The architecture of the Great or Classical period of pueblo Indian culture (Pueblo III--1050–1300 A. D.) includes many famous archaeological ruins of the southwest United States, including Pueblo Bonito at Chaco Canyon, old Picuris Pueblo, Sapawe, and the Pajarito Plateau site (Steen, 1977) within the state of New Mexico (figs. 3–4). Jacal (vertical wood posts chinked with adobe) and stone masonry combined with adobe were the techniques generally employed during this era (fig. 5).

The Pueblo IV division of the Indian period, spanning the years from 1275 A.D. to 1598 A.D., marks the migration of the pueblo Indians into the Rio Grande valley and is represented by such famous structures as the puddled-adobe multi-storied Taos Pueblo housing complex (fig. 6). Pueblo IV culture was markedly less advanced than that of Pueblo III, as evidenced in the less sophisticated building technology and smaller and less complex community organization of the period. Ruins dating from this time can be seen at Bandelier, Pecos, Hawikuh, and Kuaua (Bunting, 1976), although only at Taos has a structure dating from Pueblo IV times been continuously occupied.

The Pueblo V segment of the Indian period began after the 1598 arrival of the Spanish and continues to the present day. This latter period of the Indian style is marked by many rapid architectural changes and a general disintegration of pure Indian structures as the influence of Spanish and later-American newcomers encroached upon the pueblo communities.

Upon the arrival of the Spanish colonists in 1598, new building techniques and forms of architecture were introduced to New Mexico. Yet, because of the isolation of the region and the severe survival conditions imposed on the new settlers, the colonial era was characterized by little technical or cultural advancement. In fact, most building of this era was reduced to the barest essentials, and techniques and materials remained virtually unchanged from what the Indians had used before. A major contribution of the Spanish, however, was the introduction of the formed standard

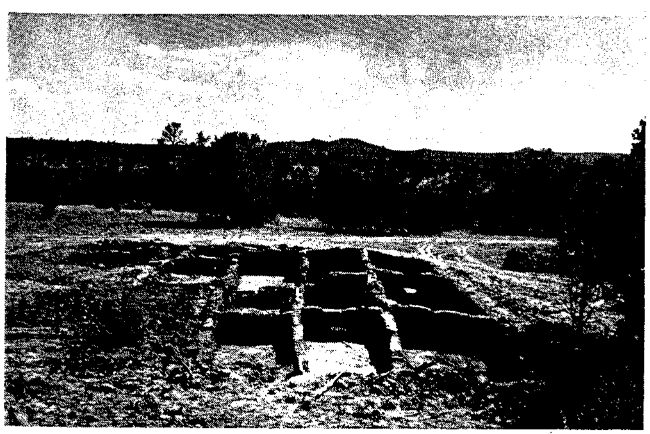


Photo by Los Alamos Laboratory

FIGURE 4-PUDDLED-ADOBE WALLS LOCATED AT THE PAJARITO INDIAN SITES NEAR LOS ALAMOS.

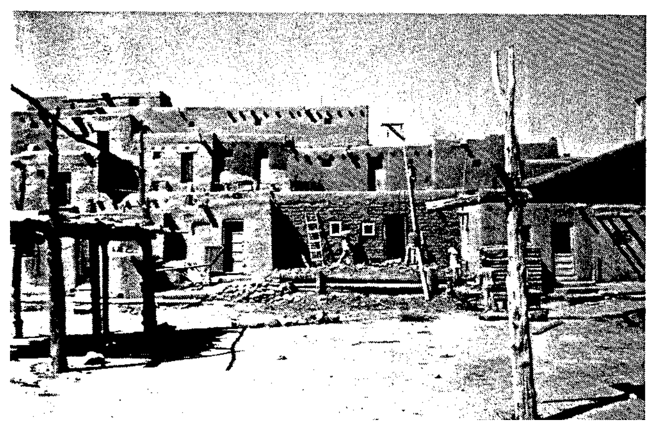


FIGURE 6—TAOS PUEBLO MULTISTORIED NORTH PLAZA BUILDING DURING ANNUAL PLASTERING WITH ADOBE MUD IN AUGUST 1980. Original structure was built of puddled adobe.

FIGURE 7-PASCUAL MARTINEZ HACIENDA IN TAOS, A TYPICAL ADOBE FORT STRUCTURE OF THE SPANISH COLONIAL PERIOD.

FIGURE 10—FELIPE S. DELGADO BUILDING IN SANTA FE, REPRESENTATIVE OF TERRITORIAL STYLE ARCHITECTURE.

FIGURE 8-PLAZA DEL CERRO. C^n-H_IM __AYO: this type of Spanish Colonial fortification was achieved by consolidating structures around four sides of an open space. Such fortified areas were referred to as plazas (Bunting, 1974).

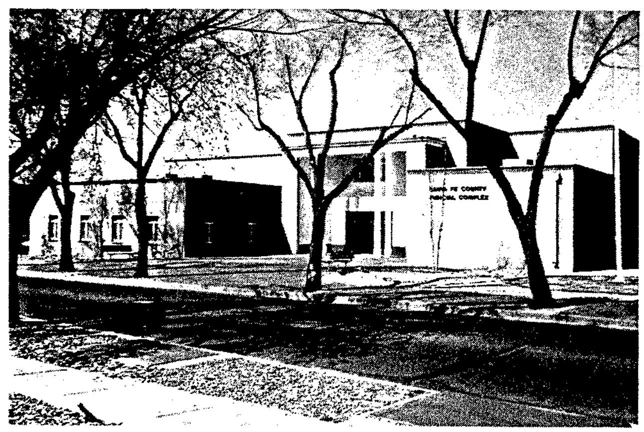


FIGURE 1 1-RECENTLY REMODELED SANTA FE COUNTY JUDICIAL COMPLEX. BUILT OF CEMENT BLOCK AND CONCRETE IN TERRITORIAL STYLE.

FIGURE 9-BORREGO BUILDING IN SANTA FE, A CHARACTERISTIC TERRITORIAL BUILDING WITH A PORTAL.

FIGURE 12 T Y P I C A L SANTA FE STYLE ARCHITECTURE, WITH SURROUNDING ADOBE WALLS AND FLAT ROOFS.

adobe brick to the Indian population of the area (Bunting, 1976). In addition, the classic Spanish linear floor plan also began to appear, sometimes forming around a central plaza area for defense (Bunting and others, 1964; figs. 7 and 8). Another notable architectural characteristic of the Spanish and Mexican Colonial period is what was known as "fortress churches"—solid, rectangular, adobe churches that resembled fortresses in their imposing size and lack of fenestration.

With the opening of the Santa Fe Trail in 1821, influences from the east and midwest United States began to trickle slowly westward, and upon annexation of the territory of New Mexico in 1848, the flow of new materials and ideas increased. The Territorial period was one of rapid economic and cultural development that contrasted markedly with the centuries of cultural isolation and stagnation that directly preceded it. This change is reflected clearly in the architecture of the period, which went through several phases. However, the new style was in essence nothing more than a transported version of the Greek Revival style that had been popular in the East in the 1820's. The Territorial style is probably best known for its elaborate neo-Classic wood trim on windows and doors, the symmetrical floor plan based around a center hall, two-story construction, and columned verandas (Bunting, 1976). The influx of new materials such as milled lumber, window glass, burned brick (used to trim the tops of adobe walls), and corrugated iron contributed to the new modem American look of New Mexican architecture. Many people felt traditional adobe architecture was jeopardized during the Territorial period (figs. 9-11). Some attempt was even made to disguise adobe-building material completely with a cement coating that was scored to resemble ashlar masonry; additionally, some curious examples of elaborate Gothic-style wood trim occurred.

The later American period began with the arrival of the railroad in New Mexico in 1880, yet this style did not reach some of the more remote mountain villages until after World War II. During this period, many diverse architectural movements from California and the East were represented simultaneously as New Mexico rushed to catch up with the rest of the country. The availability of iron, improved tools and fittings, and other manufactured items hastened New Mexico's arrival in the 20th century. In addition, pueblo-like architecture was experiencing a rebirth in what became known as the Santa Fe style, which is now associated in the minds of many people with the soft, earth-tone, curvilinear adobe architecture of this area (fig. 12). All these influences, covering a period of thousands of years yet always with adobe as a common denominator and timeless reminder of the Indian, Spanish, and Anglo heritages of the region, have contributed to form a unique and eclectic blend of architecture that continues to visually distinguish New Mexico from the rest of the nation.

Terminology and characteristics

Bricks

Adobe has a long history of widespread use by the Indians, Spanish, and Anglo-Americans in the southwest United States. Fig. 13 is a map showing the areas most suitable for adobe construction (Hubbell, 1943) and outlines the locations of low annual precipitation where most adobe construction in the United States can be found today. However, the use of adobe need not be restricted to arid and semiarid climates if the buildings are properly protected or certain soil stablizers are used (Hubbell, 1943). In fact, examples of earth-wall construction can be found from the New England states to South Carolina in climates that are far from arid or semiarid. Modern residences of earth-wall construction have been built since 1920 in Washington, D.C., Michigan, North Dakota, Idaho, Illinois, Arkansas, Oklahoma, Colorado, Wyoming, and in all the southwest states (Long and Neubauer, 1946).

The introduction of the wooden form by the Spanish in the late 1600's permitted the adobero (adobe maker) to control the size and weight of the bricks, which in turn allowed for greater construction flexibility. Many sizes of adobe bricks with considerable variation in weight have been produced in the Southwest. Long and Neubauer (1946) noted brick weights from early California adobe structures that varied from 30 to 100 lbs.

Dimensions (inches)	Weigh (lbs)
4x 8x16	30
4x 9x18	38
4x12x18	50
5x 9x18	48
5x12x18	60
6x12x24	100

The adobe bricks that are produced today in New Mexico vary from the small mosque-type bricks of 3 x 5 x 10-inch size, which weigh 8 lbs and are used in the construction of domes and arches, to the Isleta Pueblo terrón brick of 7 x 7 x 14-inch size, which weighs 35 lbs. The principal size adobe brick manufactured (97%) today by the majority of adobe producers in New Mexico is the 10 x 4 x 14-inch brick that averages 30 lbs in weight. Other sizes of bricks are made that are usually produced only in limited quantities or on special order (table 3).

During the course of this investigation, over 75 adobe producers were located. A total of 48, including two adoberos in Las Palomas, Mexico, were actively producing or selling within the state in 1980. Adobe-brick samples were collected from 56 locations and were tested at Socorro. The adobe producers were classified as small-, medium-, or large-scale manufacturers. Their estimated combined dollar value for production for the three major types of adobe bricks

FIGURE 13-AREAS SUITABLE FOR ADOBE CONSTRUCTION; shaded areas are those where adobe is used for building; area included in dashed lines is that recommended for adobe construction, except those mountainous regions having normal annual precipitation of more than 20 inches (after Hubbell, 1943).

(traditional, semistabilized, and stabilized) totaled $1,174,598 in 1980, accounting for the commercial production of 4,133,000 bricks (table 4).

During the study many questions were raised, considerable discussion occurred, and much advice was offered about the quality and characteristics of adobe bricks. Some agreed advantages of adobe as a construction material are as follows:

1) Adobe is a native material that is widely available throughout the state at little or no cost to individuals willing to produce their own adobe bricks.
2) Adobe bricks were reasonably priced in 1980, averaging 26.6 cents for a traditional 10 x 4 x 14-inch adobe for those wishing to purchase bricks from a local adobe yard.
3) Adobes are adaptable to most types of new housing construction including solar-designed buildings and certain types of commercial structures.
4) Test results as noted in the section on physical properties show that the majority of adobes meet the Uniform Building Code and the New Mexico State Building Code for strength and durability.
5) Buildings of adobe are fire resistant, unaffected by termites, and good sound insulators.
6) Traditional, semistabilized, and stabilized adobe bricks have excellent durability and resistance to erosion by wind and sandstorms, thus requiring little maintenance.
7) Semistabilized and stabilized adobe bricks are resistant to penetration and degradation by water and, because they remain so dry, provide an especially comfortable and healthy thermal environment.
8) The traditional adobe structure, coated with a protective cement scratch cover and stucco, is fully protected against excessive wear and weather. A well-maintained traditional adobe building, plastered with nothing but adobe mud, can also be extremely durable as is demonstrated by the 900-yr-old Taos Pueblo buildings and the over 300 yrs of continuous governmental use of the Palace of the Governors building in Santa Fe (fig. 14).

TABLE 3--NEW MEXICO ADOBE-BRICK SIZES AND WEIGHTS.

Type of adobe	**Dimensions (inches)**	**Weight (lbs)**
Egyptian brick	3 x 5 x 10	8
Veneer brick	4 x 4 x 16	26
Half adobe	4 x 4 x 8	23
Burnt adobe (Las Palomas, Mexico)	8 x 3 ih x 16	30
New Mexico standard adobe	4 x 10 x 14	30
Adobe (old style)	4x 5 1/2 x 16	28
Adobe (old style)	4x 12 x 18	50
Mexico (standard Las Palomas adobe)	3½ x 10 x 16	35
Taos standard adobe	4 x 8 x 12	26
Hydra Brikcrete pressed adobe	3 5/8 x 10 x 14	30
Porta Press pressed adobe	3 x 10 x 14	35
Tenon (Isleta Pueblo)	7 x 7 x 14	35
Dome brick (mosque)	2 x 10 x 6	8
CINVA-Ram pressed adobe	3 3/4 x 5 'h x 1 1/2	20

Soils

Adobe soil is a term applied to clay and silt deposits that are acceptable for use in the production of adobe bricks and

TABLE 4-ESTIMATED 1980 ADOBE-BRICK PRODUCTION TOTALS. * indicates summer adobe-brick price averages for 38 traditional adobe producers, eight semistabilized, and six stabilized adobe-brick producers.

Type of adobe	**Average* price/adobe**	**Estimated production total**	**Estimated dollar value**	**Percentage of total production**
Stabilized	36.9e	460,000	169, 740.00	11
Semistabilized	27.8	2,320,000	644,960.00	56
Traditional	26.6	1,353,000	359,898.00	33
Totals	30.4e	4,133,000	$1,174,598.00	100%

FIGURE 14-PALACE OF THE GOVERNORS IN SANTA FE, BUILT IN 1613.

usually are found in the basin areas of New Mexico where they have been exposed to weathering for many years. The majority of the state's cities and villages have examples of adobe construction utilizing local adobe soil. An especially suitable adobe soil is found in New Mexico's Rio Grande basin area that extends from Colorado to the Texas border. This is a sandy loam consisting of roughly 55—75% sand and 25—45% finer material, usually composed of equal parts of silt and clay. Traditional, semistabilized, and stabilized adobe bricks have essentially the same soil requirements and can be made from a wide variety of soils.

Soils are made up of finely divided particles of mineral and organic matter. A good agricultural soil containing loam, silt, and organic matter is not suitable for adobe bricks, while soils higher in clay and sand content, poor for crop production, are usually more satisfactory for adobes. Too much clay will cause excessive shrinkage during drying and cracks will develop. Too much sand will result in bricks that crumble easily because they lack sufficient binder to hold the grains together (California Research Corporation, 1963). In many cases the adobe maker will blend together two or more otherwise unsuitable soils to produce a mixture with the desired properties for use in adobe bricks.

In the evaluation of potential adobe soils, various grain-size classifications are used by different engineering and scientific groups. Most of the classifications distinguish between sand and the finer silt and clay material at some grade size near the 200 mesh sieve size. Most soils can be placed in five categories identified as gravels, sand, silts, clays, and organic material. The soils used for making adobes in New Mexico are usually a mixture of sand, silt, and clay which varies considerably in depth and thickness at a specific location. A sieve is used to measure and classify the particle size as a percent that passes through or is retained by the various sized sieves. The Uniform Building Code specifications and the New Mexico State Code (appendix 2) state that soils to be used in making sun-dried bricks must have from 55—75% sand content and a 25—45% content of finer material (silt and clay sizes). The finer grained fraction should contain sufficient clay to bind the coarser particles strongly together (Construction Industries Division, 1979). The Unified Soil Classification system published by the U.S. Department of Interior (table 5) includes the range of soils (group symbols SM and SC) related to adobe-brick making (DOI, 1974).

Another consideration when selecting a proper adobe soil is the strength of the finished sun-dried brick. The compressive-strength specification of the New Mexico State Building Code (Construction Industries Division, 1979) requires 300 pounds per square inch (psi) and the tensile-strength specification (modulus of rupture) requires 50 psi. Generally clay provides the strength of the brick, although it should not be added in overly high proportions as it depends on its bonding properties with sand to produce an adequately strong brick.

Soils containing a large amount (more than 0.2%) of soluble salts are unsuitable for use in making semistabilized and stabilized adobe bricks as the soluble salts interfere with the bonding of asphalt films to the clay particles. Because salts also slow the curing rate of bricks, a longer period is required (30 days) before the bricks can be used in construction. Such soils are peculiar to arid and semiarid regions of the Southwest (California Research Corporation, 1963).

Several preliminary tests on soils can be performed by the adobe producer to aid in the selection of a proper adobe soil prior to making the bricks. The gravity-separation test (jar test) has been effectively used in many areas of the state. In this test the soil is placed with water in a glass jar with vertical sides and shaken until it is well mixed. The soil is then allowed to settle in layers. The coarser material (sand and gravel) will settle at the bottom and the finer silt and clay particles will settle above them. One can then estimate the various percentages of sand, silt, and clay contained in the soil. Other simple tests that determine the properties of local soils have been outlined in the *Handbook for building homes of earth* (Wolfskill and others, 1970) and include visual tests, wet-shaking tests, thread tests, ribbon tests, and dry-strength tests.

Although experiments have been carried out for years to determine which soils will make a satisfactory earth wall, a reliable system of soil selection still does not exist. The final test of a soil to determine its suitability for adobes is to make several full-sized (10 x 4 x 14 inches) bricks of the selected adobe material, allowing them to dry prior to evaluation. The soil should be easy to mix and mold and upon drying should not warp or crack excessively. The bricks should also be sufficiently strong to withstand transporting and handling.

The Soil Conservation Service (SCS) has mapped by county the soils of major areas in New Mexico. The soils are usually investigated to depths of up to 5 ft, and the maps classify soils according to color, structure, texture, physical constitution, chemical composition, biological characteristics, and morphology (DOI, 1974). Usually the soil surveys that have been conducted in various New Mexico counties contain a table or section on engineering classifications and estimated properties of local soils. Of particular value to an adobe producer who is interested in securing a supply of adobe soil is the section on estimated soil properties significant to engineering and test data showing the percentage of material passing a number 4 to a 40 sieve (sand material) and the percentage passing a number 200 sieve (clay and silt material). The *liquid limit* and *plasticity index* indicate the effect of water on the strength and consistency of the soil material. The acidity or alkalinity of the soil is expressed in pH values; the salinity refers to the amount of soluble salts in the soils (Hacker, 1977). The adobero should pay particular attention to the shrink-swell potential of the soil material, which changes with the moisture content because of the amount of clay in the soil material. A low to moderate shrink-swell potential in adobe soils will usually produce an adequate

TABLE 5-UNIFIED SOIL CLASSIFICATION INCLUDING IDENTIFICATION AND DESCRIPTION (from U.S. Department of the Interior, 1974). [1]*Boundary classifications*—soils possessing characteristics of two groups are designated by combinations of group symbols. For example, **GW-GC** means well graded gravel-sand mixture with clay binder. [2]All sieve sizes on this chart are U.S. standard; the no. 200 sieve size is about the smallest particle visible to the naked eve. Adooted by Corps of Engineers and Bureau of Reclamation, January 1952

Field identification procedures (Excluding particles larger than 3 inches and basing fractions on estimated weights)				Group symbols[1]	Typical names
Coarse-grained soils More than half of material is larger than no. 200 sieve size[2]	**Gravels** More than half of coarse fraction is larger than no. 4 sieve size.	**Clean gravels** (Little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes	**GW**	Well graded gravels, gravel-sand mixtures, little or no fines
			Predominantly one size or a range of sizes with some intermediate sizes missing	**GP**	Poorly graded gravels, gravel-sand mixtures, little or no fines
		Gravel with fines (Appreciable amount of fines)	Nonplastic fines (for identification procedures see **ML** below)	**GM**	Silty gravels, poorly graded gravel-sand-silt mixtures
			Plastic fines (for identification procedures see **CL** below)	**GC**	Clayey gravels, poorly graded gravel-sand-clay mixtures
	Sands More than half of coarse fraction is smaller than no. 4 sieve size.	**Clean sands** (Little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate particle sizes	**SW**	Well graded sands, gravelly sands, little or no fines
			Predominantly one size or a range of sizes with some intermediate sizes missing	**SP**	Poorly graded sands, gravelly sands; little or no fines
		Sands with fines (Appreciable amount of fines)	Nonplastic fines (for identification procedures see **ML** below)	**SM**	Silty sands, poorly graded sand-silt mixtures
			Plastic fines (for identification procedures see **CL** below)	**SC**	Clayey sands, poorly graded sand-clay mixtures

Identification procedures on fraction smaller than no. 40 sieve size

		Dry strength (Crushing characteristics)	Dilatancy (Reaction to shaking)	Toughness (consistency near plastic limit)	Group symbols[1]	Typical names
Fine-grained soils More than half of material is smaller than no. 200 sieve size	**Silts and clays** Liquid limit less than 50	None to slight	Quick to slow	None	**ML**	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity
		Medium to high	None to very slow	Medium	**CL**	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		Slight to medium	Slow	Slight	**OL**	Organic silts and organic silt-clays of low plasticity
	Silts and clays Liquid limit greater than 50	Slight to medium	Slow to none	Slight to medium	**MH**	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		High to very high	None	High	**CH**	Inorganic clays of high plasticity, fat clays
		Medium to high	None to very slow	Slight to medium	**OH**	Organic clays of medium to high plasticity
Highly organic soils		Readily identified by color, odor, spongy feel, and frequently by fibrous texture.			**Pt**	Peat and other highly organic soils

adobe brick. Where necessary, a high clay-content soil with a higher shrink-swell potential can be blended with additional sand or straw to prevent cracking.

The majority of adobe soils used in the Albuquerque and Española Basin areas are largely derived from the Santa Fe Formation (Tertiary) and are associated with recent alluvial plain, arroyo, floodplain, and terrace deposits. In the Española Basin area, the material is usually a sandy loam that is classified by the U.S. Department of Agriculture as the Fruitland series. Soil samples taken in December 1980 from the San Juan Pueblo adobe site and a Santa Fe adobe soil location were screen tested and the results are shown in table 6.

The gradation test and Atterberg-limits test are frequently used together as a method for determining very generally the amount and types of clay contained in a soil sample and the relative plasticity of those clays. Test figures like those shown in table 6 can be used as a quality-control device. Regardless of present or future sources of adobe material, similar test results will ensure similar physical properties and the least amount of variation in the quality of the adobe bricks.

The two soil samples in table 6 are representative of soils used in the Albuquerque and Espanola Basin areas. The test results on the Santa Fe sample indicate a soil possessing characteristics of two groups: SM, a relatively clean to slightly silty sand, and SC, a clayey sand. The sample from San Juan Pueblo is a clayey sand with greater plasticity; the higher the plasticity index, as indicated in the Atterberg-limits test, generally the greater the plasticity of the sample.

Stabilizers

Adobe makers have always experimented with additions to the traditional adobe soil mix of clay and sand in an effort

TABLE 6-GRADATION AND ATTERBERG-LIMITS TEST RESULTS ON ADOBE SOILS FROM SAN JUAN PUEBLO AND SANTA FE. Adobe soils tested were acquired during land leveling of the adobe yard at San Juan Pueblo and during removal of the overburden in the Santa Fe area. Tests were done by the Albuquerque Testing Laboratory in 1980.

	San Juan Pueblo	Santa Fe
	Gradation test (cumulative % passing)	
(sieve size) ⅜"	100	100
no. 4	100	88.1
no. 10	99.9	72.5
no. 40	54.4	26.4
no. 80	29.5	16.9
no. 200	29.3	16.5
Atterberg-limits test (% water on material passing no. 40 sieve)		
Liquid limit	27.9	24.3
Plastic limit	16.1	15.8
Plasticity index*	11.8	8.5

*Plasticity index represents the difference between the liquid limit and the plastic limit. Generally, the higher the plasticity index, the more plastic the sample.

to improve upon the many different qualities of the finished adobe brick. Attempts to increase resistance to moisture and weathering, to prevent excessive shrinkage and cracking, or to increase the bonding strength of the brick have resulted in the addition of substances as varied as straw, animal blood, and molasses. Wolfskill and others (1970), in the *Handbook for building homes of earth,* list over 20 stabilizers that have been used commonly throughout the world to improve one or more qualities of adobe bricks. Here in the United States, however, in commercial and individual production, this number is limited to only a few added substances, the most common of which are sand, straw, portland cement, lime, and bituminous and asphalt emulsion (Clifton, 1977). Although the addition of such stabilizers adds to the cost of the basic adobe brick, great value is derived from the increased durability and overall higher quality of the final brick.

The common practice of adding either clay or sand to an existing soil to achieve the proper percentages for making adobes that neither crack excessively nor crumble too easily can be considered a form of stabilization, as is the addition of straw used as a deterrent to shrinkage in bricks with a fairly high clay content. Straw does not improve water resistance or the strength of the brick, however, and, in many cases, may be added more for reasons of aesthetics or tradition than because of any actual benefit to the brick.

Probably the most widespread reason for adding stabilizers to soil bricks is the desire to increase the water resistance of the finished product. The single biggest drawback of traditional unstabilized adobes is their lack of water resistance and susceptibility to rapid erosion in heavy rains. Moisture re-entering an adobe brick will cause the clay particles to swell and release their bonding so that the entire mass will slump. For the waterproofing of adobe bricks, bituminous and asphalt emulsion and portland cement are the most commonly used stabilizers; cement also contributes additional strength and bonding power to the brick. Commercial producers in New Mexico use asphalt emulsion exclusively as a stabilizer in the manufacture of adobe bricks because of its relatively low cost and superior mixing and waterproofing properties. In 1980, approximately 67% of the adobes produced in the state by the large-scale manufacturers (table 4) were semistabilized or stabilized adobes made with asphalt emulsion.

In the Albuquerque and Española Basin areas, the majority of adobe producers purchased their asphalt emulsion from the Chevron USA, Inc. (formerly American Bitumuls and Asphalt Company) asphalt plant located in Albuquerque. In the fall of 1980, the price for the emulsion was $140 per ton (237 gal) or approximately $0.60 per gal. Because the recommended percentage of emulsion to be used per fully stabilized (treated) adobe brick is between 5—8% by weight, the emulsion price adds a stabilizer cost of approximately 8—12 cents per adobe brick over the cost of a traditional adobe. However, the majority (56%) of the adobe manufacturers in New Mexico produce a semistabilized adobe brick containing approximately 2—3% asphalt emulsion by weight and costing an estimated 5—7 cents per brick for the stabilizer addition. Table 7 shows the state highway specifications for Arizona, New Mexico, and Texas on the Cationic Emulsified Asphalt slow set (CSS-1), which is the same stabilizer used by the adobe manufacturers. In New Mexico the slow-setting CSS-1 and CSS-lh are the most commonly used and readily available types of asphalt emulsion.

The following brief explanation of asphalt-emulsion specifications as they relate to adobe-brick manufacturing has been furnished by the Chevron Research Company of California (personal communication, 1980, formerly California Research Corporation):

VISCOSITY-This is important only as it affects handling and application of the emulsion. The viscosity needs to be in an optimum range to give proper spreading and mixing with aggregate in road work. Since the emulsion is mixed with water or added to moist soil in brick making, it is not an important factor as long as the emulsion can be pumped or handled easily.

PARTICLE CHARGE-This test is used to distinguish between anionic and cationic emulsion and is sometimes important in determining the wetting and spreading characteristics with some aggregates. However, we do not have any data relating to the application of the test in soils work. In our experience, if the asphalt emulsion can be diluted with water or mixed with moist soil without coagulation, there will not be any mixing problems. Both anionic and cationic emulsions have been used successfully for stabilizing adobe bricks. However, not all emulsions work; the difference depends on the particular emulsifier and asphalt source used. Good performance in making adobe bricks is not necessarily indicated by any of the emulsion specification tests. Any emulsion being considered should be tested by using it to make a small batch of test bricks. Water resistance and cracking of the cured bricks are the critical factors. Only emulsions of the "slow-setting" type should be considered as this type of emulsion has sufficient stability to allow thorough mixing with the soil without coagulation.

RESIDUE FROM DISTILLATION-This test is to determine the amount of asphalt in the emulsion. This is typically in the range of 60–65 wt%. Its value is mainly to assure the purchaser that he is getting full value.

TESTS ON RESIDUE-Penetration and ductility tests performed on the residue from the distillation tests are made to determine the physical properties of the asphalt used in making the emulsion. The lower the penetration value the harder the asphalt. Emulsion grades designated with an "h" suffix are generally used for brick making because they contain a somewhat harder asphalt than emulsion used for some

TABLE 7-CATIONIC EMULSIFIED-ASPHALT *SLOW-SET* SPECIFICATIONS FOR *ARIZONA. NEW* MEXICO, AND TEXAS (from

State	Asphalt grade (cationic slow set)	Residue by distillation weight % min	pH max	Particle charge[3]	Consistency test: Viscosity @ 77° F SFS[4] min	Consistency test: Viscosity @ 77° F SFS[4] max	Stability tests: Demulsibility $CaCl_2$ %	Stability tests: Settlement (5 day) % max	Stability tests: Cement mixing % of break max
Arizona	CSS-1	57	6.7		20	100		5	
	CSS-1h	57	6.7		20	100		5	
New Mexico	CSS-1	57	6.5	positive	20	100		5	2.0
	CSS-1h	57	6.5	positive	20	100		5	2.0
Texas	EA-CSS-1	60		positive	20	100		5	2.0
	EA-CSS-1h	60		positive	20	100		5	2.0
	Test designation no.								
	ASTM[1]	D-244	standard pH test	D-244	D-88		D-244	D-244	D-244
	AASHTO[2]	T-59	standard pH test	T-59	T-59		T-59	T-59	T-59

[1]ASTM, American Society for Testing Materials.
[2]AASHTO, American Association of State Highway and Transportation Officials.
[3]If particle-charge test is inconclusive, materials having a maximum pH value of 6.7 will be acceptable.
[4]SFS, Saybolt Furol Seconds.

other paving uses. This gives better resistance to softening at high temperatures. Possibly the other grades may also be satisfactory in this respect, but we do not have any data upon which to make a recommendation.

The best explanation of the theory of asphalt stabilization of adobe soil is in the California Research Corporation (1963) report on the manufacture and use of asphalt-emulsion stabilized adobe bricks. Because of its importance I quote it here:

THEORY OF ASPHALT STABILIZATION OF ADOBE SOIL- Asphalt stabilization is based upon the fact that clay is the only portion of a soil or aggregate which is unstable in the presence of moisture and that by changing this fraction to a stable material, the entire mass of soil or aggregate is stabilized.

The clay which binds the coarser particles of soil together when wetted and then dried consists of particles of such extreme fineness that they have colloidal properties. Water mixes with clay-bearing soils very easily and quickly breaks down and penetrates all hard clods, wetting and separating the finest particles. Due to the great total surface areas of the fine particles of which it is composed, clay has a tremendous capacity for absorbing water.

Emulsified Asphalt Soil Stabilizer (American Bitumuls and Asphalt Company) comprises asphalt globules of microscopic size surrounded by and suspended in a water medium. It is completely dispersable in water; a few drops perceptibly color a large amount of clear water and remain suspended without any breakdown or coalescence of the asphalt. The Stabilizer is stored and used at above freezing atmospheric temperature at which it is always fluid.

When the Stabilizer is mixed into a clay-bearing soil or aggregate in the presence of sufficient water to separate and wet all fine particles of clay, the water carries the asphalt globules into direct contact with the surfaces of the clay particles. The water-carrying capacity of the clay many times exceeds that of the sand and small rock particles; therefore, practically all of the asphalt in the Stabilizer is brought into close contact with the clay. As the evaporation of the water progresses, the asphalt globules are drawn out by adsorption into very thin films so dense that they become practically solid and unremovable upon the surface of each clay particle. The amount of asphalt required is very small, as compared to most other methods of coating particles, and darkens the soil only to a very slight extent.

When fully dry, the entire mass of soil thus treated is found to have about the same firmness and compressive strength as the untreated soil mixed with water only, then dried. The cohesion of the clay particles is not interfered with. However, since the asphalt films are repellent to water, the clay particles cannot become wetted again. Some absorption of water may occur upon prolonged exposure due to hydrostatic pressure and the natural void structure of the material, but the fine clay particles do not expand and lose cohesion in the presence of such moisture. The so-called affinity for water previously possessed by the clay is found to no longer exist.

The comparative water resistances of traditional, semistabilized, and stabilized adobe bricks are shown in fig. 15. This photograph shows three stacks of adobe bricks, one each of traditional, semistabilized, and stabilized bricks. The stacks were subjected to 30 min of a water spray from an ordinary garden hose at a water pressure of 40—50 lbs. The photograph shows that the traditional adobes were completely destroyed in 30 min, whereas the semistabilized and stabilized adobe bricks experienced no erosion damage at all.

Molding forms

The construction and design of the wooden molding forms used to make adobes are as numerous and varied as are the makers of adobes themselves. Many typical sizes and types

ASTM, 1969; AASHTO, 1978; Chevron USA, Inc.— Asphalt Division, personal communication, 1980).

		Examination of residue						
Sieve test % retained max	Coating ability	Ash content weight % max	Solubility $Cl_2C{:}CHCl$ min	Penetration of needle under 100 g load @ 77° F for 5 s min	max	Ductility @ 77° F cm min	Storage stability (1 day) % max	Float test
.10			97.0	100	200	40		
.10			97.0	40	90	40		
.10				100	200		1	
.10				40	90		1	
.10		2.0	97.5	120	160	100	1	
.10		2.0	97.5	80	100	100	1	
D-244	D-244	D-2415	D-2042	D-5		D-113	D-244	D-139
T-59	T-59		T-44	T-49		T-51	T-59	T-50

of molding forms can be seen in use in New Mexico today; some of the more common ones are illustrated in fig. 16.

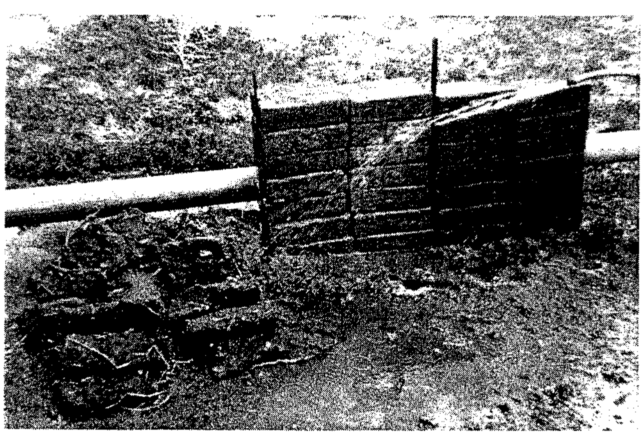
Adobe molding forms made of wood have been used for centuries and usually are made of dry clean fir or pine (Lumpkins, 1977). Traditionally, the sides, ends, and divider members used in making the wooden molding forms are 4 inches wide and produce a full 4-inch thickness for the adobe. While some adobe producers still utilize molding forms of this size, a great many of today's adobe manufacturers are now using standard fir or pine 2 x 4's to build their forms (figs. 17 and 18). As these cuts of lumber are actually only 3½ inches wide, they yield a molding form producing a smaller, lighter adobe averaging 27—30 lbs in weight and usually from 3½ to 3⅝ inches thick when fully dry.

Traditional adobe makers with small-scale production operations generally use a two- or four-adobe wooden molding form which can be handled by a single individual. Larger scale adobe producers will typically have several hundred wooden molding forms resembling ladders that are called gang molds. They may vary from seven to ten molds per form. In several cases, single molding forms constructed of standard 2 x 4's were observed that were capable of producing up to 48 bricks per form. Molding forms of this large size usually require two or more persons to lift the form from the drying bricks.

Several of the large-scale adobe producers also soak or spray their wooden molding forms with old crank-case oil that is usually thinned with gasoline (fig. 19). This is done to keep the wood from absorbing too much water and also to allow the adobe mud to slide from the frame with a minimum of sticking and washing. However, the majority of traditional adobe producers using the two- or four-mold form still wash their wooden molding forms after each lifting of the form from the adobes. Many of the traditional adobe producers also use a water tank or pit to soak their wooden molding forms prior to use (fig. 20). Another antisticking method employed by several adobe makers is the application of a thin metal liner to the interior side of the wood molding form. These thin sheets of aluminum, tin, or other sheet metal eliminate the need to oil or wash the forms after each adobe laying (fig. 21). In some cases, adobe molding forms were constructed entirely of steel, aluminum, or plastic. An example of a steel six-adobe form used in the Nambé, New Mexico, adobe yard of Roman Valdez and James Lujan for the molding of several thousand adobes in 1980, is shown in fig. 22.

A hand-operated mobile brick-molding machine called the "Adobemaster" was used during the summer of 1980 at Medina's Adobe Factory located in Alcalde, New Mexico. The machine molds 24 10 x 4 x 14-inch bricks per form (fig. 23). The Adobemaster equipment is manufactured in Austin,

FIGURE 15-WATER-SPRAY TEST ON THE THREE MAJOR TYPES OF ADOBE BRICKS: after 30 min of water at 40—50 lbs of pressure, the pile of traditional adobes dissolved completely.



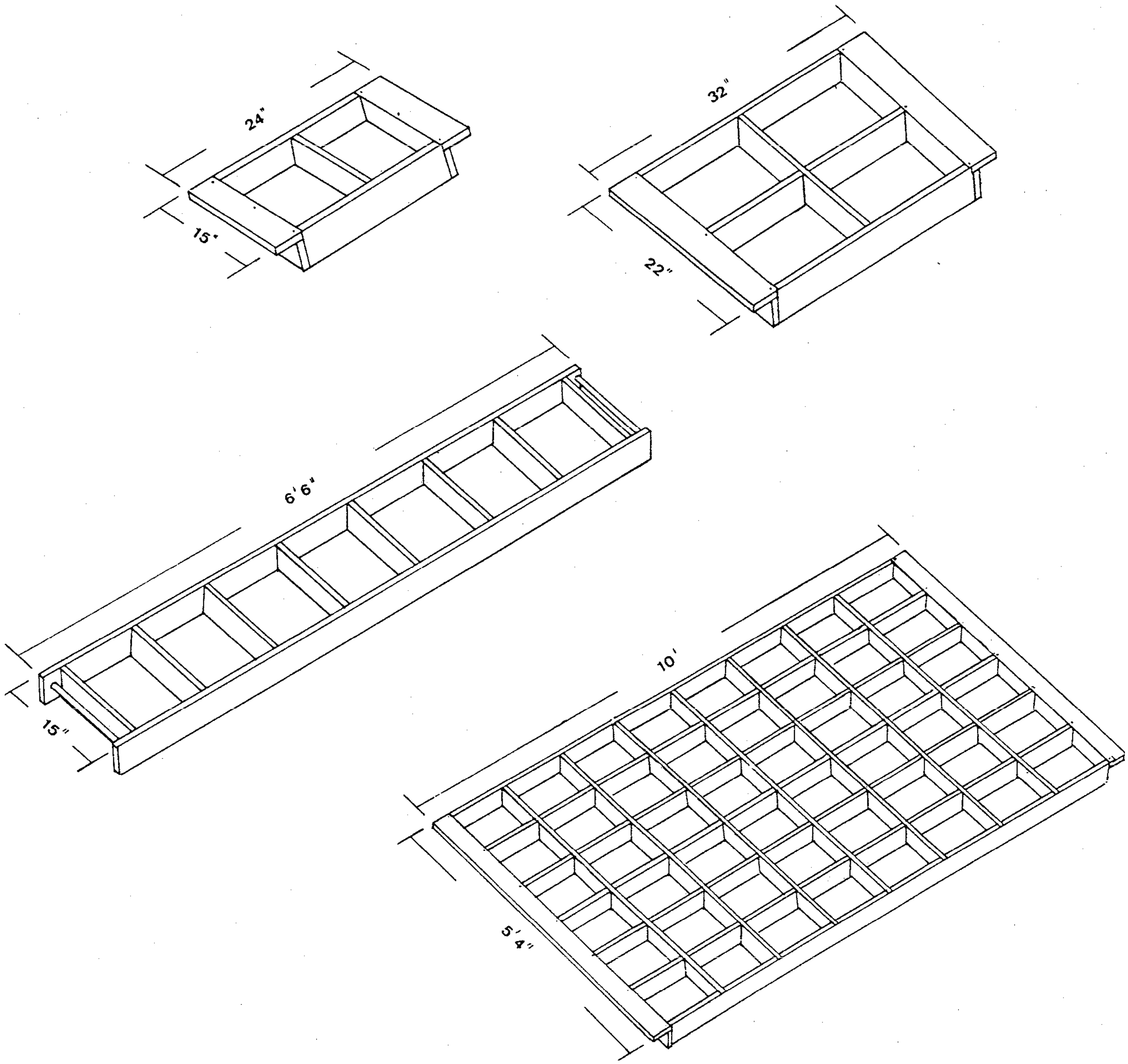


FIGURE I6-DIAGRAMS OF TYPICAL NEW MEXICO WOODEN MOLDING FORMS WITH APPROXIMATE OVERALL DIMENSIONS.

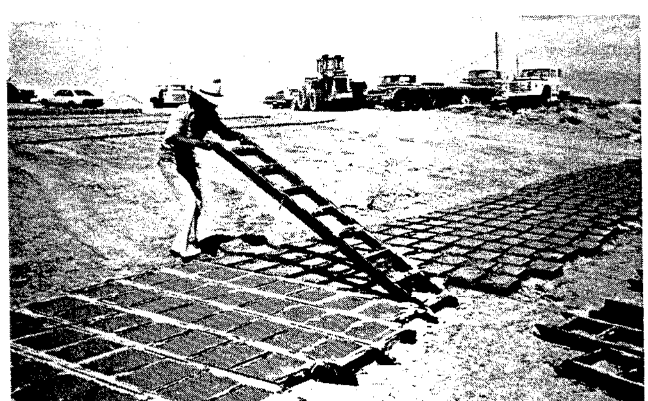


FIGURE I7—LIFTING OF SEVEN-MOLD WOODEN FORM MADE OF 2 x 4's; Adobe Enterprises, Inc., Albuquerque.

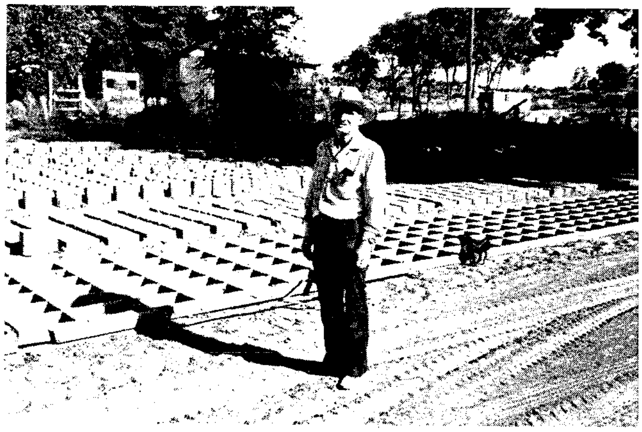


FIGURE 18-LARGE GANG-MOLD WOODEN FORM MADE OF 2 x 4's; D. T. Wiley adobe yard, Aztec.

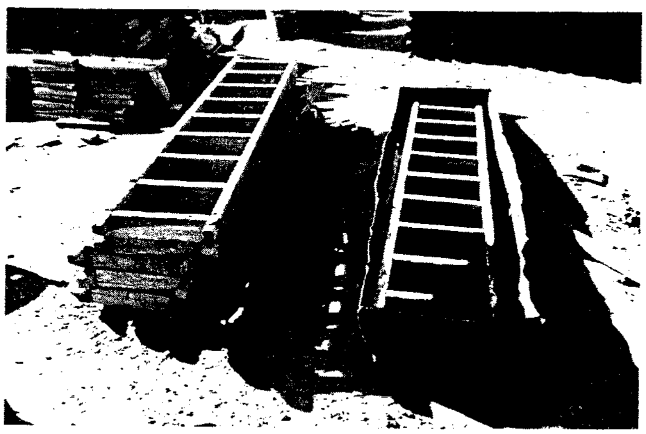


FIGURE 19-WOODEN MOLDING FORM SOAKING IN OIL TANK; Adobe Enterprises, Inc., Albuquerque.

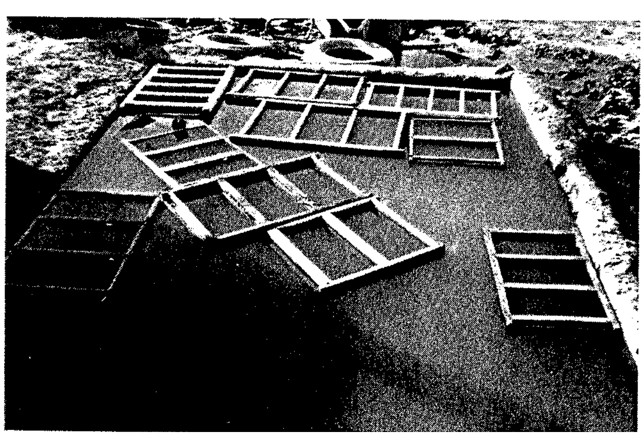


FIGURE 20—VARIOUS SIZES OF WOODEN MOLDING FORMS SOAKING IN WATER PIT; Alfonso Carrillo adobe yard, Las Palomas, Mexico.

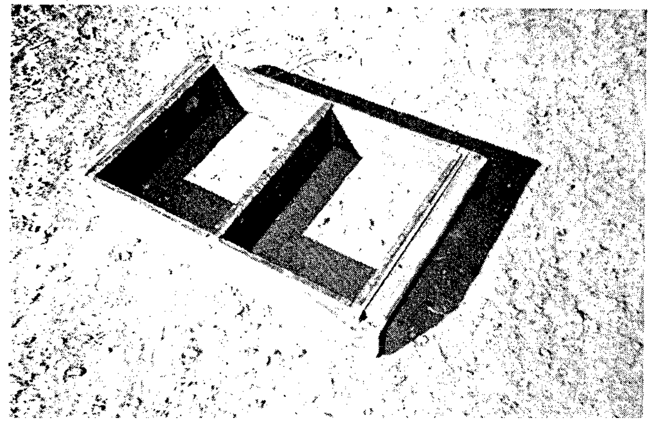


FIGURE 21-TWO-MOLD WOODEN FORM; a lining of sheet metal has been added to prevent adobes from sticking.

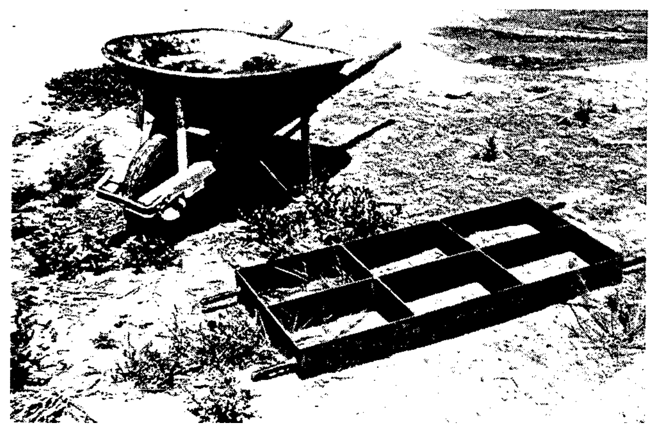


FIGURE 22—SIX-MOLD STEEL FORM; adobe yard of Roman Valdez and James Lujan, Nambé.

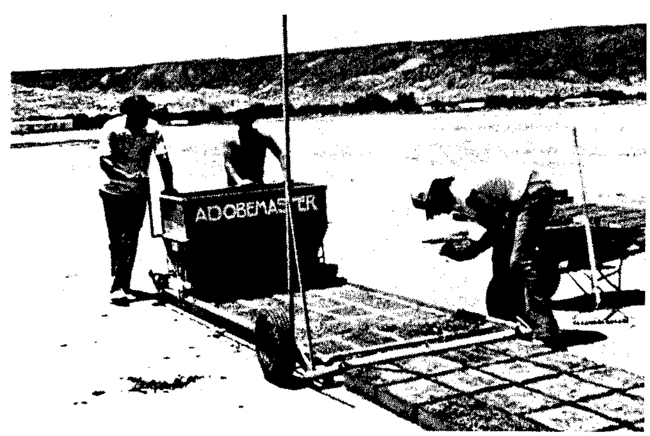


FIGURE 23-HAND-OPERATED 24-MOLD BRICK-LAYER CALLED THE "ADOBEMASTER", Medina's Adobe Factory, Alcalde.

Texas, and in 1980 sold for approximately $2,500 per unit. Various interchangeable molds are available for the machine that can be used to produce several different sizes of adobe bricks.

In the more mechanized adobe-production operations, the self-propelled mechanical adobe layer is generally used in place of wooden molding forms. The mechanical adobe layer was developed by the Hans Sumpf Company adobe operation located in Madera, California. The machine is currently manufactured by the Structural Steel Company of Pinedale, California, and was priced in 1980 from $25,000 to $28,000 per machine. The equipment utilizes a standard 25-brick metal molding form, but molds of other sizes, including those for custom-designed bricks, may also be used. A diagram of the machine, with its general dimensions, is shown in fig. 24, and the adobe layer in operation is shown in figs. 25 and 26. Many advantages are apparent in using this system, chief among them the savings in labor, as the hand lifting of molding forms is entirely eliminated. Other advantages include the consistently uniform quality of the adobes produced and the facility with which various different sizes of adobe can be produced by a simple change of the metal form. The owners of The Adobe Patch in La Luz (approximately 1 mi north of Alamogordo) and the Adobeworks in Artesia have developed their own mechanical adobe layers. The equipment attaches to the ready-mix trucks that pour the adobe mud into the metal molding form, producing 42 bricks at a time (fig. 27).

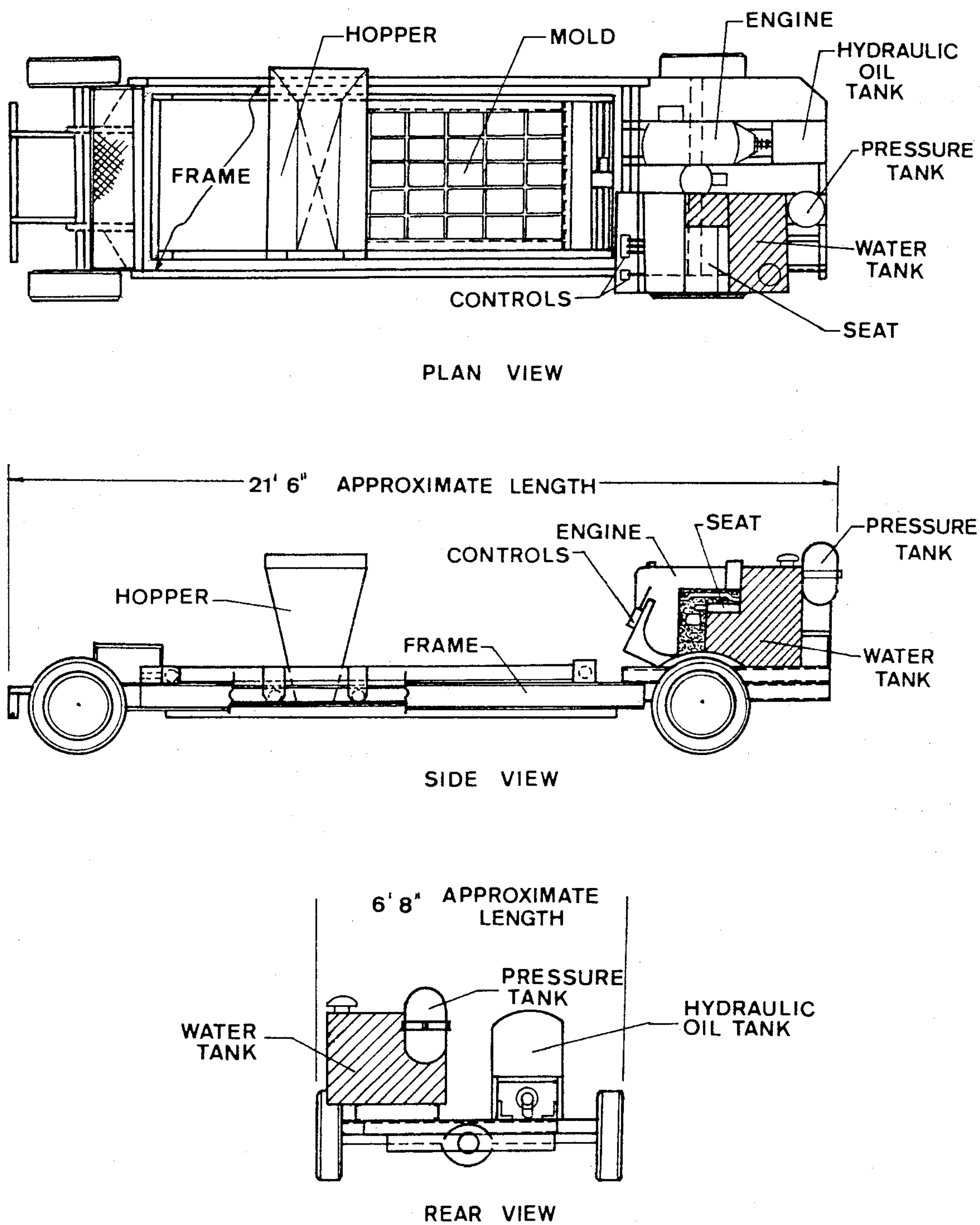


FIGURE 24-DIAGRAM OF HANS SUMPF MECHANICAL ADOBE LAYER.

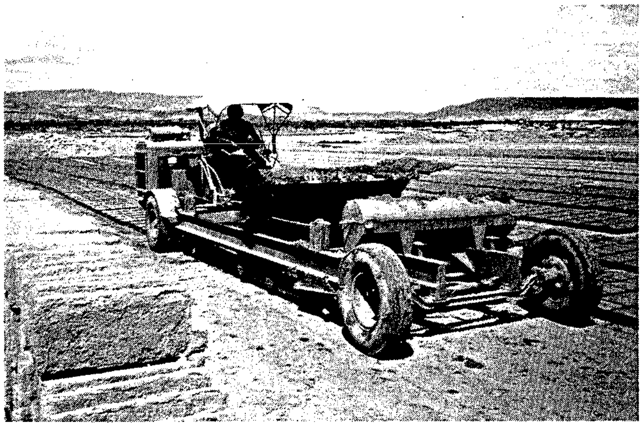


FIGURE 25-MECHANICAL ADOBE LAYER IN OPERATION Eight Northern Indian Pueblos Council adobe yard, San Juan Pueblo.

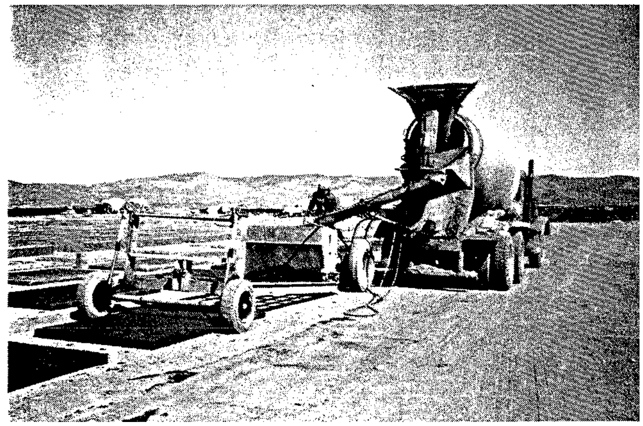


FIGURE 27-MECHANICAL ADOBE LAYER ATTACHED TO READY-MIX TRUCK: The Adobe Patch, La Luz.

Traditional bricks

Often referred to as an untreated, unstabilized, or standard sun-dried adobe brick, the traditional adobe is made with soil composed of a uniform mixture of clay, sand, and silt, usually with straw added to the brick to prevent it from cracking while being cured.

Traditional adobe construction has been used in all climates and under many adverse weather conditions throughout the world. Examples of traditional adobe bricks can be found in the majority of cities, villages, and pueblos of New Mexico. The durability of adobe structures that are carefully maintained is well illustrated by the multistoried Taos Pueblo structure, which has been continuously inhabited for over 900 yrs by the Taos Pueblo Indians. Many other examples of existing, old, traditional adobe architecture can be seen in the numerous Spanish mountain villages of New Mexico, including adobe structures that are over 300 yrs old. In many of these villages, adobe was combined with logs in jacal construction, or was used as mortar with native field stone in addition to the traditional sun-dried brick construction (fig. 28). During the field investigation, several samples of very old adobe bricks were removed from various adobe buildings and their physical properties tested for the purpose of comparison with present-day sun-dried bricks. The results show that the bricks, ranging in age from 45 to over 145 yrs old, tested very well compared to today's bricks.

At Taos Pueblo, Ranchos de Taos, and many other sites of old adobe structures, loving care and continual maintenance are necessary requirements for building longevity. Two types of brick protection were noted, one a simple adobe-mud plaster, which needs periodic reapplication, (figs. 29–31) and the other a more permanent cement stucco applied over a wire mesh (fig. 32). The major problem in the use of the traditional adobes is the risk of excessive erosion because of heavy rains. As the majority of old adobe structures in New Mexico were built on field-stone or river-rock foundations with mud mortar, undercutting of the walls at ground level is the most common cause of structural failure due to weathering (fig. 33). In many areas of the state, the owners of adobe structures have added tin-roof sheds with proper overhangs in an effort to help protect the adobe walls and dirt roofs from this type of erosion (fig. 34). To prevent this problem in new structures, the New Mexico State Building Code requires that all foundation walls that support adobe units extend to an elevation not less than 6 inches above the finish grade (Construction Industries Division, 1979).

Although the majority of commercial adobe producers visited during this survey were making traditional adobe bricks, their total production in 1980 was only 1,353,000 bricks. However, if we add the estimated production of 3–4 million additional bricks by individuals for their own construction projects, nearly all of which are untreated bricks, the traditional adobe still emerges as the type seen most widely in New Mexico today.

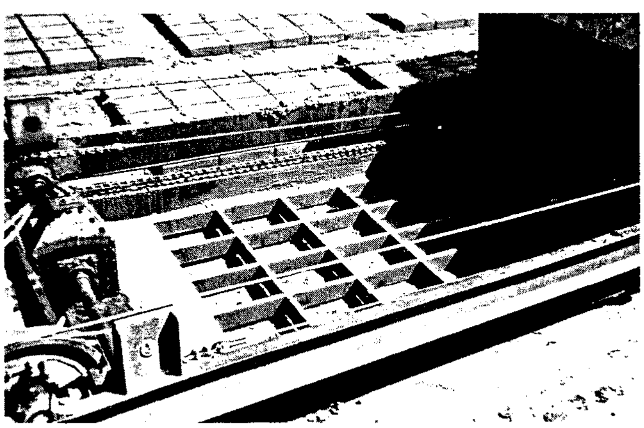


FIGURE 26-TWENTY-FIVE-MOLD STEEL FORM FOR PRODUCING 10 X 4 x 14-INCH ADOBE BRICKS IN MECHANICAL ADOBE LAYER.

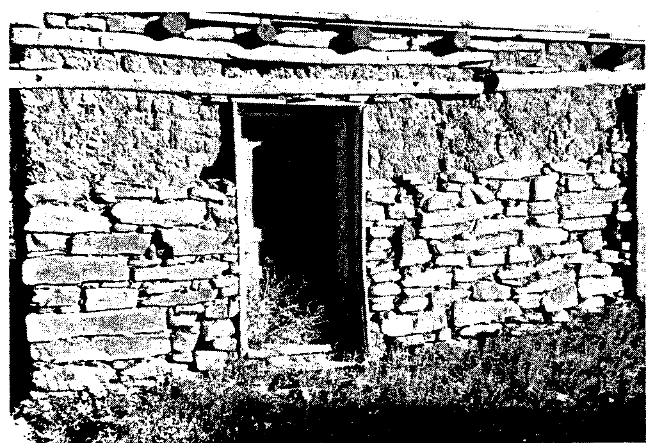


FIGURE 28-COMBINATION OF FIELD STONE AND ADOBE BRICKS. SAN JOSE.

FIGURE 29-SCREENING ADOBE SOIL FOR REPLASTERING HOMES IN TAOS PUEBLO.

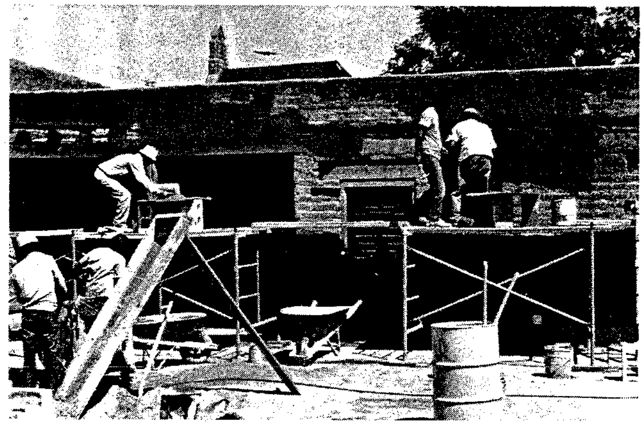


FIGURE 32—APPLICATION OF STUCCO WIRE OVER EXTERIOR OF ADOBE BRICKS AND ADDITION OF CEMENT COAT; final finish will be colored stucco.

FIGURE 30—PLASTERING NORTH PLAZA AREA OF TAOS PUEBLO DURING SUMMER OF 1980.

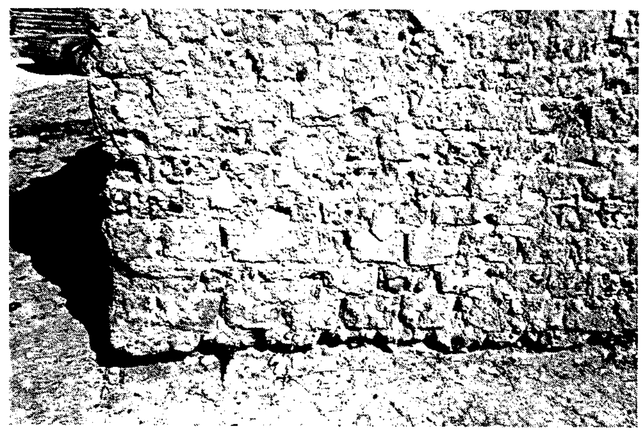


FIGURE 33-UNDERCUTTING OF ADOBES AT GRADE LEVEL; note size of gravel in adobe bricks.

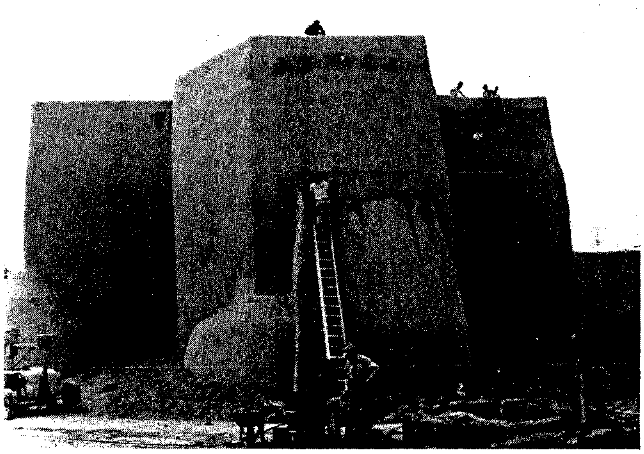


FIGURE 31--FAMILIES PLASTERING THE OLD CHURCH IN RANCHOS DE TAOS WITH ADOBE MUD.

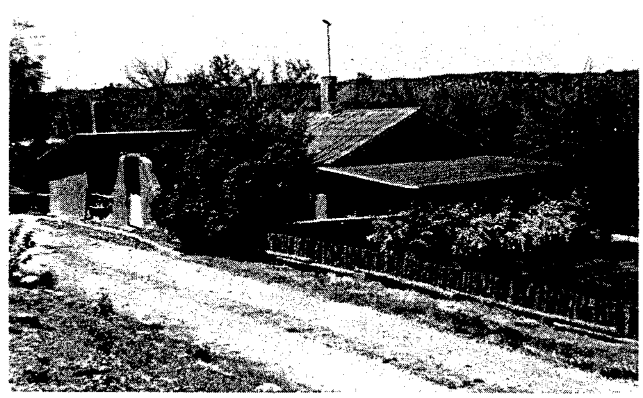


FIGURE 34-OLD TIN-ROOFED ADOBE HOUSE BELONGING TO AUTHOR. LOCATED IN TESUQUE. Roof was added to protect original adobe long-house structure and to cover dirt-roof area.

In the cold climates of New Mexico, the adoberos produce their adobes in the warm summer months and stockpile certain quantity for the building projects that will be under construction in the winter and early spring months. During the summer, these bricks sold for prices ranging from 19 to 35 cents per brick, yielding an average of 26.6 cents per brick. Usually the commercial adobe producer raises these prices by 20–30% during the off-production season or winter months.

Semistabilized bricks

The semistabilized adobe brick is a relatively new classification in adobe-production terminology and was developed by large-scale adobe producers to describe the practice of adding a small amount of stabilizing material to the adobe in order to obtain a somewhat water-resistant brick. Made in essentially the same way as the traditional adobe, the percentage of asphalt emulsion added is usually 50% less than the amount used to produce the fully stabilized adobe brick, or approximately 2–3% emulsion by weight in the final product. Tests made on several samples obtained from various producers of semistabilized bricks showed considerable variation in percentages of water absorption, moisture content, and erosion characteristics. Several of the semistabilized adobes tested were of the quality of a fully stabilized brick and would have easily passed the New Mexico State Building Code requirements for a treated (stabilized) adobe brick.

Limited tests on the percentage of asphalt emulsion in several of the semistabilized, sun-cured adobe bricks indicated that the adobes contained an average of 1.5–3.8% by weight of asphalt emulsion. Several laboratory methods are available for determining the amount of oil in adobe bricks. According to R. L. Ferro of California (personal communication, 1981), the best method is that of solvent extraction. This is accomplished by placing a weighed sample of crushed adobe in a filter paper thimble in a Soxlet extractor. The extractor is connected to a heated flask and a reflux condenser. Chloroform, or some other organic solvent, is boiled in the flask; the vapor condenses and is caught in the Soxlet extractor, from which it siphons back into the boiling flask. After several hours the adobe sample has been treated many times with the solvent, and the asphalt content has been concentrated in the flask. The contents of the flask are then evaporated on a hot plate to leave only the asphalt residue. The flask is weighed and the weight of the asphalt residue is used to calculate the percentage of asphalt solids in the adobe. Since some clay fines may be washed down from the extractor into the flask, the solvent solution should be settled and decanted or filtered before the final evaporation.

In discussion with several of the large-scale adobe producers, clearly the main interest was in using asphalt emulsion to produce bricks that are resistant enough to penetration by water that the bricks in the drying yards are protected from the destruction which would otherwise be caused by a sudden snow or rainstorm during the critical drying period. In the same way, an individual purchasing semistabilized adobes is not obliged to cover the adobe stack at the construction or storage site in order to protect the bricks from weathering and erosion before use. Several examples of the durability and water resistance of the adobes, as well as buildings constructed with semistabilized adobe bricks that have been left unplastered, are shown in figs. 35–37. Also

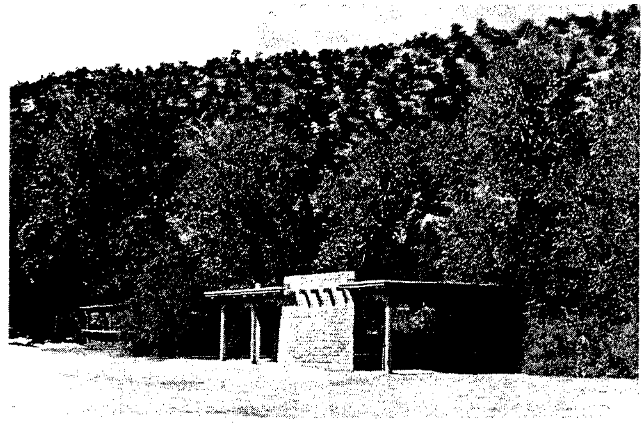


FIGURE 35—PICNIC RAMADA, CONSTRUCTED OF STABILIZED ADOBE BRICKS AT NAMBÉ FALLS RECREATION AREA.

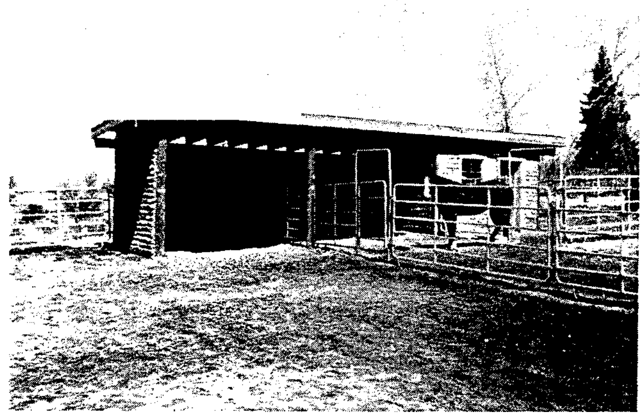


FIGURE 36--TACK ROOM AND HORSE SHEDS, CONSTRUCTED OF SEMISTABILIZED ADOBE BRICKS AND LEFT UNPLASTERED.

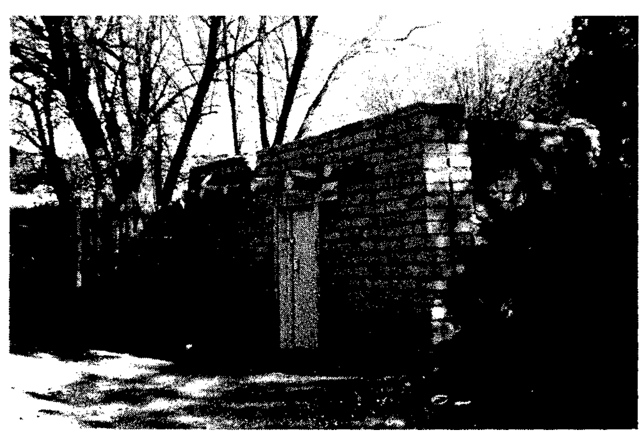


FIGURE 37-ROOT CELLAR, BUILT OF SEMISTABILIZED ADOBE BRICKS, TESUOUE.

under construction during 1980 and using semistabilized adobes was the Dar-Al-Islam mosque located in Abiquiu, New Mexico (fig. 38A—C).

Six adobe producers in 1980 manufactured 2,320,000 semistabilized bricks for 56% of the state's total production (table 4). Prices for the bricks varied at the adobe yard from a low of 22 cents to a high of 32 cents, for an average price of 27.8 cents per adobe.

Stabilized bricks

The fully stabilized adobe, referred to in the New Mexico State Building Code as a treated adobe, is defined by the addition of a sufficient amount of stabilizer to limit the brick's 7-day water absorption to less than 2.5% by weight. The fully stabilized adobe bricks sold commercially in New Mexico were all manufactured with 5—12% asphalt emulsion, which resulted in a superior adobe brick.

The advantages of construction with asphalt-stabilized adobe bricks outlined in the California Research Corporation report (1963) are as follows:

1) RESISTANT TO PENETRATION AND DEGRADATION OF WATER:

Stabilized adobe bricks are repellent to moisture from all sources, including rain, fog, dew, and even capillary moisture from the ground. They will not swell, shrink, warp, rot, or disintegrate from prolonged contact with moisture and are the driest masonry known. A healthy atmosphere is promoted within the dwelling by the absence of dampness.

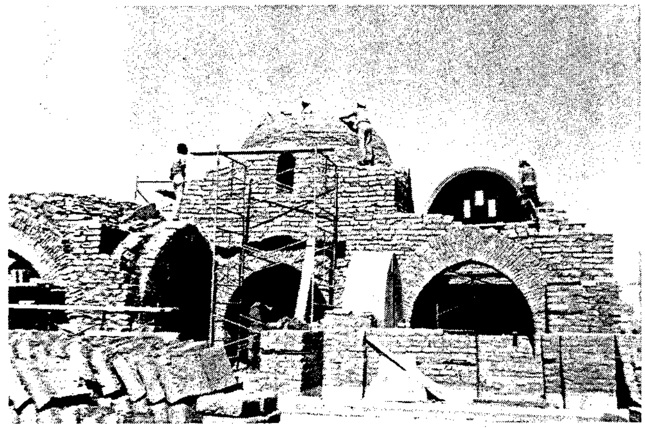
The approximated capillary absorption of various materials when their lower surface, without protective water-resistant coating, is kept continuously in contact with wet sand in a moisture cabinet is as follows:

Material	Water absorption %	**Time**
Light-Weight Cement Bricks	20–25	24 hours
Burnt Brick	8–12	24 hours
Cement Mortar (Stucco)	8–10	24 hours
Wood	4–8	24 hours
Asphalt-Stabilized Adobe Brick	2.5–3.0	7 days

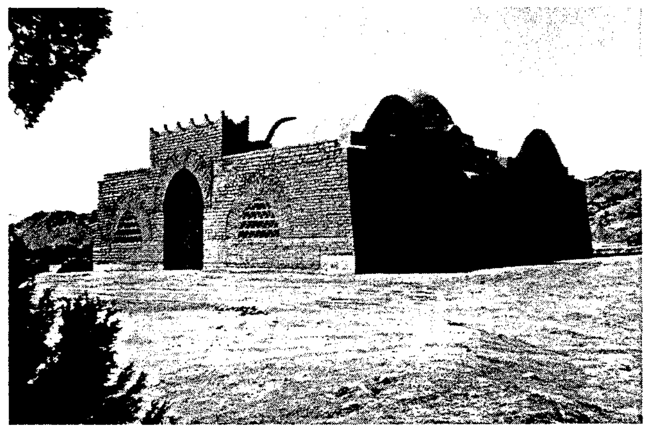
When materials other than asphalt-stabilized soil bricks are used in the construction of new buildings, the exposed exterior surfaces are generally protected by a waterproof paint or coating. Nevertheless, they will still be highly vulnerable to penetration by moisture throughout their interior if the protective coating cracks or peels, if it weathers to low efficiency, or if there is leakage at the joints. Consequently, periodic maintenance is definitely needed if these materials are to retain their waterproof properties over the years. Asphalt-stabilized adobe bricks, on the other hand, are relatively maintenance free because the interior, as well as the exterior, is stabilized against moisture.

2) HAS EXCELLENT INSULATING QUALITIES-Because stabilized adobe brick walls always remain dry, they have excellent natural insulating properties. Buildings are easily heated with a minimum of fuel in cold weather and retain the heat as does no other type of conventional construction. They are comfortable in hot weather, usually having an inside temperature considerably lower than the outside atmospheric temperature.

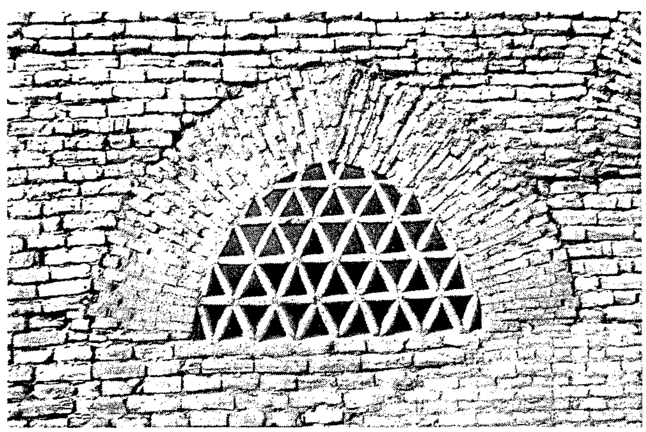
The "K" factor for various types of masonry materials are: asphalt-stabilized adobe brick (4.0), common fired brick (7.7), concrete (9.0), and limestone (9.0).



A-UNDER'CONSTRUCTION DURING 1980 WITH SEMISTABILIZED ADOBE BRICKS.



B-OVERALL VIEW OF MOSQUE.



C-COMPLETED ARCH AND WINDOW DETAIL BEFORE PLASTERING.

FIGURE 38—DAR-AL-ISLAM MOSQUE, ABIQUIU.

"K" is defined as the thermal conductivity; i.e., the quantity of heat in Btu's that flow in a unit time (1 hour) through a unit area of plate (1 square foot) of unit thickness (1 inch) for a unit difference of temperature (1° F) between its bases.

In determining the "K" factor, it is necessary that the material be absolutely dry. The above figure for materials such as firebrick, concrete, and limestone might be doubled or even tripled in value when a small amount of moisture is present. Since asphalt-stabilized adobe bricks have excellent resistance to penetration by moisture and remain relatively dry at all times, they have exceptional insulating qualities. Their low rate of heat transfer makes them particularly well suited for use in constructing buildings which require an abnormal inside temperature (i.e., refrigerated or cold storage buildings).

3) DURABILITY IS GOOD-Stabilized adobe bricks resist the erosion of wind and sandstorms to a far greater degree than untreated [traditional] adobe bricks and require less maintenance. The thick walls of well-designed adobe buildings also have good resistance to damage by earth-quake stresses.

4) TERMITEPROOF—Stabilized adobe brick walls are completely unaffected by termites, dry rot, and other destructive insects, thus promoting the durability of the wood used to construct the roof and fittings such as door and window frames.

5) FIREPROOF—Walls made with either treated [stabilized] or untreated [traditional] adobe have no fire hazard, and the structure is completely fireproof if noncombustible interior fittings such as floors, windows, and door frames, are used.

6) STABILIZED ADOBE STRUCTURES ARE SAFE—Because stabilized adobe is waterproof, structures built with this material have little tendency to disintegrate or collapse under exposure to prolonged or extreme moisture conditions. Properly manufactured stabilized bricks meet...[the Uniform Building Code and New Mexico State Code]... requirements as a construction material.

7) PAINTING IS EASILY ACCOMPLISHED-Stabilized adobe bricks may be painted or colored to any shade desired for those who do not care for natural earth color. The waterproof quality of this material permits the decorative coating on its surface to be exceptionally durable.

8) COST IS REASONABLE—Stabilized adobe brick construction has a low materials cost and furnishes good opportunity for fabrication by the owner himself, using either commercially-made or home-made bricks. In many cases the soil in the immediate vicinity of the construction site can be used. Stabilized adobe buildings are far superior in living comforts and durability to all of the other types of similar cost range in common use, most of which are of much less substantial design. Generally, sun-dried adobe bricks are less expensive to make as compared to common fired clay bricks. In the manufacture of fired bricks, a suitable fuel is required to provide the high temperatures used. Often this fuel is scarce, and the cost of producing fired bricks is prohibitive.

Figs. 39—44 illustrate the durability and versatility of semistabilized adobe bricks.

In 1980 seven adobe manufacturers were producing a fully stabilized adobe brick with the majority using the CSS-1 type of asphalt emulsion largely purchased from Chevron USA, Inc. of Albuquerque, New Mexico, at $140 per ton. A total of 460,000 stabilized adobe bricks were produced and sold for an average price of 36.9 cents per brick, for a total value of approximately $169,740.00. The production totals normally would be higher; however, the cost of the asphalt emulsion, which adds from 8 to 12 cents to each adobe brick, presently limits the market. The majority of adobe producers usually limited their manufacture of stabilized bricks to specific orders only. Three manufacturers, 1) The Adobe Patch of La Luz, New Mexico, 2) Adobeworks of Artesia, New Mexico, and 3) Hachita Adobes of Deming, New Mexico, produced only fully stabilized adobes. The remaining four manufacturers made fully stabilized adobes only on special order.

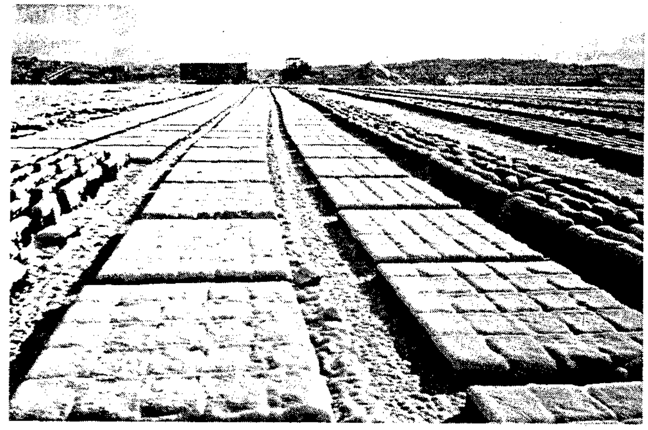


FIGURE 39—SNOW-COVERED ADOBE YARD: Eight Northern Indian Pueblos Council adobe operation, San Juan Pueblo.

FIGURE 40—STABILIZED PATIO ADOBE BRICKS. CHIMAYO.

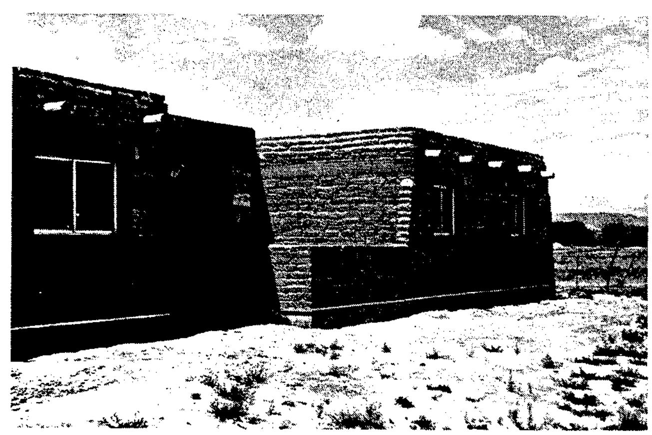


FIGURE 4 1 - H U D STABILIZED-ADOBE HOUSE UNDER CONSTRUCTION. SAN ILDEFONSO.

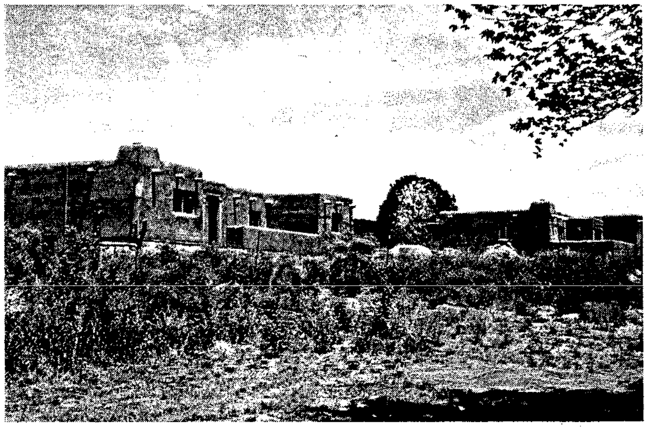


FIGURE 42-COMPLETED HUD ADOBE HOUSES. PICURIS PUEBLO.

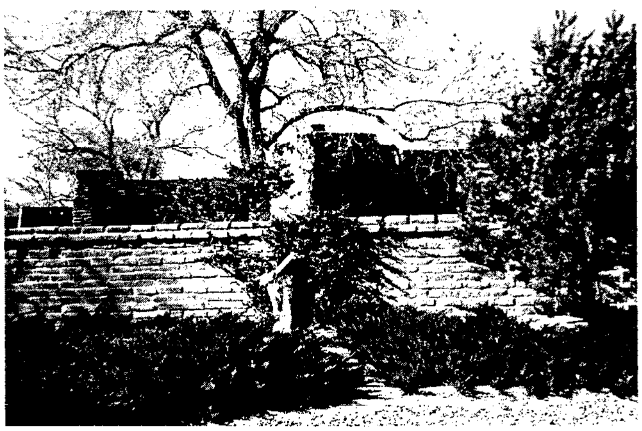


FIGURE 43-EXPOSED STABILIZED ADOBE BRICKS. ALBUQUERQUE.

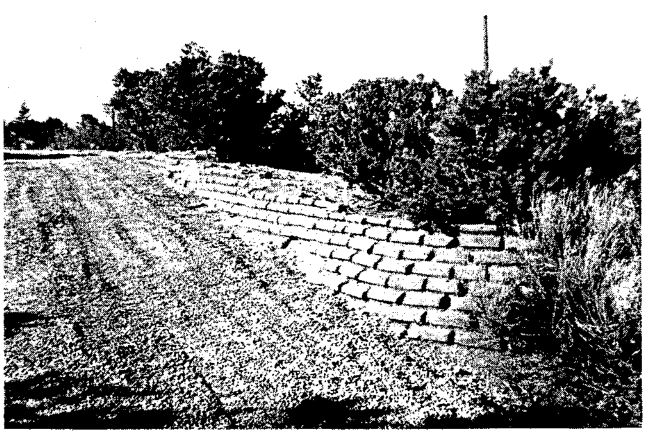


FIGURE 44-DRIVEWAY RETAINING WALL BUILT OF STABILIZED ADOBE BRICKS. SANTA FE.

Pressed bricks

Pressed-adobe bricks are manufactured using traditional or stabilized adobe materials but usually contain a somewhat higher clay content than standard adobes (30—35%) and are made with a damp, low-moisture mixture. The soil mix is pressed into a dense adobe brick of varying size, using either a hydraulically operated power machine or a hand-operated press. The machine-made pressed-adobe bricks investigated were all produced in the standard 10 x 4 x 14-inch size. The hand-operated CINVA-Ram press produced a 3¾ x 5½ x 11½-inch-size brick. Both traditional (untreated) and stabilized (treated) pressed-adobe bricks were manufactured; however, production of all types of pressed adobes was very limited with an estimated total of only 15,000 bricks manufactured statewide in 1980. Of this total, the majority of the pressed adobes produced were used by the adobemakers in personal construction projects. Only a few thousand pressed bricks were sold commercially.

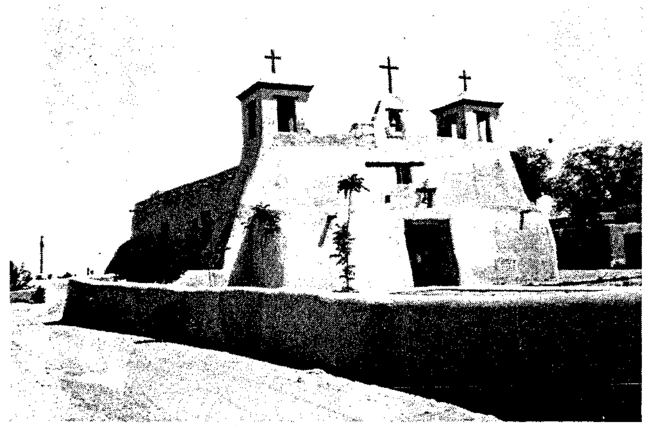
The major types of equipment used to produce the pressed bricks include the following: 1) Adobe Farms' Hydra-Brikcrete Press located in Española, New Mexico; 2) David Griego's Porta Press located in Ledoux, New Mexico; 3) W. S. Carson's CINVA-Ram portable press used in Columbus, New Mexico; 4) Al Niblack's Sun Mountain Adobe press located in Santa Fe, New Mexico; and 5) Bill Davidson's Soil-Crete Solar Company press located at Navajo Dam, New Mexico. The production methods used to manufacture the various types of pressed-adobe bricks are detailed in the section on production methods.

An advantage to pressed-adobe bricks is that, in the majority of cases, they average higher in compressive strength than other more traditionally made adobes. Also the shorter period of sun curing necessary for pressed adobes normally permitting the use of the adobe within 4—8 days of manufacture is an advantage. However, unless a stabilizer such as asphalt emulsion or portland cement is added to the soil mixture, the bricks must be protected from moisture at all times, because they have a tendency to disintegrate rapidly when wet. The prices for the pressed-adobe bricks varied from a low of 30 cents for the traditional pressed adobe to a high of 35 cents for the stabilized pressed adobe.

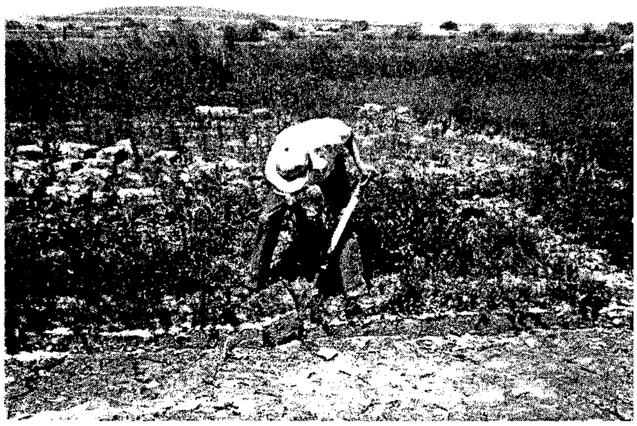
Terrónes

The Spanish word, terrón, meaning "a flat clod of earth" refers to the type of adobe brick that is made of cut sod or turf material (McHenry, 1973). The terrónes are still widely used in the Albuquerque Basin area of New Mexico and particularly at the Pueblo of Isleta. Here the terrónes usually measure 7 x 7 x 14 or 4 x 7 x 14 inches and are cut during the spring of each year from the sod areas of the floodplains of the Rio Grande (fig. 45A). Both tribal pasture land and individual-ownership lands have areas along the river bottom where the bricks are cut. An ordinary garden spade with a blade that has been flattened and cut down to measure 7 x 8 inches is used to cut the sod. Usually two or more individuals will be engaged in the cutting, stacking, and final transportation of the terrónes to the construction site. To produce the 7 x 7 x 14-inch full-sized terrón, which weighs an average of 35 lbs, one cut is made at each end of the sod and two cuts are made on each side of the brick (figs.

A-TYPICAL TERRÓN MEASURES 7 x 7 x 14 INCHES AND WEIGHS AN AVERAGE OF 35 LBS.



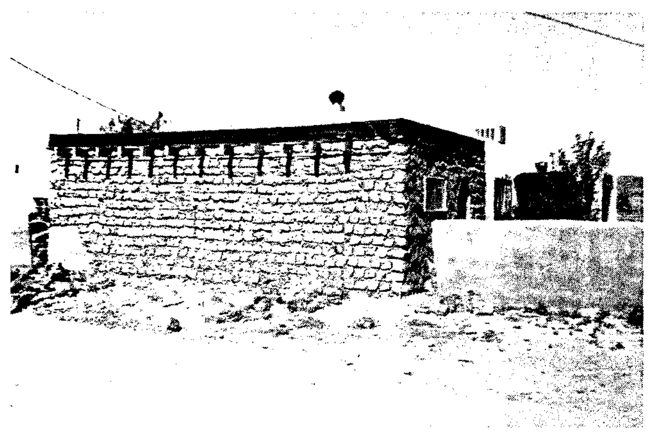
D-SAINT AUGUSTINE CHURCH CONSTRUCTED OF TERRÓNES IN 1613.



B-AFTER SIDE AND END CUTS HAVE BEEN MADE DOWN TO ROOT LEVEL. TERRÓN IS WEDGED FROM SOD.

E TERRÓN HOUSE UNDER CONSTRUCTION DURING SUMMER OF 1980.

C-SOD-CUTTING AREA AND STACKED TERRÓNES.



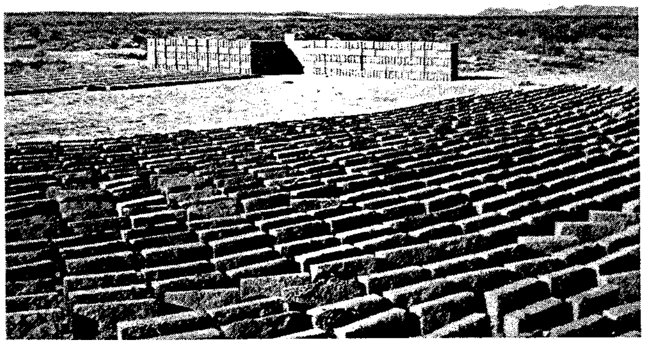
F-TERRÓN ROOM ADDITION UNDER CONSTRUCTION.

FIGURE 45-ISLETA PUEBLO TERRONES CUT FROM SOD FOUND IN RIO GRANDE FLOODPLAIN AREA FOR TRIBAL CONSTRUCTION PROJECTS.

45B and C). The smaller terrón, measuring 4 x 7 x 14 inches, requires only one side cut in the sod to produce the half-brick.

After cutting, the terrónes are removed and placed on dry ground to cure for approximately 20 days, at which time they are usually stacked and allowed to dry for an additional 20–30 days.

The majority of the old pueblo buildings at Isleta Pueblo are constructed with terrónes. The largest and one of the oldest buildings in the pueblo is the Saint Augustine Church, which was constructed in 1613 and attests to the durability of the bricks (fig. 45D). Several new pueblo homes were under construction with terrónes during the field visit to the pueblo (fig. 45E). However, the majority of pueblo residents were using the terrónes to add rooms, walls, or storage sheds to their existing houses (fig. 45F). Although terrónes were not available for sale to the general public during 1980, the average price for the bricks that have been used in tribal construction projects was $120.00 per thousand.



A-SOME BRICKS DRYING IN ADOBE YARD WILL BE USED TO BUILD A KILN WHERE ADOBES ARE FIRED FOR QUEMADOS.

B-REMOVING QUEMADOS FROM KILN AFTER FIRING.

FIGURE 46-QUEMADO PRODUCTION IN LAS PALOMAS, MEXICO.

Quemados

The quemado or burnt adobe is a traditional sun-dried adobe brick that has undergone a modified low-firing process. Combustible materials (wood, kerosene, old tires) are burned in a stacked-brick oven that is built to allow air circulation within the kiln. Usually firewood is fed through the small doors at each end of the kiln with smoke escaping

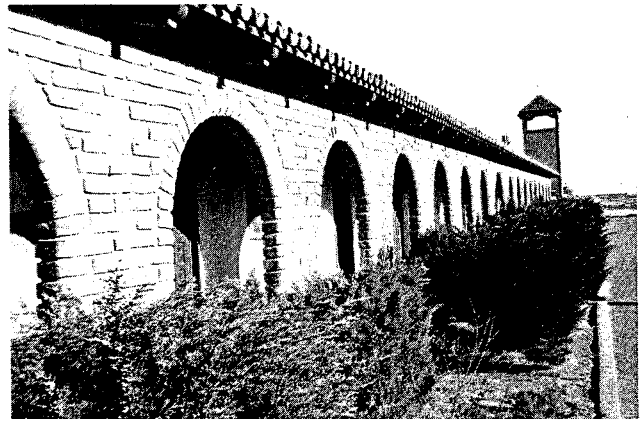


FIGURE 47-QUEMADO-CONSTRUCTED PORTAL AT COLUMBUS AIRPORT.

through the smoke holes at the top. According to Tibbets (1974), mesquite is the most common fuel used and is usually gathered from nearby surrounding hills. The firing process usually takes from 2 to 4 days and approximately 300–500 quemados are produced per firing (figs. 46A and B).

The majority of quemados used in the southwest United States are manufactured along the border of northern Mexico, from Rosarito and Tecate in Baja California, to Sasabe and Querobabi in northern Sonora, and Las Palomas and Juarez in northern Chihuahua (Tibbets, 1974). Quemados, when purchased for an individual's own construction project, are shipped into the United States duty free and sell (1980) for an average of 30 cents per brick (size 8 x 3½ x 16 inches) in the Las Palomas area. Various sizes of quemados are produced, with the 8 x 4 x 16-inch dimensions usually standard. Other sizes include a 12 x 4 x 16- and a 10 x 4 x 16-inch brick and a 4 x 4 x 16-inch header brick.

The quemados collected at the adobe yard of Alfonso Carrillo in Las Palomas, Mexico, were of the standard 8 x 3½ x 16-inch size. In Carrillo's adobe yard, traditional adobes and quemados of the same size and made from the same adobe soil were manufactured and sold. The traditional adobe bricks are stacked and fired to produce the burnt adobes. Fig. 47 shows the architectural usage of quemados at the Columbus, New Mexico, airport.

Soil geology

Usable adobe materials are found in large areas of New Mexico and constitute a virtually inexhaustible supply and reserve. The adobe materials are obtained principally from stream deposits, particularly terrace deposits, and older geologic formations. Approximately 10% of the adobe producers purchase their adobe material from local sand and gravel operations, and a total of 46% of the producers excavate and haul their adobe soil to the adobe yard from nearby terrace and floodplain deposits. The remaining 44% secure their adobe material by removing the overburden at their adobe site or by land leveling of the adobe drying yard. A total of 87% of the adobe producers are located between Belen and Taos, New Mexico, with the majority using a sandy loam that has been derived from the Santa Fe Formation (Tertiary; fig. 48). For detailed geologic information on the major locations of the adobe materials, see the geology reports and maps of the Albuquerque and Espanola Basin areas (Kelley, 1977, 1978). Fig. 49 outlines the locations of the adobe producers in relation to the major land forms and rivers of New Mexico. Fig. 50 details the general locations of the main sources of adobe materials used by the majority of the commercial adobe brick producers and is adapted from the W. D. Carter report on sand and gravel in New Mexico (1965). Brief descriptions of the major sources of soil used for adobe making in the state follow.

Stream deposits

Most of New Mexico's adobe material is obtained from sand, silt, and clay located in stream deposits. New Mexico's mountains are drained by streams with steep gradients. During heavy rains and at flood stage these streams transport large volumes of sand, silt, and gravel that are deposited in channels, on floodplains, on terraces, and in alluvial fans.

STREAM-CHANNEL DEPOSITS-Stream- or arroyo-channel deposits consist of sand, silt, clay, and gravel deposited in stream beds along present stream courses. In the arroyos the deposits are readily accessible during the dry season and the materials are easily removed by front-end loaders and hauled by trucks to the adobe yards. Most channel deposits are replenished with alluvium by seasonal rains.

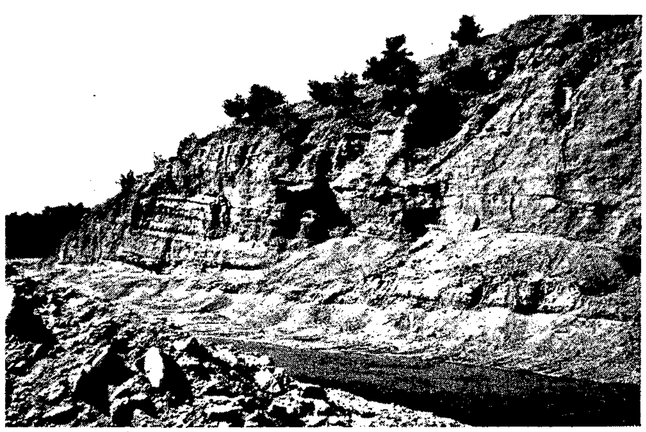


FIGURE 48-TESUQUE FORMATION (TERTIARY); this formation is a major source of sand and gravel in the Española Basin area of northern New Mexico.

FLOODPLAIN DEPOSITS-Floodplain deposits consist of sediments normally composed of fine-grained sand and silt materials that are deposited on the plains bordering streams. The fine-grained materials may also mantle usable deposits of sand and gravel. Floodplain deposits are best exemplified in the Albuquerque and Española Basin areas of the Rio Grande valley.

TERRACE DEPOSITS-Stream-terrace deposits are bevel-like deposits of sand and gravel that border on streams, but which lie above the level of the present floodplain (Goldman, 1961). These deposits are remnants of older floodplains through which the stream has cut. The terrace materials are widely used by both sand and gravel producers and adobe producers who have located deposits on private, state, Indian, and federal lands, particularly in Bernalillo, Santa Fe, and Rio Arriba Counties. Elston (1961) stated that "all of the sand and gravel in Bernalillo County comes from Quaternary terraces of the Rio Grande, especially the lowest terrace above the present floodplain." Usually in the Albuquerque Basin the upper 15–30 ft of overburden that covers the terrace deposits in many areas is composed of a sandy loam that contains the proper percentage of sand, silt, and clay to produce a good quality adobe brick (fig. 51).

ALLUVIAL FANS-An alluvial fan is a gently sloping, fan-shaped mass of gravel and rock material deposited at the mouth of a canyon where the stream exits from the mountains and enters the valley or plain. The flattening of the gradient causes the cobbles and boulders to be deposited at the apex of the fan with the average particle size decreasing toward the sides and base of the fan. The major sources of sand and gravel and crusher fines for the Alamogordo area are the alluvial fans of Alamo Canyon. Screen tests of the crusher fines obtained from this canyon and used at The Adobe Patch in La Luz, New Mexico, averaged 15–18% clay and produced a superior, fully stabilized adobe.

Older geologic formations

Older geologic formations, containing extensive sources of sand, gravel, and adobe materials, are the partially consolidated beds of sandstone, mudstone, arkose, conglomerate, and fanglomerate of middle and late Tertiary deposits. This includes the Ogallala Formation in the eastern part of the state and the Santa Fe Formation in the north-central part. Early Tertiary deposits include the San Jose, Chuska, and Ojo Alamo formations in the western part of the state and the Raton and Galisteo Formations in the eastern part. In many of these deposits mining both sand and gravel as well as clay from the same area is possible. Mixed together, these materials produce a good quality adobe brick.

Irrigation-ditch materials

In the Rio Grande basin are extensive irrigation systems that each year require cleaning and removal of silt and sand deposits. These fines are stockpiled adjacent to the ditches

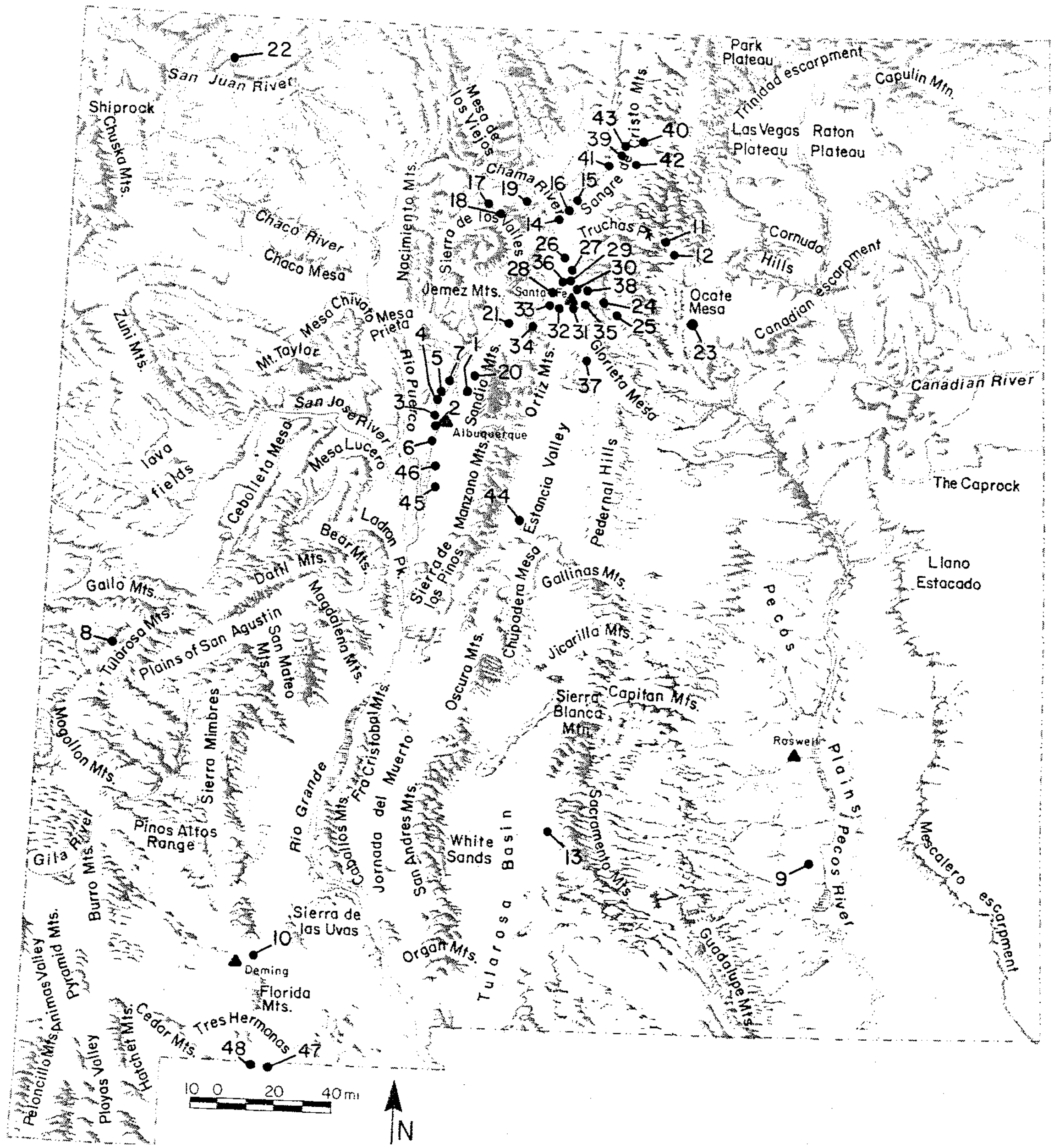


FIGURE 49-ADOBE PRODUCERS IN RELATION TO MAJOR LANDFORMS AND RIVERS OF NEW MEXICO: for names of producers and information see table 1 (modified from Raisz, 1957, and Snead, 1979).

and in many areas are used by local adobe producers as a source of adobe soil (fig. 52). Permits are usually obtained from the Middle Rio Grande Conservancy District for the removal of the ditch material.

Clay mineralogy

The suitability of clays in New Mexico for various uses (adobes, pottery, bricks, and tile) depends on properties that are controlled by the mineral and chemical composition of the clay. Clays are natural, earthy, generally plastic materials, composed of very fine particles of clay minerals that are principally hydrous aluminum silicates, but that may also contain small quantities of iron, magnesium, potassium, sodium, calcium, and other ions (Patterson and Holmes, 1965).

Clay is the chief binding agent in adobe bricks, and the majority of the clay-size material (less than-2-micrometer fraction) are clay minerals. Four clay-mineral groups are commonly represented in New Mexico's adobe clays. The high-aluminum kaolinite group and the high-potassium illite group generally make up about one-half of the clay present in the 49 samples tested. Both groups are nonexpansive (nonexpandable) or will expand only slightly in the presence of water. The calcium- or sodium-rich smectite group and mixed-layer illite-smectite group contain varying expansive clay minerals and also make up about 50% of the clay minerals. A member of the chlorite group was found in only one New Mexico adobe clay material and the vermiculite group was not represented. Fig. 53 diagrams the silicon-oxygen tetrahedron and aluminum-hydroxyl octahedron, the fundamental building blocks of most clay minerals, and includes the schematic representations of crystal structures

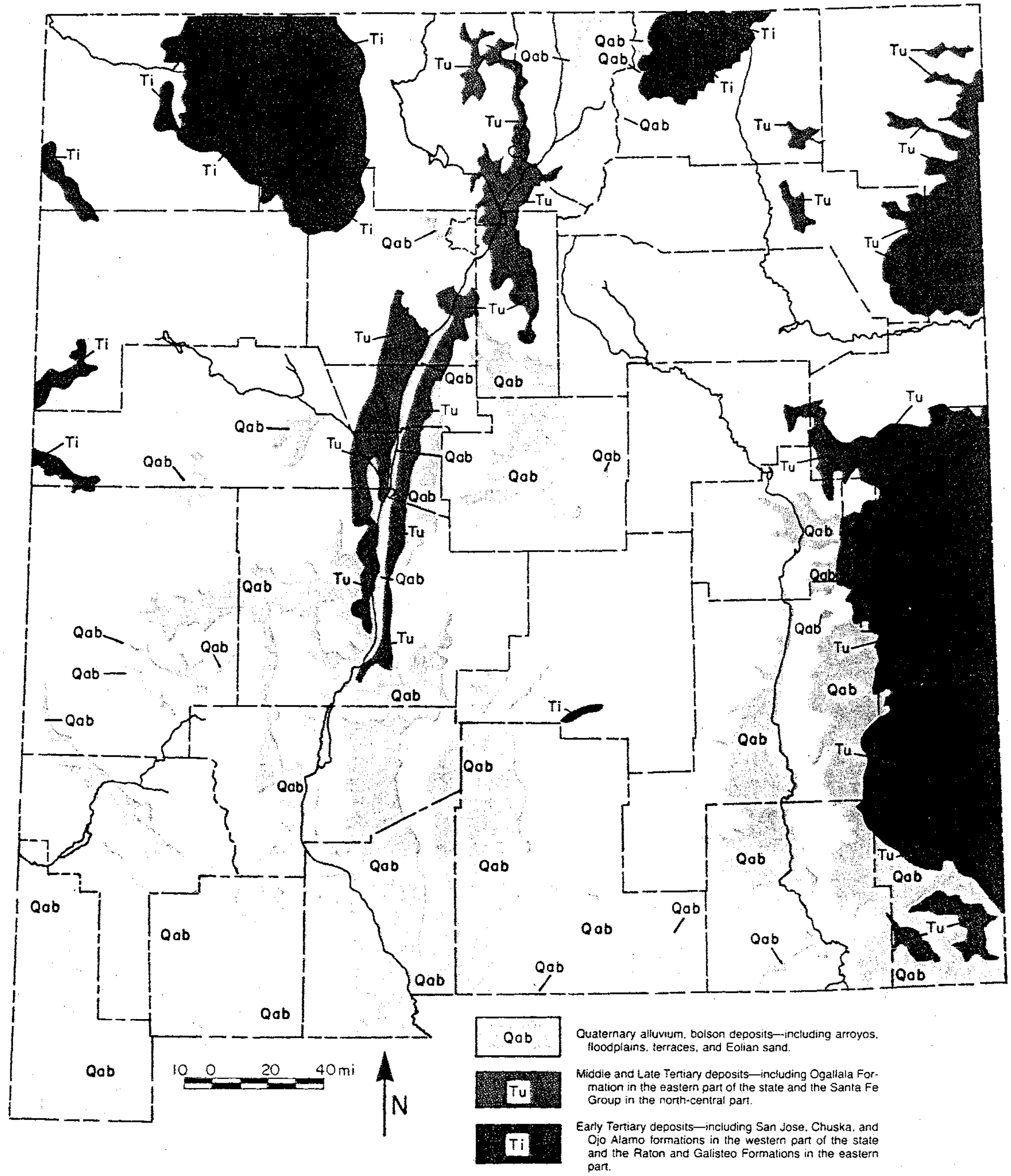


FIGURE 50-MAJOR SOURCES OF ADOBE MATERIAL IN NEW MEXICO (modified from Carter, 1965).

of major clay-mineral types (Harrison and Murray, 1964; Austin, 1975).

The total amount of clay minerals and the presence or absence of a particular mineral affect the physical properties of the adobe bricks. A soil with a high percentage of non-expansive clay minerals, particularly the kaolinite group, would tend to be more brittle than one with expansive (expandable) clay minerals. Similarly, a clay material with a large percentage of expansive minerals will produce a brick that has a greater compressive strength than one with the same amount of clay, but with a larger percentage of non-expansive clay minerals. This also means that an adobe material with more expansive clay minerals but less total clay will have an equal strength to one with more clay but less expansives. However, a clay material with an abundance of expansive clay minerals, particularly the smectite group which is the most expansive, may make a poor adobe product. In such clays expansion and contraction of the clay minerals may cause excessive cracks in the adobe brick. More silt or sand or even straw can be added to the mix to dilute this effect.

Calcite ($CaCO_3$) was also found in the majority of the adobe soils tested in New Mexico and is typical of adobe soils located throughout the arid Southwest. Calcite in the clay-size fraction may also act as a binder in adobe bricks. If moderate heat is applied, a brick of this type of clay may have increased strength. However, if the temperature is elevated to structural brick temperatures (approximately 1,800° F or 1,000° C), the calcium ion of the calcite acts as a flux, lowering the firing temperature and narrowing the firing range to the point where a brick will change quickly from one with a relatively low bonding strength to a melted blob of glass. Such clays will, therefore, make very poor structural brick clays.

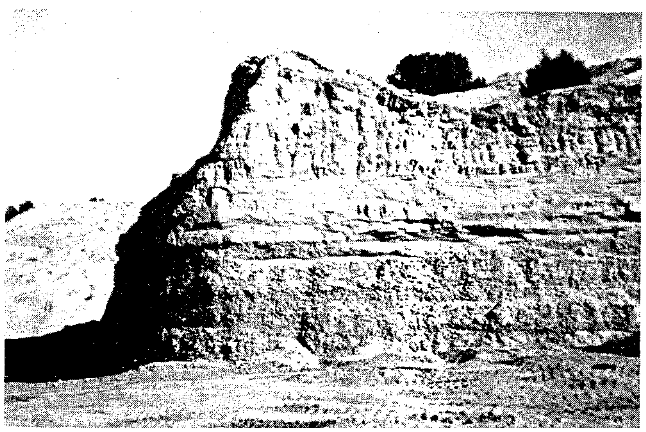


FIGURE 51-CROSS SECTION OF QUATERNARY TERRACE DEPOSIT AT SAN JUAN PUEBLO; upper 10—15-ft overburden contains a fine sandy loam that makes an ideal adobe brick.

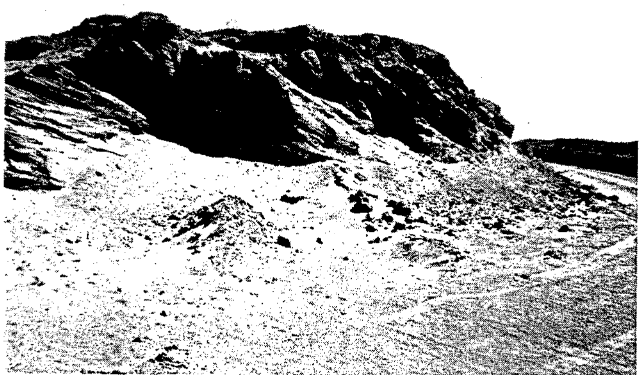


FIGURE 52-STOCKPILED FINES REMOVED IN CLEANING IRRIGATION DITCH. CORRALES.

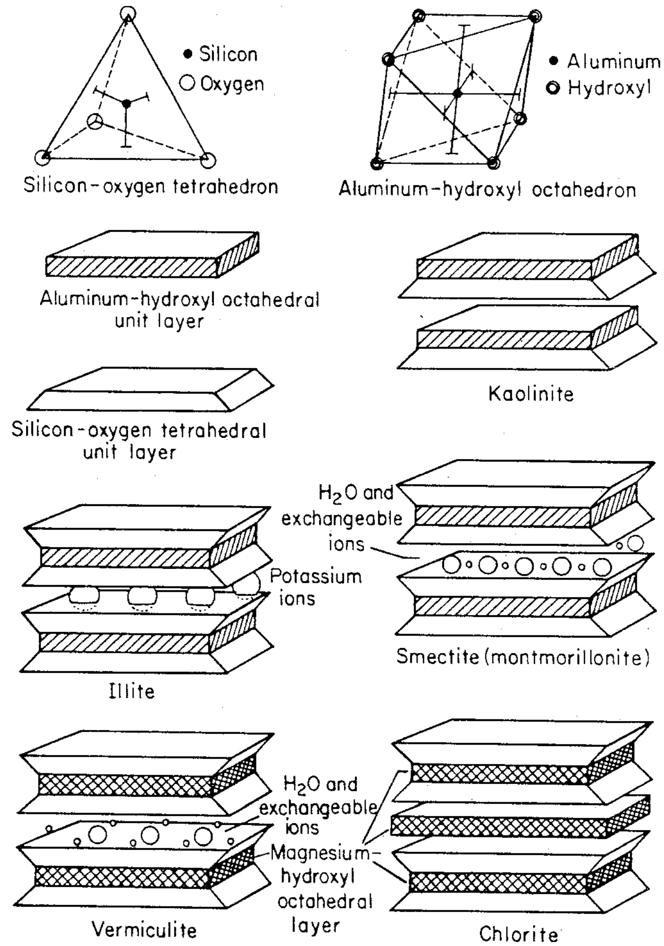


FIGURE 53-DIAGRAMS OF MAJOR CLAY MINERALS; the silicon-oxygen tetrahedron and the aluminum-hydroxyl octahedron are the fundamental building blocks of most clay minerals (modified from Harrison and Murray, 1964, and Austin, 1975).

The clay-mineral analyses on portions of the adobe bricks were completed by George Austin of the New Mexico Bureau of Mines and Mineral Resources for 49 brick samples and one bag sample collected from the various adobe producers. In the clay-mineral analyses the less-than-2-micrometer fraction was taken from a portion of an adobe brick by a sedimentation technique that separates this fraction from coarser materials. The effective spherical diameter of the sample has been shown to be about 1 micrometer. Although nonclay minerals do not make up a large part of the 2-micrometer fraction, they are present and are noted. The results are listed in parts in 10 for the clay mineral suite (appendix 1).

Physical properties

In any building project certain minimum requirements or specifications have been developed regarding the durability, strength, thermal characteristics, and fire safety of the construction materials (Long and Neubauer, 1946). In New Mexico the building of adobe structures is regulated by specifications adopted from the Uniform Building Code as outlined in Section 2405 of the 1977 revision of the New Mexico State Building Code (Construction Industries Division, 1979). The sections of the code on unburned clay masonry state basic requirements concerning adobe brick, including regulations on soil composition, standards of water absorption, compressive strength, and modulus of rupture, as well as construction specifications.

One of the most important tests in the New Mexico State Code requires that an adobe brick have a compressive strength averaging 300 pounds per square inch (psi). This standard assures that all units from the tested brick batch will resist a compressive force equal to 300 lbs for each square inch of surface area. The importance of this test for a relatively heavy material such as adobe brick is apparent when considering the great amount of weight a typical wall unit must bear. In addition to the weight of the roof structure supported by a load-bearing wall, each layer of bricks must support all others above it, and each depends on the compressive strength of the lower layers to support it.

The other test required on all types of adobe bricks is the modulus-of-rupture test. This test helps indicate the relative cohesion of the materials that make up the adobe and the ability of those materials to resist the tension or shear forces that might result from settling of foundations or wind action. Other tests used only on semistabilized and stabilized adobes determine the water-resistance quality of the bricks. The water-absorption test and erosion tests are important only if the bricks are left unplastered or if the tests are a building requirement of the architect or federal housing agency.

Samples for this study were collected from 56 different locations throughout the region. They represent 48 active adobe producers in New Mexico, as well as several samples from old Spanish and pueblo adobe structures, terrónes from Isleta Pueblo, and a few burnt adobes from Mexico. All adobe bricks were tested under the direction of Kalman Oravecz and Tibor Rozgonyi of the New Mexico Institute of Mining and Technology, Rock Mechanics Laboratory, located in Socorro, New Mexico.

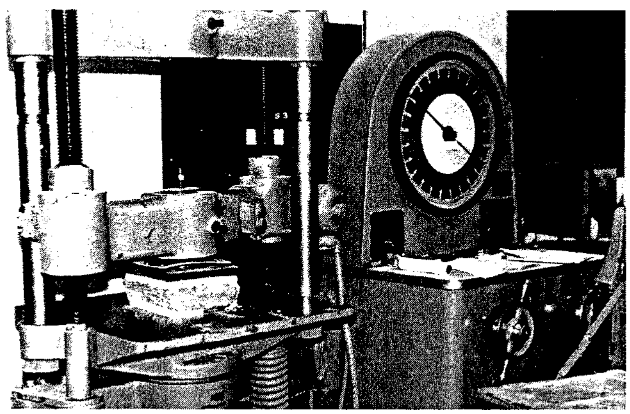
Testing methods

The specifications for testing adobe bricks are outlined in Section 2405 of the New Mexico State Building Code and can be found in appendix 2. The methodology of each of the major tests is described here. Samples to be tested should be selected at random and should be sun-cured for a minimum of 3 weeks or longer depending upon local weather conditions. Most tests are made on five randomly selected bricks from the same batch, to assure a more representative range of values than that available from testing a single brick.

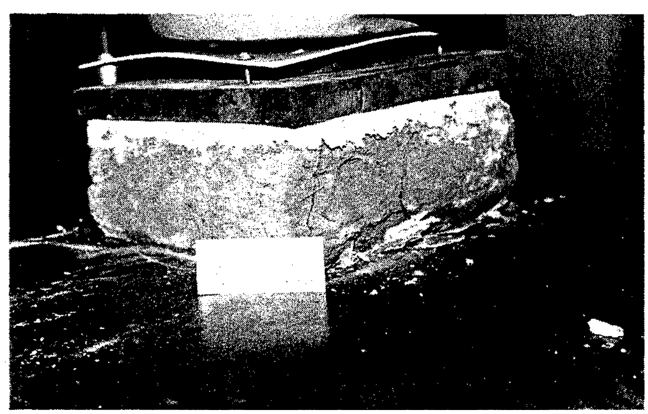
Compressive strength

In order to provide the necessary flat and smooth loading planes for this test, the adobes are capped with plaster of pans and dried to a constant weight in an oven maintained at 140° F (60° C; fig. 54A). After cooling to room temperature, the samples are placed in a standard hydraulic testing machine between two flat loading plates (fig. 54B). One of the plates is fixed and the other is on a hemispherical mounting. A loading rate of approximately 500 psi/min is then applied to the plates. The compressive strength is calculated from the maximum load sustained before the brick shows evidence of failure. Fig. 54C shows a closeup of a 100 + -yr-old adobe brick from San Juan Pueblo in the compression-testing machine at point of failure.

A--CAPPING ADOBE BRICK WITH PLASTER OF PARIS PRIOR TO TEST.



B-ADOBE BRICK LOADED BETWEEN FIXED AND HEMISPHERICAL MOUNTING OF TESTING MACHINE.



C-OLD ADOBE BRICK (100 + YRS) FROM SAN JUAN PUEBLO IN COMPRESSION-TESTING MACHINE AT POINT OF FAILURE.

FIGURE 54-TESTING ADOBE BRICKS FOR COMPRESSIVE STRENGTH.

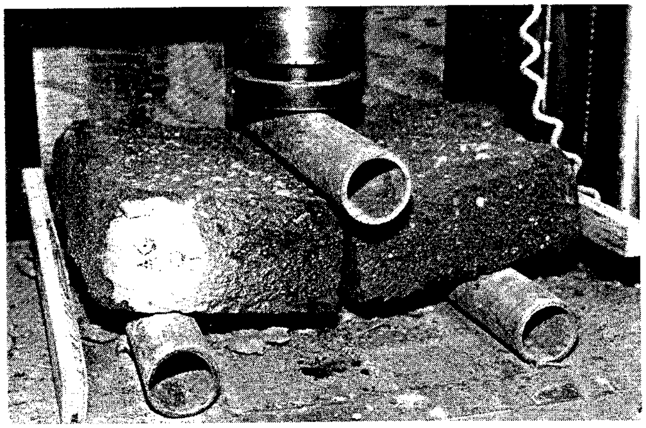


FIGURE 55-THREE-POINTS LOADING METHOD USED ON TYPICAL ADOBE BRICK TO ESTABLISH RUPTURE STRENGTH.

Figure 57-FOUR INCH ADOBE-CURE SAMPLES DRYING FOR MOISTURE CONTENT DETERMINATION.

Modulus of rupture

To establish the rupture strength of the adobe, a three-points loading method is used. A cured brick is placed symmetrically on two supporting parallel pipes 2 inches in diameter that extend across the full width of the adobe. A third 2-inch pipe is placed on top of the brick midway between and parallel with the lower supports. The relative positions of the supporting and loading pipes is fixed by means of two slotted retaining boards (fig. 55). The load is applied to the top pipe at a rate of 500 psi/min using a static loading device until the rupture occurs. The modulus of rupture is then calculated by the formula:

$$\text{modulus of rupture} = \frac{3 \times \text{maximum load} \times \text{support length}}{2 \times \text{width} \times \text{thickness}^2}$$

Seven-day water-absorption test

Four-inch cube specimens are cut from all the bricks being tested and are dried at 140° F (60° C) to a constant weight. After cooling to room temperature, the specimens are placed on a constantly water-saturated porous surface and enclosed in a moisture cabinet (fig. 56). The weight gain from the absorbed water after 7 days is determined and recorded as a percentage of the dry weight.

FIGURE 56--FOUR-INCH ADOBE-CUBE SAMPLES ON WET, POROUS SURFACE IN MOISTURE CABINET.

Moisture content

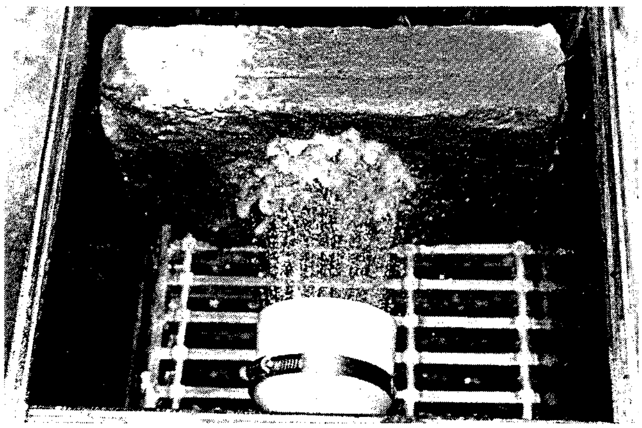
Four-inch cube specimens are cut from all the bricks being tested and are first weighed and then dried at 140° F (60° C) to a constant weight (fig. 57). Moisture content is then calculated as the percentage of weight change relative to the dry weight.

Erosion—average of three bricks

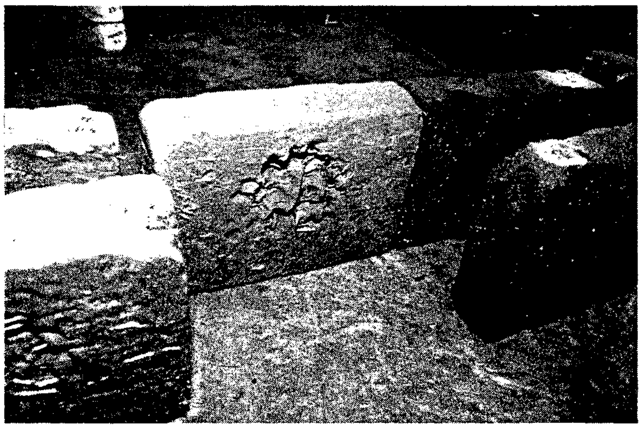
Although the water-spray erosion test is not required under the New Mexico State Code, I have included it here because it is used to test stabilized and semistabilized bricks in other states. The procedure for testing three randomly selected adobe bricks includes the use of a pressure regulator, a standard pressure gauge, and a 4-inch-diameter shower head fitted to a pressure water line. The full-sized brick is placed vertically 7 inches from the face of the shower head, and water is directed horizontally against the brick face for 2 hrs at a pressure of 20 psi (fig. 58A). Slight erosion or minor pitting is not interpreted unfavorably provided the bricks exceed test requirements for other properties (fig. 58B). A traditional adobe brick subjected to this test eroded fully in less than 2 hrs; however, the semistabilized and stabilized adobe bricks' erosion-test results were generally good. Several outstanding stabilized adobe-brick samples from The Adobe Patch in La Luz, New Mexico, were subjected to 2 full days of the water-spray erosion test, which resulted in only minor pitting of the bricks.

Recommended specifications

Following is a summary of the recommended test specifications for adobe bricks as outlined in the New Mexico State Building Code, Section 2405, on unburned clay masonry. (The code is reprinted in its entirety in appendix 2.) *Compressive strength* shall average 300 psi with a tolerance of 250 psi for one brick in a test series of five. *Modulus of rupture* shall average not less than 50 psi with a tolerance to 30 psi for one brick in a test series of five. *Water absorption* shall average less than 2.5% of dry weight in 7 days. *Moisture content* of the brick shall not exceed 4% by weight. *Shrinkage cracks*—no adobes shall contain more than three shrinkage cracks over 3 inches in length or 1/8 inch in width.



A-WATER DIRECTED AGAINST BRICK FACE.



B—ADOBES AFTER EROSION TEST.

FIGURE 58-WATER-SPRAY EROSION TEST.

Test results

In general a range of result values exists for the physical properties of the adobe bricks tested from the majority of the adobe producers located throughout the state (table 8). This variability in data is the result of differences in the composition of adobe soils, methods of producing adobe bricks, and the quality of workmanship. A summary of the test results on adobe bricks produced by the manufacturers of the six types of bricks follows.

Traditional bricks

Bricks from 34 producers were tested. Results indicated that the compressive strength for the traditional sun-dried adobe brick averaged 383 psi and varied from 153 to 1,071 psi. The modulus of rupture averaged 44.6 psi and ranged from 13 to 89 psi. A set of traditional adobe bricks from the New Mexico Earth Company in Alameda, New Mexico, was subjected to the full series of physical-property tests as outlined by the New Mexico State Code for a treated (stabilized) adobe brick. The compressive strength of the bricks averaged 489 psi, the modulus of rupture averaged 66 psi, and the moisture content averaged only 0.9%; however, the 7-day water-absorption tests averaged 11.6%. The three bricks subjected to the water-spray erosion test eroded in less than 2 hrs. Architects and others have estimated that under actual conditions, in a semiarid region such as New Mexico, an untreated (traditional) adobe wall can be expected to erode at the rate of approximately 1 inch every 100 yrs. This amount of erosion is probably typical of the majority of traditional adobe bricks produced in New Mexico and indicates a surprising resistance to weathering and erosion.

Semistabilized bricks

The compressive-strength values for the semistabilized adobe bricks averaged 388 psi, ranging from 259 to 586 psi. The modulus of rupture averaged 61 psi and ranged from 36 to 99 psi. The 7-day water-absorption tests averaged 1.93% and the moisture content averaged 1.4%.

Stabilized bricks

The compressive-strength values for the stabilized adobe bricks averaged 426 psi, ranging from 249 to 578 psi. The modulus of rupture ranged from 50 to 157 psi and averaged 91 psi. The 7-day water-absorption tests on the stabilized adobes fell between 1.3 and 5.0% for an average of 2.35%, and the moisture content of the adobes ranged from 0.4 to 1.5%, with an average of 0.79%.

Pressed bricks

In reviewing the test results of all types of adobes, it was seen that pressed adobes, made both traditionally and with stabilizers of straw and asphalt emulsion, had very high compressive-strength averages with values ranging from 512 to 1,071 psi. These values were generally higher than those for standard sun-dried adobes. The modulus of rupture varied from 46 to 51 psi.

Terrónes

Two terrónes were tested in this survey, one from Isleta Pueblo that was cut and dried in 1980 from the Rio Grande floodplain sod, and one which was taken from an old adobe building in Algodones. The Isleta Pueblo terrón (7 x 7 x 14 inches) met all code requirements with an average of 303 psi in compressive strength and 53 psi in modulus of rupture. The 145-yr-old terrón from an adobe building in Algodones, New Mexico, measured slightly smaller than the Isleta terrónes ($7\frac{1}{2}$ x 4 x $15\frac{1}{2}$ inches) and averaged 261 psi in compressive strength and 20 psi in modulus of rupture. During the testing of the Isleta terrónes, a unique failure load was not noted, as the presence of the grassroot structure apparently holds the terrón together even after considerable deformation.

Quemados

Quemado (burnt adobe) samples were collected from the Alfonso Carrillo adobe operation located in Las Palomas, Mexico, where traditional adobe bricks (8 x $3\frac{1}{2}$ x 16 inches) were being made, stacked, and fired in a kiln to produce a standard quemado of approximately the same size. The average compressive strength of the quemados tested was 644 psi and the average modulus of rupture was 180 psi. The bricks were also tested for their moisture content which

TABLE 8—SUMMARY OF PHYSICAL-PROPERTY TESTS; tests were performed on a limited sampling of adobe bricks from each adobe yard, and the results may not be representative of total annual production. The New Mexico State Building Code recommends testing of samples selected at random from each 25,000 bricks produced. Symbol: —test not applicable. Specification requirements for Uniform Building Code and New Mexico State Building Code: *compressive strength,* average of 5 bricks—300 psi minimum, 1 out of 5 bricks—250 psi minimum; *modulus of rupture,* average of 5 bricks—50 psi minimum; *7-day water absorption,* 2.5% maximum by weight; *moisture content,* 4.0% maximum by weight.

Name	Location	Type of adobe	Size of adobe (inches)	Compressive strength (psi)	Modulus of rupture (psi)	7-day water absorption %	Moisture content %
Small-scale adobe producers							
R. Vigil	Moriarty	Traditional	10 x 4 x 14	704	27	----	----
M. Martinez	Arroyo Seco	Traditional	8 x 4 x 12	486	49	----	----
Isleta Pueblo	Isleta	Terrón	8 x 6 x 14	303	53	----	----
Frank Gutierrez	Corrales	Traditional	10 x 4 x 14	312	45	----	----
Danny Porter	Pecos	Traditional	10 x4 x 14	285	70	----	----
Mariano Romero	Las Vegas	Traditional	10 x 4 x 14	329	25	----	----
Charles C de Baca	La Cienega	Traditional	10 x 4 x 14	358	35	----	----
D. Sandoval/E. Trujillo	Peña Blanca	Traditional	10 x 4 x 14	262	26	----	----
Edward Sandoval	Nambé	Traditional	10 x 4 x 14	282	42	----	----
Roman Valdez/James Lujan	Nambé	Traditional	10 x 4x14	242	no sample tested	----	----
Emilio Abeyta	Ranchos de Taos	Traditional	8 x 4 x 11½	442	38	----	----
Adrian Madrid	Santa Fe	Traditional	12 x 15½ x 3½	391	33	----	----
Robert Leyba	Pecos	Traditional	10 x 3½ x 14	365	36	----	----
Al Montano	La Cienega	Traditional	10 x 3½ x 14	328	23	----	----
Albert E. Baca	Nambé	Traditional	10 x 3½ x 14	148*	32*	----	----
Albert E. Baca	Nambé	Traditional	10 x 4 x 14	118*	18*	----	----
Joe Pacheco	Taos	Traditional	8 x 4 x 10	153	38	----	----
Felix Valdez	Cañones	Traditional	10 x 3½ x 14	321	40	----	----
Andy Trujillo	Abiquiu	Traditional	10 x 4 x 14	196	54	----	----
Aragon/Garcia Adobes	Aragon	Semistabilized	10 x 4 x 14	389	36	2.0	1.3
David Griego	Ledoux	Pressed adobe	10 x 3½ x 14	1,071	46	----	----
David Griego	Ledoux	Pressed adobe	10 x 3½ x 14	1,036	58	----	----
Lawrence Tenorio	Corrales	Traditional	10 x 4 x 14	321	31	----	----
Big "M" Sand & Cinder	Bernalillo	Traditional	10 x 4 x 14	403	67	----	----
D. T. Wiley	Aztec	Traditional	10 x 4 x 14	500	89	----	----
Antonio Serrano	Cañones	Traditional	10 x3½ x 14	262	41	----	----
Humberto Camacho	Mountainair	Traditional	10 x 4 x 18	556	56	----	----
Ralph Mondragon	Ranchos de Taos	Traditional	8 x 4 x 12	393	21	----	----
Leonardo Duran	Las Palomas, Mexico	Traditional	8 x 3½ x 16	484	13	----	----
W. S. Carson	Columbus	Semistabilized	5½ x 3¾ x 11½	580	54	12.7	2.2
W. S. Carson	Columbus	Traditional	5½ x 3 ¾ x 11½	512	46	----	----
W. S. Carson	Columbus	Traditional	5½ x 4 x 11½	769	69	----	----
Medium-scale adobe producers							
Otero Brothers	Los Lunas	Semistabilized	10 x 4 x 14	586	57	2.9	1.1
Pete Garcia	Corrales	Traditional	10 x 4 x 14	245	20	----	----
Taos Pueblo Native Products	Taos	Traditional	7½ 4 x 15½	261	20	----	----
Taos Pueblo Native Products	Taos	Traditional	4 x 12 x 8	548	85	----	----
Taos Pueblo Native Products	Taos	Traditional	10x 14 x4	492	50	----	----
Medina's Adobe Factory	Aicalde	Traditional	10 x 3'/, x 14	303	46	----	----
Joe Trujillo	Ranchos de Taos	Traditional	7½ x 4 x 10	615	68	----	----
Hachita Adobe	Deming	Semistabilized	10 x 4 x 14	530	105	2.2	1.5
Rodriguez-Brothers	Santa Fe	Traditional	10 x 3½ x 14	714	36	----	----
Adobeworks	Artesia	Stabilized	10 x 4 x 14	320	74	1.7	0.4
Oliver Trujillo	Nambé	Traditional	10 x 4 x 14	251	57	----	----
Robert Ortega	Dixon	Traditional	10 x 4 x 14	202	33	----	----
Alfonso Carrillo	Las Palomas, Mexico	Traditional	8 x 3½ x 16	426	51	----	----
Alfonso Carrillo	Las Palomas, Mexico	Quemado	8 x 3½ x 16	644	180	15.5	0.5
Large-scale adobe producers							
New Mexico Earth	Alameda	Traditional	10 x 4 x 14	489	66	----	----
New Mexico Earth	Alameda	Stabilized	10 x 4 x 14	499	89	1.3	0.5
Adobe Enterprises, Inc.	Albuquerque	Stabilized	10 x 3½ x 14	249	51	1.7	0.75
Eight Northern Indian Pueblos Council	San Juan Pueblo	Semistabilized	10 x 4 x 14	317	99	4.3	0.9
Eight Northern Indian Pueblos Council	San Juan Pueblo	Stabilized	10 x 4 x 14	382	71	5.0	1.0
The Adobe Patch	La Luz	Stabilized	10 x 4 x 14	578	157	2.2	0.6
Adobe Farms	Española	Stabilized	10 x 3½ x 14	322	82	2.1	1.1
Victor Montaño	Santa Fe	Traditional	10 x3¾ x 14	438	46	----	----
Western Adobe	Albuquerque	Semistabilized	10 x 4 x 14	456	96	11.1	1.1
Eloy Montaño	Santa Fe	Traditional	10 x 4 x 14	320	42	----	----
Manuel Ruiz	Corrales	Traditional	10 x 4 x 14	311	55	----	----
Rio Abajo Adobe Works	Belen	Stabilized	10 x 3i/2x 14	486	101	1.8	0.76
Hans Sumpf Co.	Madera, California	Stabilized	7½ x 4 x 16	611	155	0.55	0.54

*Bricks damaged en route to testing facility averaged 0.5%. For the 7-day water-absorption test they averaged 15.5%. Very little erosion was evident when the bricks were subjected to the water-spray erosion test, with less than 1% of the bricks' thickness showing any type of disintegration. The traditional adobe brick used to make the quemado showed an average increase of compressive strength from 426 to 644 psi upon firing, and the modulus of rupture increased from an average of 51 to 180 psi.

Water-spray erosion tests were completed on all of the test samples identified as semistabilized and stabilized adobes. Considerable variation was noted and further testing should be carried out because of the limited sampling of this survey.

The New Mexico State Code does not address the use of semistabilized adobes, although our study shows that 57% of the state's adobe production is in this category. For semi-stabilized bricks, the erosion-test averages varied from a low of 5% erosion of the surface to a high of 30%. The stabilized adobe bricks' test averages varied from a low of less than 1% to a high of 22%.

The majority of adobes of all types sold throughout the state met the state code specifications for shrinkage cracks. Any adobes that do not meet this standard usually are set aside during the drying and stacking operation or during the loading of the bricks for delivery.

Thermal properties

In New Mexico, thermal specifications for building materials are covered in the 1977 New Mexico Energy Conservation Code as adopted from the Uniform Building Code and the New Mexico State Building Code. Portions of the New Mexico State Building Code relating to adobe appear in appendix 2.

Traditionally, materials are evaluated for thermal performance based on measurements known as *R-* and *U-values.* The *R-value* is an indicator of the ability of a wall to insulate effectively. Insulation is nothing more than the resistance of a material to the transfer of heat, and naturally the higher that resistance, or R-value, the better insulator a material is. The R-value is calculated by dividing the thickness of the wall by the wall's thermal conductivity, a value established by the amount of heat per ft^2- per hr flowing from the hotter to the cooler side of the wall.

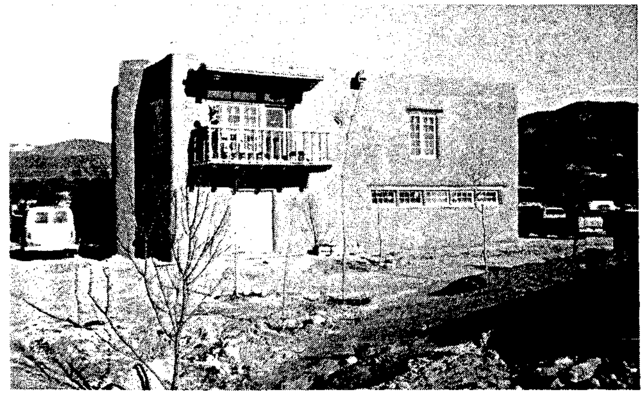
The *U-value,* sometimes referred to as the *value of conductance,* is represented by the reciprocal of the R-value and reflects the rate at which heat is conducted through a material. Total R- and U-values may be calculated for a given wall by adding up the sum of the values of each of the individual components of the wall structure; for example, all insulation, interior sheathing, framing, or masonry must be taken into consideration.

R- and U-values do not, however, tell the full story in determining what constitutes a high-quality, thermally efficient wall (Fine, 1976). Both of these values reflect the rate at which heat passes through a wall only after it has achieved the *steady-state condition,* or the state when heat energy is passing uninterrupted from one side of the wall to the other at a constant rate. What is not taken into consideration, and what is of critical importance in the case of masonry-mass walls such as adobe, is the *heat capacity* of the wall, which determines the length of time that passes before a steady state of heat flow is achieved. The higher the heat capacity of the wall, the longer period of time it will take for heat flow to reach a steady state. In real situations, external and internal temperatures are changing constantly so that a true steady-state condition is rarely achieved. What does occur, in the case of a high-capacity wall such as adobe, is outlined below.

In the morning, when the sun rises, heat from the warmer, exterior side of the wall begins to move through the adobe mass. Depending not only on the resistance (R-value) of adobe, but also on the heat capacity of the wall (a factor both of the specific heat capacity of adobe and the wall thickness), the heat takes a certain length of time to reach the cooler, interior side of the wall and to be released in the surrounding air. In adobe walls of sufficient thickness and of sufficient R-values (perhaps supplemented by other insulation), the normal daily fluctuations of temperature never allow much heat to pass through the wall at a steady state. At night, when the warmer side of the wall drops in temperature, heat already absorbed into the masonry-mass wall continues to flow, not just in one direction, but to both sides of the wall until a temperature equilibrium has been reached. This cycle is repeated in what is known as the *flywheel effect* and is responsible for the comfort well known to those who inhabit properly designed adobe homes.

Taking into account these principles, clearly the thermal properties of masonry materials in general, and adobe in particular, have often been unjustly maligned because only R- and U-values have been considered when evaluating these properties. For mass materials such as adobe, a more accurate representation of thermal performance than R- and U-values is given by what is known as the *effective U-value.* This value is determined as a factor both of the resistance of the wall to the transfer of heat and of its capacity to hold heat. Therefore, in actual home use, optimum comfort may be achieved by a mass wall with a moderate R-value and high heat capacity (adobe with a small amount of insulation), as well as by a highly resistant wall with little or no heat capacity (traditional highly insulated frame wall). The New Mexico Energy Institute has recently developed effective U-values for many different wall types (including adobe), and recently such performance-based criteria has been incorporated into the New Mexico Energy Conservation Code for building materials. The effective U-values may be used in lieu of traditional R- and U-values for cases where a design relying primarily on passive-solar gain and masonry-mass materials would not normally pass code standards. The hope is that the elimination of regulations that restrict

A-SPRAYED URETHANE INSULATION ADDED TO EXTERIOR.



B-INSULATION IS WIRED AND CEMENT COAT AND COLORED STUCCO ARE ADDED TO FINISH EXTERIOR OF HOUSE.

FIGURE 59-HOUSE IN SANTA FE THAT MEETS THERMAL REQUIREMENTS OF NEW MEXICO ENERGY CONSERVATION CODE.

the use of adobe because of the essentially incomplete performance data of traditional R- and U-values will remove yet one more obstacle to those individuals who prefer to build with adobe. Figs. 59A and B illustrate the necessary steps required to cover an adobe building with spray-on insulation to meet the thermal requirements of the New Mexico Energy Conservation Code for buildings.

In an effort to provide more scientific data on the thermal performance of adobe, the Eight Northern Indian Pueblos Council, in conjunction with the Department of Energy, the Department of Housing and Urban Development, and the State of New Mexico (New Mexico Energy Institute), is conducting a study to gather thermal-performance data on various building materials, with an emphasis on adobe structures of various thicknesses. The Southwest Thermal Mass Study, as the project is known, is located at Tesuque Pueblo in northern New Mexico, and expects to complete its research by 1982.

Production methods

The adobe-brick production operation is a labor-intensive, fuel-efficient industry employing easily extracted, indigenous materials. The production of adobe bricks is a seasonal operation and is usually limited by the number of available frost-free days for that particular adobe yard. In general the production season varies from 5 to 9 months, depending on the climate and weather conditions.

Bricks are made in various sizes according to their intended use. The principal standard-size adobe brick used in this state (97%) measures 10 x 4 x 14 inches and weighs approximately 30 lbs, although other sizes and types of adobes are usually made upon special order. An average of 1 yard^3 of adobe soil is used to produce approximately 80 standard-size bricks. Three major techniques are used to produce adobe bricks in New Mexico. Producers in each category have been selected as representative of the adobe industry and are described below.

Traditional handcrafted adobe production

Although this method was used by 19 of the adobe producers visited in 1980, total production of commercially produced, traditionally made bricks did not exceed 1,353,000. This figure significantly increases when added to the large number of adobe bricks (an estimated 3—4 million) that were produced by individuals at the site of their own construction projects.

Montaño Brothers (Santa Fe) and Roman Valdez and James Lujan (Nambé)

The ageless traditional system of adobe production is a relatively simple process that was observed at many locations throughout the state. At the adobe yards of the Montaño Brothers in Santa Fe and the Roman Valdez and James Lujan adobe yard in Nambé, the following production procedure is used:

1) The adobe soil is either excavated by hand shovels at the adobe yard or is delivered from various adobe soil locations and stockpiled by the mudpit. A small pit is formed into which is placed the loose adobe soil and water to form the mud mixture. The mud is mixed, sometimes by foot, but more commonly by hoeing until the proper mixture has been achieved (fig. 60). Depending upon the type of soil used, straw is also added sometimes to prevent the adobes from cracking excessively.

FIGURE 60-FOOT-TREADING *STRAW INTO* ADOBE IN MUDPIT; Roman Valdez and James Lujan adobe operation, Nambe.

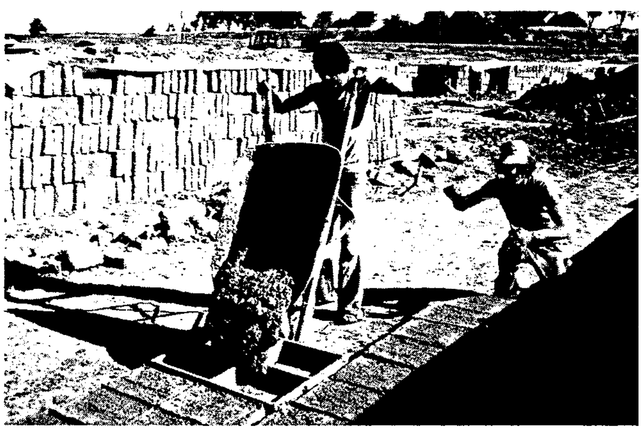
2) The prepared adobe mud is shoveled into a wheelbarrow and delivered to several four-mold wooden forms that have been laid out on the leveled ground of the adobe yard. The mud is then dumped into the molding forms, and the adobero tamps the mud into the corners and smooths off any excess material (figs. 61A and B).
3) The molding form is removed by hand, with care taken to retain the shape of the adobe, and the excess mud is washed from the wooden frame prior to replacing it on the level ground (figs. 61C and D).
4) After 2 or 3 days of drying, the bricks are turned on edge, trimmed of excess material or rough edges and further allowed to sun cure for 3-4 weeks before stacking and delivery.

Considerable variation in daily production rates was noted using the traditional techniques, with various individual adoberos producing from 100 to 300 bricks per day. Several adobe operations, utilizing two or three adobe makers, were producing 300—500 adobe bricks per day.

Semimechanized adobe production

The semimechanized method of production is similar to the traditional handcrafted method except for the addition of various types of mechanical lifting and mixing equipment, such as a front-end loader, pugmills, and plaster or cement mixers. It also represents the lowest capital-investment (equipment) type of operation capable of large-scale adobe-brick manufacturing (150,000—1,000,000 adobe bricks per yr) that was noted during this survey of adobe producers.

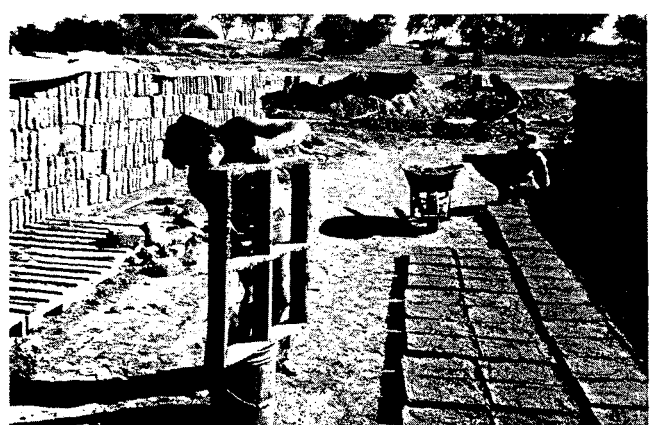
During the field investigation, a total of 25 adobe producers were identified who manufactured 2,831,000 adobe bricks (traditional, semistabilized, stabilized) using the semimechanized method. Their annual production varied from 2,000—700,000 adobe bricks, the majority of which



A-ADOBE MUD IS DUMPED INTO WOODEN FORMS.

C-LIFTING ADOBE FORM.

B-ADOBERO TAMPS ADOBE MUD INTO CORNERS OF WOODEN FORM



D -FORM IS THEN WASHED AND REPLACED TO AWAIT NEXT POURING OF ADOBE MUD.

FIGURE 61-TRADITIONAL SYSTEM OF ADOBE PRODUCTION AT THE ELOY MONTANO ADOBE YARD, SANTA FE.

FIGURE 62-ADOBE YARD, NEW MEXICO EARTH, ALAMEDA.

were the standard 10 x 4 x 14-inch-size adobes. The nine different and representative examples of the semimechanized method of production are detailed as follows:

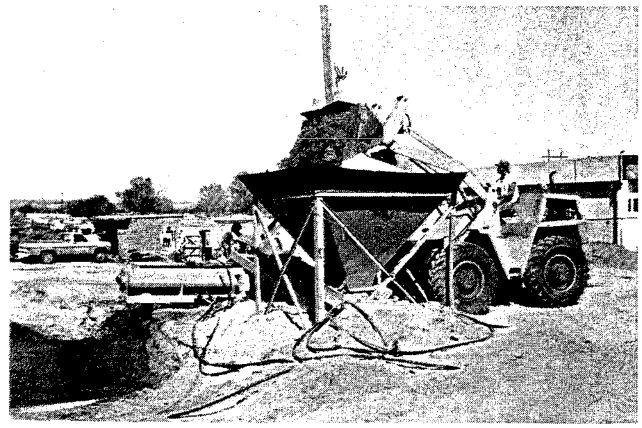
New Mexico Earth (Alameda)

The largest producer of adobe bricks in the state is the New Mexico Earth Company which was established in 1972 and is managed by Richard Levine of Alameda, New Mexico. The operation is located on 4 acres in Alameda (fig. 62), where over 1,000,000 adobe bricks were produced in 1979 and 700,000 bricks in 1980. The adobe site has an average elevation of 4,800 ft and a semiarid climate. The average annual rainfall is 10—14 inches and the mean annual temperature is 57° F. The adobe season usually extends from March through November and normally has a frost-free period of 203 days.

Equipment at the adobe yard includes two front-end loaders, a pugmill, a material storage and conveyor system, and several hundred (700—800) wooden adobe forms of 10 molds per form. The adobe soil is purchased from a local sand and gravel operation where it is obtained from the overburden (15—30 ft) of the alluvial plain and Quaternary terrace deposits in the Albuquerque Basin. The sandy loam is typical of the material used by the majority of Rio Grande valley adobe producers.

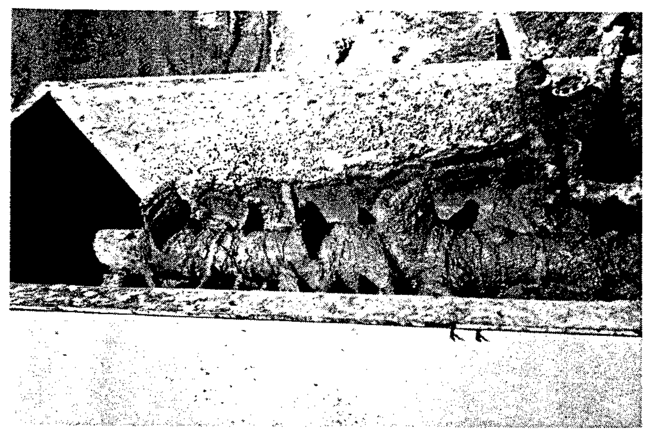
The method used by the company for the large-scale production of adobe bricks is detailed as follows:

1) The sandy loam alluvial soil is delivered to the adobe yard from a nearby sand and gravel operation and stockpiled adjacent to the hopper. The material is removed from the stockpile by a Michigan Model 55 front-end loader (1-yard^3 capacity) and placed into an 8 x 8-ft material hopper (fig. 63A). The soil is then conveyed to a screen that covers part of a 7-ft pugmill trough where large gravel and other foreign materials are removed (fig. 63B).
2) The adobe soil, water, and asphalt emulsion are added simultaneously to the pugmill. Two shafts studded with paddles rotate in the trough of the pugmill and continuously mix the adobe material as it works its way to the open end of the trough (fig. 63C). The mud drops into a large mudpit (30 x 80 ft), and a second front-end loader removes and carries the mud to the adobe-laying yard (figs. 63D and E).
3) Located in the leveled adobe yard are usually 500—600 wooden molding forms, yielding 10 bricks per form. The adobe mud is dumped into the forms and then raked and leveled (figs. 63F and G). The newly laid bricks are allowed to dry for several hours or until they have started to shrink from the form sides. The molding forms are then lifted and moved to a new area (fig. 63H).
4) The adobe bricks are allowed to sun dry for 2 or 3 days at which time they are turned on edge, trimmed, and allowed to either remain in the adobe yard ready for delivery or are stacked to cure (fig. 63I). This operation produces an average of 5,000—6,000 adobe



A-FRONT-END LOADER DUMPING ADOBE SOIL INTO HOPPER.

B-ADOBE MATERIAL IS CONVEYED TO SCREEN THAT COVERS PART OF PUG-MILL TROUGH WHERE LARGE GRAVEL IS REMOVED.



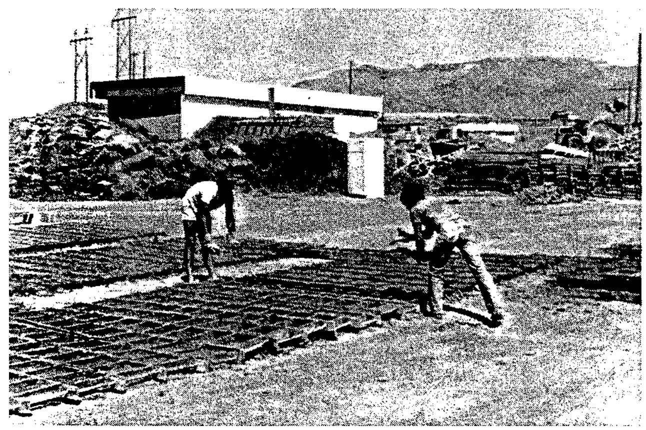
C-ADOBE MUD MIXING IN PUGMILL.

FIGURE 63-SEMIMECHANIZED PRODUCTION METHOD OF NEW MEXICO EARTH, ALAMEDA.

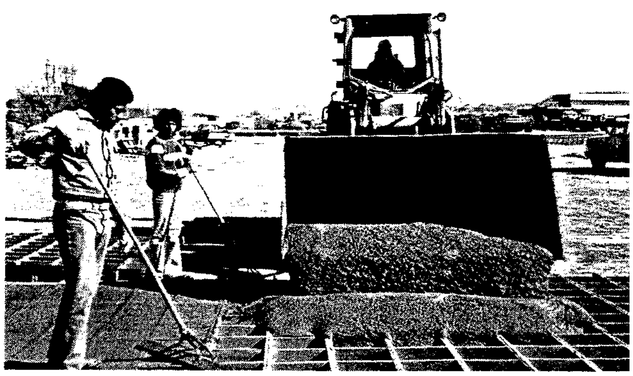
D-ADOBE MUD IS DUMPED INTO LARGE MUDPIT

G-ADOBEROS RAKING ADOBE MUD INTO MOLDING FORMS.

E-FRONT-END LOADER REMOVING MUD FOR DELIVERY TO WOODEN MOLDING FORMS IN DRYING YARD.



H-LIFTING WOODEN ADOBE FORMS AFTER ADOBES HAVE SHRUNK FROM FORM SIDES.



F-FRONT-END LOADER POURING MUD INTO WOODEN FORMS.

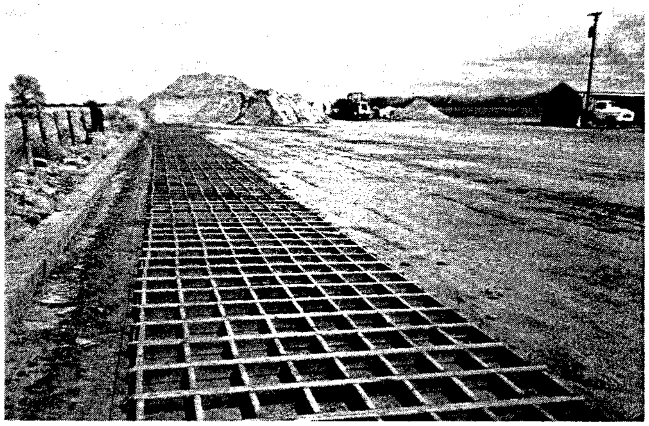
I-AFTER DRYING FOR 2 OR 3 DAYS, ADOBES ARE TURNED ON EDGE AND TRIMMED OF EXCESS MATERIAL.

bricks per day, and this production figure can be doubled with available yard space.

5) The delivery system at New Mexico Earth consists of eight 2½-ton flatbed trucks with a local delivery capability of approximately 5,000 adobe bricks per day. This number of trucks also requires a shop mechanic and dispatcher to coordinate the schedules. An effective delivery system is essential to continue the company's production goals since the 4-acre adobe yard can only hold a maximum of 65,000 bricks.

Rio Abajo Adobe Works (Belen)

An outstanding and organized adobe operation observed during this study was the Rio Abajo Adobe Works, which is owned by Jerry Sanchez of Belen, New Mexico. The operation is located on 3 acres where over 150,000 semi-stabilized adobe bricks were produced in 1980. The adobe yard also produces fully stabilized adobe bricks on special order. All adobe bricks are of the standard 3½ x 10 x 14-inch size. The adobe site has an average elevation of 4,700 ft and a semiarid climate. The average annual rainfall is 10



A-WOODEN MOLDING FORMS PLACED ON LEVELED ADOBE YARD AND READY FOR POURING OF ADOBE MUD.

B--FRONT-END LOADER WORKING IN MUDPIT TO BLEND WATER. ASPHALT EMULSION, AND ADOBE SOIL.

C-PORTABLE MUD VAT MOUNTED ON TRUCK FOR DELIVERY TO CONSTRUCTION SITE.

FIGURE 64-SEMIMECHANIZED BRICK PRODUCTION OF RIO ABAJO ADOBE WORKS, BELEN.

inches and the average annual temperature is 57° F. The adobe season usually extends from March through November and normally has a frost-free period of 200 days.

Equipment in the adobe yard includes a 2-yard^3-capacity Michigan Model 75 front-end loader, 200 wooden molding forms that yield 8 adobe bricks per form (fig. 64A), a portable mud vat, a portable oil tank, and a 21-ton flatbed truck. The adobe soil is secured from nearby Quaternary terrace deposits and the Santa Fe Formation (Tertiary) and is hauled to the adobe yard where the soil is stockpiled adjacent to the irrigation ditch and mudpit. The sandy loam and clay soil is typical of the adobe material used by the majority of the Rio Grande adoberos.

The method used by Jerry Sanchez for the large-scale production of adobe bricks is detailed as follows:

1) The sandy loam and clay are removed by the front-end loader from the soil stockpile and are blended in a large mudpit that measures approximately 30 x 65 ft and slopes to a maximum 3-ft depth at one end. Water from an adjacent irrigation ditch is added to the adobe soil (8 yards^3) and is then allowed to soak overnight in order to assist the breaking down of the clay in the mixture. A measured amount of asphalt emulsion (33 gal) is added to the adobe mud and the front-end loader works the mud in the pit until a uniform mixture is achieved (fig. 64B).
2) The adobe mud is removed from the pit by the front-end loader and delivered to the adobe-laying yard where over 200 oil-sprayed wooden molding forms, yielding 8 bricks per form, have been placed next to each other. The mud is poured into the molding forms and the excess material raked and leveled. The adobes are allowed to dry in the molding forms for several hours, depending on the weather, and when they have shrunk from the form sides the forms are lifted and moved to an adjacent location for the next pouring of the adobe mud.
3) The bricks are allowed to dry for 2 or 3 days at which time they are turned on edge, trimmed, and later stacked ready for delivery. This method of production with a crew of two or three employees is capable of producing 1,500—3,000 adobe bricks per day.
4) In addition to the adobe-brick delivery system using a 2½ ton flatbed truck, Jerry Sanchez has designed and constructed a portable mud vat that is mounted on the truck (fig. 64C). The adobe mud mixed in the yard is transferred by the front-end loader to the mud vat which is then delivered to the construction site. Once at the site a valve on the mud vat is opened and the mud is poured into a wheelbarrow. The mud mortar is then transported to the workers engaged in laying the bricks in adobe walls or other structures.

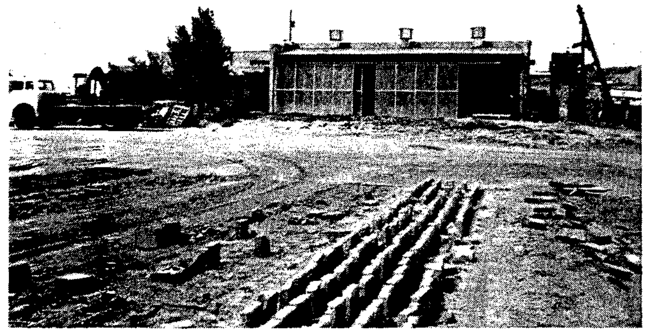
Adobe Farms (Española)

Adobe Farms' operation is located in northern New Mexico near Española, on the east side of the Taos highway (US—64). The adobe-production season for this operation is between April and October and usually averages 150 frost-free days. The adobe yard covers approximately 6 acres and has several structures used in the adobe operation including a solar adobe dryer (figs. 65A and B), an office and maintenance complex, and the Hydra-Brikcrete pressed-adobe machinery.

The production equipment used in 1980 for the large-scale manufacturing of adobe bricks included a Model 125 Michigan front-end loader, two 7.5-yard^3 ready-mix trucks, a 3,200-gal asphalt-emulsion storage tank, and a material hopper and conveyor system for delivery of the adobe soils to the cement mixer. Originally the adobe soil used in production was removed from the adobe yard by land leveling and was stockpiled by the material hopper. However, adobe soil is presently purchased from nearby sand and gravel operators who remove the material from arroyos and Quaternary terrace sand and gravel deposits. The soil type at the adobe yard was identified by the U.S. Department of Agriculture Soil Conservation Service as Fruitland sandy loam. From this classification of adobe material four types of adobe bricks (traditional, semistabilized, stabilized, and pressed) were produced in 1980. Details of the pressed-adobe method of production are outlined later in this report under the section on pressed-adobe operations.

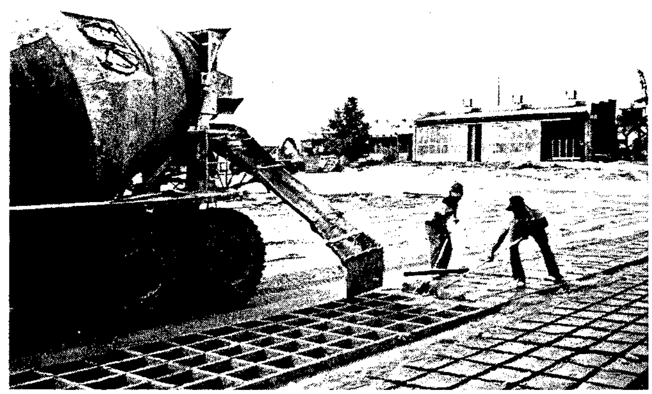
The production method for the other three types of adobe bricks is detailed as follows:

1) The front-end loader dumps the stockpiled adobe soil into the screening plant located by the material bin. The soil (7 yards^3) is conveyed to the ready-mix truck where the asphalt emulsion (125 gal) and water are added. The soil, water, and asphalt emulsion are mixed in the cement mixer for an average of 30 min.
2) The ready-mix truck then transports the adobe mixture to the adobe yard where 100–200 wooden adobe-molding forms, each producing 50 bricks, have been placed in line on the ground. The mud is poured into the molding forms and two adoberos rake and level the mud in the forms as the truck moves forward (fig. 65C).
3) The adobe bricks are allowed to dry for several hours or until they have shrunk from the wooden form sides and the forms are then lifted and relocated for a later mud pouring. The bricks are allowed to dry for 2 or 3 days, depending upon the weather, and are then turned on edge and trimmed of excess material. The bricks will dry for several weeks at which time they are loaded for delivery or stacked to clear the laying yard. This semimechanized method of manufacturing adobes is capable of producing 3,000–5,000 bricks per day per truck using a crew of two or three employees.



A-SOLAR ADOBE DRYER AND OFFICE COMPLEX.

B-INTERIOR OF SOLAR DRYER: (holes in bricks as seen in this 1979 photograph are no longer included in production method).



C-ADOBE MUD IS POURED INTO WOODEN MOLDING FORMS AND RAKED SMOOTH BY ADOBEROS.

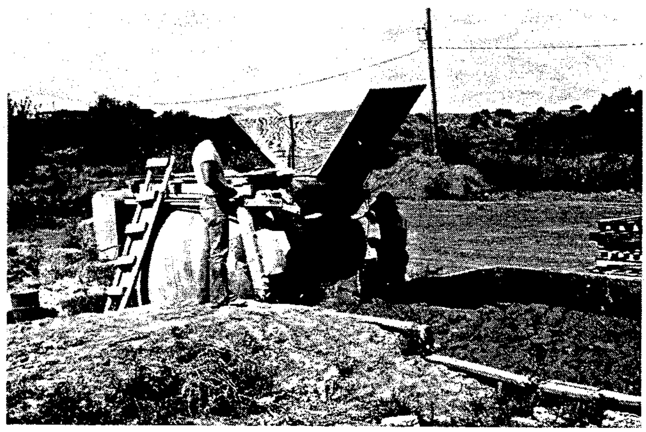
FIGURE 65-ADOBE FARMS, ESPANOLA.

Joe Trujillo (Ranchos de Taos)

The adobe operation of Joe Trujillo is located on approximately 1 acre of level land in Ranchos de Taos, New Mexico, where over 60,000 8 x 4 x 12-inch traditional adobe bricks containing straw were produced in 1980. The adobe bricks are produced using a 4-yard^3 ready-mix cement mixer that has been removed from a truck frame and mounted at ground level. A dirt ramp has been constructed to allow a front-end loader to dump the adobe soil directly into the hopper of the mixer. Other equipment includes four wooden molding forms that produce 24 bricks per form and a flatbed delivery truck and trailer. This semimechanized method of production at the Trujillo adobe yard uses the following procedure:

1) Adobe soil is excavated from nearby Quaternary terrace and recent arroyo deposits and is stockpiled adjacent to the cement mixer. The front-end loader dumps the adobe soil into the mixer, and the operator adds water and straw until a uniform mud mixture is obtained. This mixture is then dumped into a holding bin (figs. 66A and B).
2) The front-end loader removes the adobe mud from the storage bin and delivers it to wooden molding forms that have been placed on the level adobe yard. The mud is tamped and raked and the molding forms are then lifted and reset for the next pour. An average of 1,500 adobe bricks per day is usually produced using a crew of two or three employees.
3) After the bricks have sun dried for 3–4 days they are turned on edge, trimmed of excess material, and allowed to dry for an additional 1–2 weeks.

A-FRONT-END LOADER LOADING CEMENT-MIXER HOPPER WITH ADOBE SOIL.



B-MIXING ADOBE AND DUMPING MUD INTO A WOODEN STORAGE BIN.

FIGURE 66-JOE TRUJILLO'S SEMIMECHANIZED ADOBE OPERATION. RANCHOS DE TAOS.

Medina's Adobe Factory (Alcalde)

Medina's Adobe Factory is located on approximately 10 acres of level land in Alcalde, New Mexico, on the east side of Taos highway (US—64). The adobe site has an average elevation of 5,800 ft and a mean annual temperature of 57° F. The average rainfall is 9—11 inches annually and the normal frost-free period is 150 days a year, extending from May to October. The soil used for the adobe-brick production is removed by land leveling of the adobe yard and is a fine sandy loam classified by the U.S. Department of Agriculture Soil Conservation Service as part of the Fruit-land series. The soil has a low shrink-swell potential that produces a good quality adobe brick.

During 1980 over 50,000 traditional 10 x 4 x 14-inch adobe bricks with straw were manufactured and sold for an average price of 25 cents per adobe. The Medina operation was the only New Mexico commercial producer using the hand-operated mechanical adobe layer known by the trade name "Adobemaster." The details of this production method are as follows:

1) The sandy loam that is removed from the adobe yard by a road grader is stockpiled adjacent to a material conveyor system. A front-end loader moves the material to the conveyor, which feeds the soil into a 7.5-yard^3 ready-mix truck. Water and straw are added to the soil, and the mud is mixed for several minutes before delivery to the Adobemaster.

2) The Adobemaster is positioned in the adobe yard with the hopper in the center of the mold assembly. The hopper is then filled with the adobe mud and two operators push the hopper from front to rear over the mold and return the hopper to the front cutoff plate (fig. 67A). The individual molds are checked to make sure they are full and, if necessary, an additional front to rear pass is made with the hopper or the mud is raked or packed by hand into the mold. The mold-lift bar is pulled and the machine is moved forward and set on the level ground ready to receive the next pouring of mud (fig. 67B). The mold produces 24 adobes per pouring, and an average of 800—900 adobe bricks per day can be produced using a crew of two or three employees.

During the fall and winter of 1980, Joe and Mel Medina purchased additional equipment to expand their adobe operation. A large pugmill powered by a six-cylinder Chevrolet engine, a 1-yard^3 front-end loader, and several hundred wooden molding forms were secured for use during the 1981 production season. Fig. 67C shows the adobe yard and equipment during the spring of 1981.

Ralph Mondragon (Ranchos de Taos)

The unique semimechanized adobe operation of Ralph Mondragon is located on approximately 1 acre of level land adjacent to his home in Ranchos de Taos. Between 15,000 and 20,000 8 x 4 x 12-inch traditional adobe bricks made with straw were produced in 1980. The adobe site has an average elevation of 7,500 ft and a semiarid climate. The average annual rainfall is 12—16 inches and the mean annual temperature is 47° F. The adobe season usually extends from late March through September and normally has a frost-free period of 120 days.

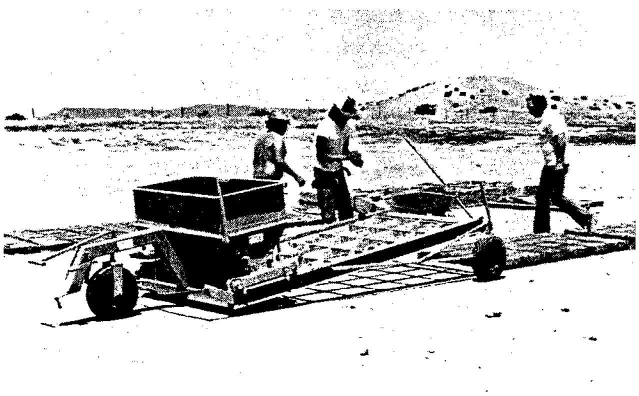
The majority of the mechanical equipment used at the adobe yard has been developed and built by Ralph Mondragon and is powered by old pickup engines. Included are a homemade pugmill, powered by a 1956 Chevrolet engine, a mud vehicle made from a 1950 Chevrolet flatbed truck, and 20 wooden molding forms that produce 25 adobe bricks per form.

The general procedure used in the production of the adobe bricks is detailed as follows:

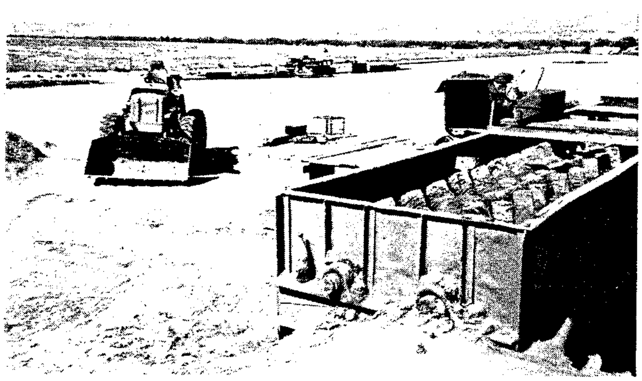
1) Adobe soil is excavated from a nearby arroyo and Quaternary terrace deposits and is hauled to the adobe yard where it is stockpiled adjacent to the material hopper. A front-end loader deposits the soil into the hopper that feeds into the pugmill where water and straw are added to secure the proper mud mixture. The pugmill is powered off the drive shaft of the old Chevrolet, and the mud is mixed for approximately 45 min (fig. 68A). The mud is then dumped into a modified Chevrolet flatbed truck that is moved under the pugmill and that has been specially equipped with two slots on each side of the wooden holding bed (fig. 68B).

2) The truck delivers the adobe mud to wooden molding forms that have been placed on sheets of polyethylene on each side of the road through the adobe yard. This system permits the operator to drive the mud vehicle between the forms. The side slots on the truck bed are opened and the mud is delivered to the molding forms with the aid of a trough added

A-OPERATORS PUSHING HOPPER FILLED WITH ADOBE MUD FROM FRONT TO REAR OVER ADOBE MOLDING FORM.

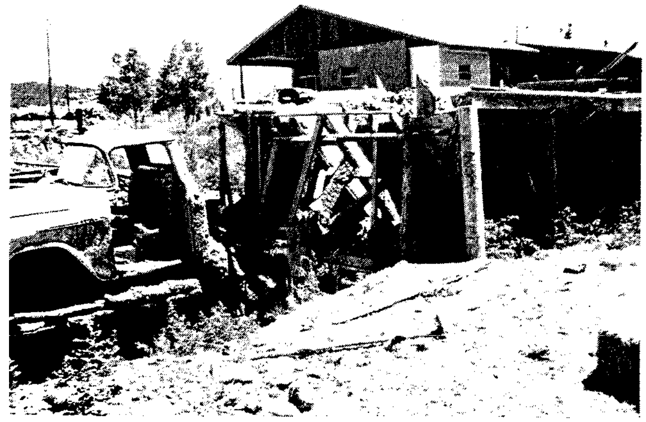


B-ADOBEMASTER FORM LIFTED FROM ADOBES AND MOVED TO NEXT SITE WHERE IT WILL BE LOWERED TO GROUND READY FOR NEXT MUD POUR.



C-NEW PUGMILL, FRONT-END LOADER, AND OVERALL VIEW OF ADOBE YARD IN SPRING 1981.

FIGURE 67-JOE AND MEL MEDINA'S ADOBE YARD, ALCALDE.



A-MATERIAL HOPPER AND POWER EQUIPMENT.

B-SIDE SLOTS ON MUD VEHICLE ARE OPENED, AND MUD FLOWS INTO WOODEN MOLDING FORMS ON EACH SIDE OF TRUCK.

C-EXCESS MUD IN WOODEN FORMS IS RAKED AND SMOOTHED; BRICKS ARE ALLOWED TO DRY FOR SEVERAL HOURS BEFORE LIFTING MOLDING FORMS.

FIGURE 68-RALPH MONDRAGON ADOBE OPERATION, RANCHOS DE TAOS.

to the slots. The mud is raked, leveled, and allowed to dry for several hours until it has shrunk from the form sides (fig. 68C). The molding forms are then lifted and reset for the next pour. An average of 300—500 adobe bricks per day are usually produced using a crew of one or two employees.

3) After the bricks have been sun dried for a few days (2 or 3), they are turned on edge and allowed to dry for an additional 2 weeks. Purchasers of the bricks usually have their own delivery system and pick up the adobes at the adobe yard.

Taos Pueblo

During the summer of 1980, Taos Pueblo reopened commercial production of traditional adobe bricks at a site located southwest of the main pueblo area. The project was managed by Marrion Threehawks and included 8—10 pueblo

A-MUDPIT EXCAVATED BY BACKHOE AND USED TO MIX WATER. STRAW, AND ADOBE SOIL.

B -TAMPING AND RAKING ADOBE MUD INTO WOODEN MOLDING FORMS.

C-ADOBE BRICKS DRYING AND SOIL STOCKPILE.

FIGURE 69-PRODUCTION OF TRADITIONAL ADOBE BRICKS AT TAOS PUEBLO.

employees, with Henry Gomez as foreman of the operation. Approximately 47,000 traditional adobe bricks were made in three sizes, 8 x 4 x 12, 8 x 4 x 16 and 10 x 4 x 14 inches. Equipment included a front-end loader and backhoe used on a part-time basis to excavate the adobe soil, wheelbarrows, and various wooden molding forms. The general procedure used in production of the bricks included the following steps:

1) The backhoe is used to excavate a large mudpit located in the center of the adobe yard (fig. 69A). The adobe soil contains a high percentage of clay that sometimes requires the addition of sand to the mixture along with the straw. The backhoe is also used to mix the mud, water, and straw until the proper adobe-mud mixture has been obtained.
2) The mud is then shoveled by hand into the wheelbarrows that are used to transport the material to a series of wooden molding forms placed on the leveled adobe yard. The mud is dumped into the forms where it is tamped, raked, and smoothed of excess material (fig. 69B). The mud is then allowed to dry for several hours or until it has shrunk from the sides of the wooden molds. At this time the forms are lifted and reset for the next pour.
3) The bricks are allowed to dry for 4—5 days at which time they are turned on edge, trimmed of excess material, and allowed to sun dry for a minimum of several weeks, depending on the weather, before final stacking for delivery (fig. 69C). The majority of bricks produced in the summer of 1980 were used to rebuild the adobe wall that surrounds the old pueblo and for restoration of the north and south pueblo structures.

Mobile adobe operations

Two mobile adobe-brick operations were active in 1980, one which was headquartered in Albuquerque and the other in Deming, New Mexico. The mobile adobero's production equipment consists of front-end loaders, cement mixers or a portable pugmill, and wooden molding forms that are transported by flatbed trucks and trailers to the client's construction site. Prior to production of the bricks, an agreement is made with the client, and a minimum of several thousand adobe bricks are ordered. The client is usually responsible for furnishing an adequate production-yard site and a supply of adobe soil that has been tested for its suitability for making satisfactory bricks.

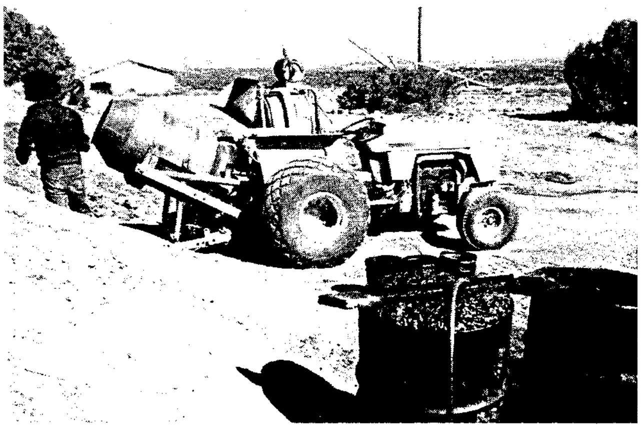
HACHITA ADOBE-Gordon Garland of Deming, New Mexico, owner of Hachita Adobe, operates a unique semimechanized method of adobe manufacturing that is capable of producing an average of 1,200—1,500 bricks per day. Garland has developed a mobile adobe-brick-production system that includes tractors equipped with cement mixers, various wooden molding forms, a front-end loader, and various containers for mixing the asphalt emulsion and water.

During August and September of 1980, the Hachita mobile-adobe equipment was set up at the site of a large construction project in Silver City, New Mexico. Over 25,000 fully stabilized adobe bricks were produced. The adobe soil and asphalt emulsion were furnished by the land owner, and the bricks were manufactured under contract for $350.00 per thousand. The general procedures used in the manufacturing of the bricks are detailed as follows:

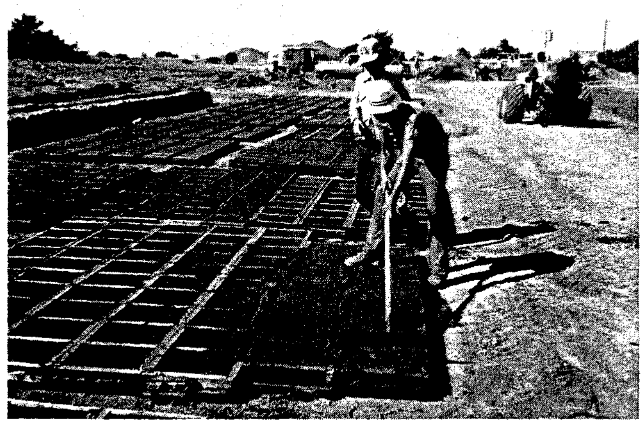
1) The adobe soil is carefully tested by making a series of small adobe pats that have a varying amount of asphalt emulsion added (4—10%). The small adobe pats are dried in a kitchen oven and upon removal are room cooled and then placed in a jar of cold water for 2—4 hrs. The pat containing the best stabilizer mixture will not become soft or discolor the water.
2) The adobe soil and sand used to produce a proper mixture at the Silver City construction site were purchased from a local sand and gravel operator

A--SHOVELING ADOBE SOIL INTO TRACTOR-MOUNTED CEMENT MIXER

C-TRACTOR MIXER DUMPS ADOBE MUD INTO WOODEN MOLDING FORMS



B-ASPHALT EMULSION AND WATER ARE MIXED IN 55-GAL DRUMS.



D-ADOBEROS RAKE OR SCREEN ADOBE MUD INTO WOODEN FORMS.

FIGURE 70-HACHITA ADOBE OF DEMING AT CONSTRUCTION SITE IN SILVER CITY.

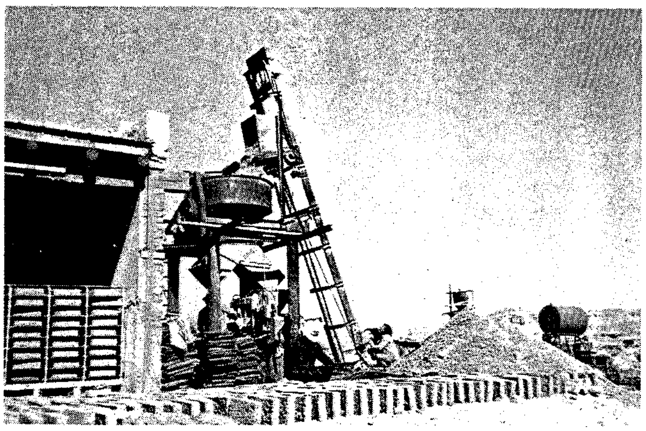
(Duke Cooper), who hauls the material from the Maude Canyon area. It is stockpiled in the adobe yard close to the water and asphalt-emulsion source. A mixture of 5—6 gal of asphalt emulsion to 50 gal of water is premixed and stored in a 55-gal drum. The soil (8 ft^3) is hand shoveled into the tractor mixer and 15 gal of the water and asphalt-emulsion mix are added (figs. 70A and B).

3) The tractor mixer contains four paddles at opposing angles for better mixing. They rotate as the tractor transports the mud to the adobe yard where a hydraulic pitch control allows the operator to dump the adobe-mud mix into the wooden molding forms. A light layer of sand has been spread on the laying area of the adobe yard previous to the setting of the wooden molding forms. This is done to prevent the bricks from sticking to the ground or from picking up excess material. The poured mud (slurry mix) is spread by the adoberos with screeners and raked into the various molds; the excess is then smoothed off. Usually 16 adobes are poured per tractor-mixer load. Once emptied, the tractor returns to the soil stockpile for the next cycle (figs. 70C and D).

4) The mud is allowed to dry in the forms for several hours or until it shrinks from the mold sides, at which time the forms are lifted and relocated to the next row for pouring. The 8-mold wooden forms produce standard-size 10 x 4 x 14-inch adobe bricks of excellent quality. A $3^5/_8$ -inch brick is also made because it dries more quickly and weighs less. The bricks are allowed to dry for 2—3 days, depending upon the weather, at which time they are turned on edge, trimmed of excess material, and later stacked in the adobe yard, ready for use.

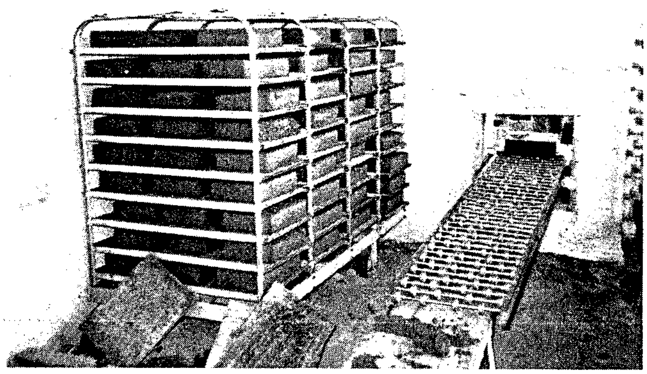
HIGH DESERT ADOBE COMPANY-High Desert Adobe Company is owned by David Harris of Alameda, New Mexico. The operation was started in 1980 with the majority of adobe production out of state. The operation produced 80,000 stabilized adobe bricks in the border areas of Texas and Kansas. The adobe bricks were produced on site for between 27 and 37 cents per brick for an average of 33 cents per brick. The owner has developed a mobile brick-production system that includes a front-end loader (usually rented in the area of the production yard), 200 wooden molding forms that produce 10 standard $3^1/_2$ x 10 x 14-inch bricks per form, and various containers for mixing the asphalt emulsion and water. Prior to production of the bricks, an agreement is made with the client for a minimum order of 10,000 adobes. The client furnishes the adobe soil, water, asphalt emulsion, and yard space. The general procedures used in the manufacturing of the bricks are detailed as follows:

1) After the production agreement has been signed by both parties, and the soil has been tested, the equipment is moved and set up at the owner's adobe site. The area is leveled using the front-end loader, and a mudpit is excavated near the water supply. The adobe soil is also excavated at the adobe site or is hauled from a nearby source and stockpiled adjacent



A-DUMPING SCREENED ADOBE SOIL INTO MIXER OF HYDRA-BRIKCRETE MACHINE.

B-PRESSED-ADOBE BRICK IS REMOVED FROM MOLDING AND PRESSING AREA.



C-PRESSED ADOBES ARE SET OUTSIDE IN GOOD DRYING WEATHER OR PLACED ON RACKS IN SOLAR ADOBE DRYER.

FIGURE 71-PRESSED-ADOBE OPERATION OF ADOBE FARMS, ESPANOLA.

to the mudpit. Approximately 5–8 yards^3 of soil are moved by the front-end loader into the mudpit. Water and a measured amount of asphalt emulsion are added, and the front-end loader works the material into a uniform mud mixture.

2) The adobe mud is then removed by the front-end loader and transported to the wooden molding forms that have been placed in the leveled adobe yard. The mud is poured into the molding forms and allowed to dry for several hours (or days, depending upon climate and weather conditions at the construction site) or until they have shrunk from the form sides. The molding forms are then lifted and reset for the next pouring. According to the owner, the operation is capable of producing 1,500–2,000 adobe bricks per day.

Pressed-adobe operations

The major techniques of production for the pressed-adobe bricks manufactured in New Mexico, including a description of the types of equipment used, are outlined as follows.

ADOBE FARMS—Owned by Ralph Rivera and located in Española, New Mexico, in the Arroyo Seco area of Santa Fe County, Adobe Farms produces pressed adobes using the Hydra-Brikcrete Press. The pressed-adobe equipment was installed at the site in 1979 and is attached to the east end of a solar adobe dryer where the bricks are stored for drying during inclement weather. The Hydra-Brikcrete Press is electrically powered and requires an average of two employees to operate it using the following procedure:

1) Previously stockpiled adobe soil containing a mixture of approximately 50% clay is shoveled by hand into a 1-inch screen placed over the loader hopper located at ground level. The material hopper is then cabled to the top of the headframe where it is tripped and the adobe soil is dumped into a circular batch mixer (fig. 71A). A measured amount of water is added to the adobe soil until a stiff damp mud mixture is obtained, which is then dropped into a holding bin.

2) The damp adobe soil from the holding bin is placed into a 10 x 4 x 14-inch metal mold where over 1,000 lbs of pressure is applied to produce a dense brick (fig. 71B).

3) The bricks are then removed from the machine by hand to a wooden plate and conveyed into the dryer where they are stacked on storage carts for drying (fig. 71C). The adobes require an average of 13 days for drying in the solar adobe dryer in winter, but during the summer using the outside drying yard, adobes can sometimes be used in 3–4 days. This system, utilizing the solar adobe dryer, can increase the production season by several months.

According to the manufacturer, a crew of three persons can produce approximately 800 adobe bricks per day. The adobes were priced at 30 cents for a traditional adobe and

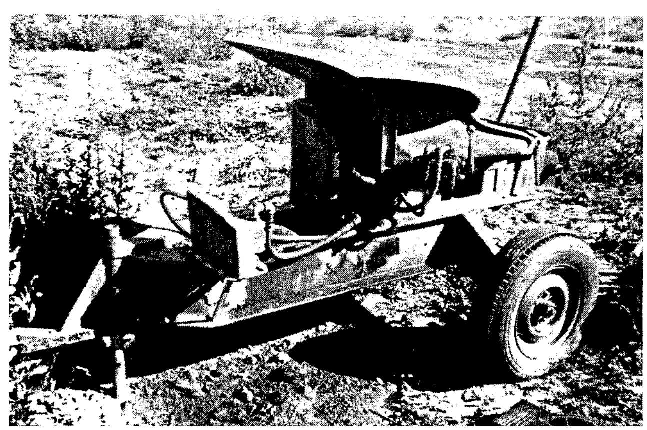
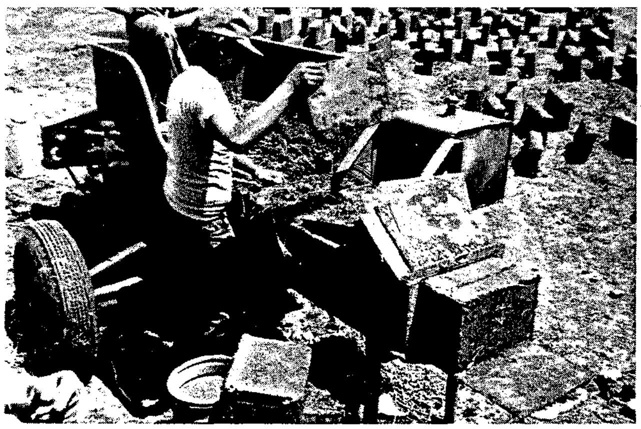
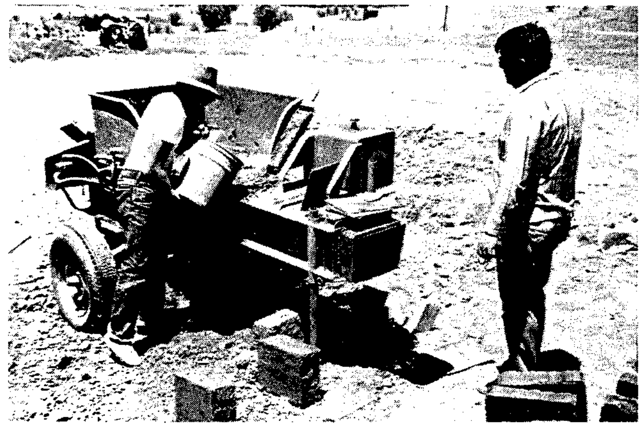


FIGURE 72-PORTA PRESS WITHOUT GASOLINE ENGINE; A. Ulibarri adobe yard, Tierra Amarilla.

A-CREW MAKING PRESSED ADOBES.



B-ADOBE SOIL IS PLACED BETWEEN TWO WOODEN PLATES IN SLOT OF PORTA PRESS.



C-WATER IS ADDED TO ADOBE MIXTURE TO PRODUCE A MOIST SOIL FOR PRESSING.

D—AFTER 20,000 LBS OF PRESSURE HAVE BEEN APPLIED TO THE ADOBE. THE BRICK IS EJECTED FROM THE MACHINE AND PLACED IN ADOBE YARD TO DRY.

FIGURE 73-PRESSED-ADOBE OPERATION OF DAVID GRIEGO. LEDOUX.

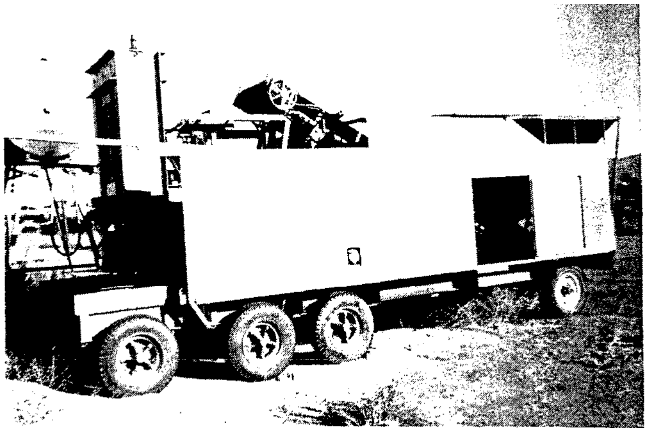
35 cents for a semistabilized adobe. The Hydra-Brikcrete Press was originally designed to produce concrete blocks and was modified and adapted by Ralph Rivera for the manufacture of adobe bricks. Several molds were built and are used to produce the following size bricks; 10 x 4 x 14-inch standard adobe, 8 x 4 x 12-inch Taos standard, 8 x 4 x 12-inch right- and left-hand corner units, 4 x 8 x 6-inch half units, and 4 x 4 x 12-inch veneer. To date, the equipment has had limited use and is still being modified to increase the production capability from the present 800 adobes per day to approximately 2,400 per day of the standard-size 10 x 4 x 14-inch adobe brick and 9,600 per day of the 4 x 4 x 12-inch adobe veneer brick. The addition of a soil-storage bin to eliminate the hand shoveling and new conveyor storage racks used with the 26 x 170-ft solar dryer will make the manufacture of pressed-adobe brick a year-round operation.

A. ULIBARRI OF TIERRA AMARILLA AND DAVID GRIEGO OF LEDOUX, NEW MEXICO—These operations produced pressed adobes during the 1980 production season using trailer-mounted, gasoline-powered, and hydraulically operated adobe presses (fig. 72). The adobe presses are identified under the trade name of Porta Press and were manufactured in 1966 by Vern and N. N. Huffaker of Santa Fe. The machine weighs approximately 3,000 lbs and is powered by a 7-hp, air-cooled, Briggs and Stratton engine. The Porta Press is no longer being manufactured, but the total package of equipment was priced in 1966 at an average of $2,700 per unit and was sold throughout the Southwest, as well as in several foreign countries.

At the adobe yards of A. Ulibarri and David Griego, the machine was set up and leveled adjacent to a stockpile of adobe soil that contained a high percentage of clay. When in production the following procedure is used:

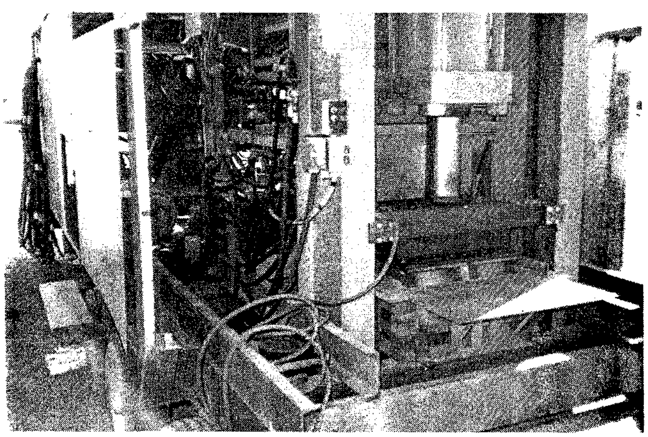
1) The soil is shoveled by hand into a small storage hopper and a measured amount of soil is placed between two wooden oiled plates in the loading slot (figs. 73A and B).
2) Water from a 5-gal bucket is added to the adobe soil to produce a moist mixture (fig. 73C), and the slot door is closed and locked. A lever is moved that activates a hydraulic ram that applies over 20,000 lbs of pressure to the soil. A second lever is then turned, and the same ram ejects the pressed brick from the machine (fig. 73D).
3) The adobes are removed and placed in the sun to dry for several days. The machine, according to its manufacturer, is capable of producing 600–800 adobe bricks per day with a crew of two or three employees.

During the summer season of 1980, David Griego produced 7,000 pressed adobes on a part-time basis at the construction sites of individual adobe purchasers. The Porta Press was moved to the desired locations and the above technique of production was employed. The bricks sold for an average of 35 cents per adobe.



A-TRAILER-MOUNTED. PRESSED-ADOBE EQUIPMENT.

B-ALLEN-TYPE SCREENING AND LOADING EQUIPMENT.



C-HYDRAULIC PRESS EQUIPMENT USED TO PRODUCE A 10 X 4 x 14-INCH ADOBE BRICK.

FIGURE 74-SUN MOUNTAIN. SANTA FE.

SUN MOUNTAIN-This operation was started in 1976 by Al Niblack, who has developed a high-production-type port-able pressed-adobe-brick system. The electric-powered equipment contains a hydraulically operated press that is mounted on an 8-wheel self-propelled platform trailer (fig. 74A). The accessory equipment includes a loading hopper, feeder conveyor, and automatic material weigher (fig. 74B). Production of pressed adobes at Sun Mountain includes the following:

1) The adobe soil is purchased from a local sand and gravel operation located a short distance from the adobe yard. The adobe material is stockpiled adjacent to a gasoline-powered Allen-type loader that contains vibrating screens and a 30-inch stacking conveyor system used to blend the stockpiled clay with crusher fines.
2) The material is then screened, wet down with a sprinkler, and loaded into the mixing hopper. The mixture is dropped into a metal form (die) measuring 10 x 6 x 14 inches and 1,200 lbs of hydraulic pressure are applied to press a completed brick to 10 x 4 x 14 inches (fig. 74C).
3) The formed adobe bricks are removed from the press and immediately stacked on pallets for drying. Because the bricks are denser than traditional adobes they weigh an average of 38–40 lbs and are usually dry enough to use in 4–5 days. Both traditional and stabilized pressed-adobe bricks can be made with the system and production of 2,000 bricks per day using a crew of two employees is possible. Sun Mountain pressed adobes sell for 30 cents per brick.

SOIL-CRETE SOLAR COMPANY-A new mechanized pressed-adobe operation was being established at Navajo Dam, New Mexico, during 1980; the beginning of production of an estimated 1,000 pressed bricks per day (6 x 4 x 12 inches) was anticipated in the spring of 1981. The owner and developer of the operation is Bill Davidson, an environmental engineer, teacher, and general contractor. The company will produce pressed adobes for the construction of its own contracted solar-designed homes, as well as for general sale to the public. Davidson's operation is located at approximately 6,500 ft elevation just south of the Colorado border, in an area that can expect an average of 140 frost-free days per year. The adobe soil is either removed from deposits on Davidson's 30-acre site or hauled from a neighboring property. A jar test is performed on all soil samples; several different mixtures have been tried to determine the best soil to use for brickmaking. Generally, a coarse sand mixture with approximately 10% clay yields the best adobe.

The equipment used in the pressed-adobe operation includes one front-end loader with backhoe and detachable forklift, a dump truck, a small 1/3-yard,-capacity mixer, a larger 2½-yard^3 industrial cement paddle mixer, a hydraulically operated automatic adobe press (with hopper) powered by a 37-hp Wisconsin air-cooled engine, several wooden pallets, a Ford 1-ton dual-wheel truck, and an 8-wheel trailer for delivery. Both the small mud mixer and the hydraulic adobe press were designed and built by Davidson himself. The production method employed by the Soil-Crete Solar Company is as follows:

1) Soil is hauled by the front-end loader and stockpiled near the paddle mixer. A measured amount of soil is added to the mixer along with a 7–10% portion of portland cement. The mixer blends the dry material for approximately 1 min while the operator removes any organic material by hand. A measured amount of water (approximately 3 gal per small batch yielding 17–20 bricks) is then added, and the soil is thoroughly mixed for 2–3 min.
2) The mud mix is picked up by the front-end loader and dumped into the hopper of the automatic adobe press (fig. 75A). When a sliding panel is pulled out, a chamber is filled with a measured amount of adobe mix, which is then released into the mold where a

single brick is formed under approximately 20,000 lbs of pressure (fig. 75B). The machine will mold a brick up to 6 x 6 x 12 inches but may be adjusted to decrease the thickness of the brick for making tiles or other custom sizes. The finished 6 x 4 x 12-inch brick weighs 20 lbs and is removed by hand to a wooden pallet, which can later be moved for storing or delivery by a forklift attached to the front-end loader (fig. 75C).

3) The bricks may be used within a few hours of production but, while curing, must be watered regularly to slow the drying process and to assure a high-quality, crack-free brick. With a crew of three employees, Soil-Crete Solar Company estimates that it will be able to produce 1,000 pressed adobes daily in good weather.

Adjacent to the adobe yard is the Davidson house and greenhouse, built of stabilized pressed adobes made by hand with a CINVA-Ram press (described in next section) during the last 3 yrs. The CINVA-Ram bricks were laid without mortar and sealed with a commercially sold fiberglass-based surface bonding called Q-Bond. Q-Bond is made for use with cement building blocks and may be used only with adobes that have some cement content. The coating is normally applied on both the interior and exterior surfaces of the laid bricks, although Davidson additionally reinforced his structure with a horizontal layer of Q-Bond laid between the bricks every 2 ft of construction height. A wall stacked and coated with Q-Bond is stronger both laterally and vertically than a conventional mortared wall. A 50-lb sack of Q-Bond, costing between $10 and $12, will cover approximately 50 ft^2 of surface area when laid Vs inch thick.

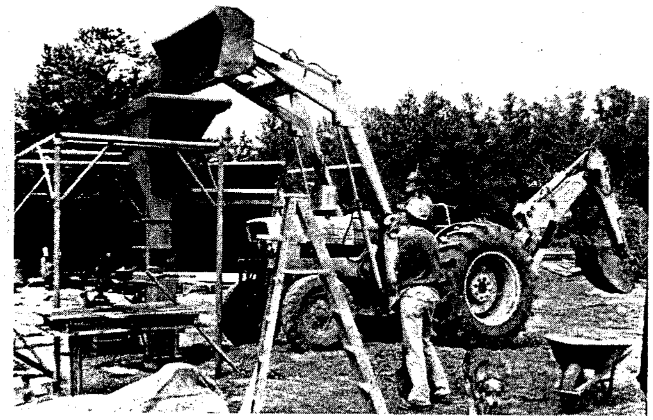
W. S. CARSON—Carson, of Columbus, New Mexico, was one of several individuals around the state who manufactured CINVA-Ram pressed-adobe bricks for the construction of their own homes. No CINVA-Ram pressed-adobe bricks were commercially made in New Mexico during 1980 for the general adobe market.

The CINVA-Ram brick press (fig. 76) is a portable press made of steel with a molding box in which a hand-operated piston compresses the slightly moistened mixture of soil. Usually a stabilizer such as lime, portland cement, or asphalt emulsion has been added to the soil mixture.

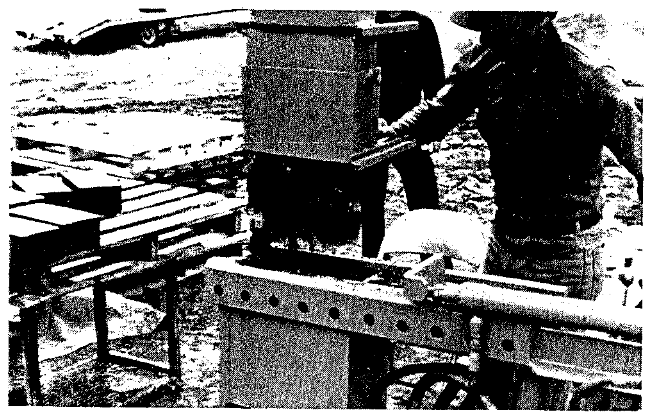
The CINVA-Ram was developed in 1955 by the Chilian engineer Raoul Ramirez, working in conjunction with the National University of Chile and the University of Illinois Housing Mission to Colombia. The press has been distributed to over 40 countries and has been extensively used by the Peace Corps throughout the developing nations of the world.

Today's machine is manufactured in Bogota, Colombia, by Metalibec, S.A., and is imported to the United States and sold by the Scovill Company, Schrader Bellows Division, 200 West Exchange Street, Akron, Ohio 44309, for $350.00 per unit (plus applicable state sales tax) F.O.B. their warehouse in Akron, Ohio. It is also available directly from Metalibec Ltda., Apartado Aero 11798, Correra 68–B No. 18–30, Bogota, D.E., Colombia. The overall equipment specifications as outlined in the Volunteers for International Technical Assistance publication, *Making building blocks with the CINVA-Ram* (VITA, 1966) are detailed at top of column at right.

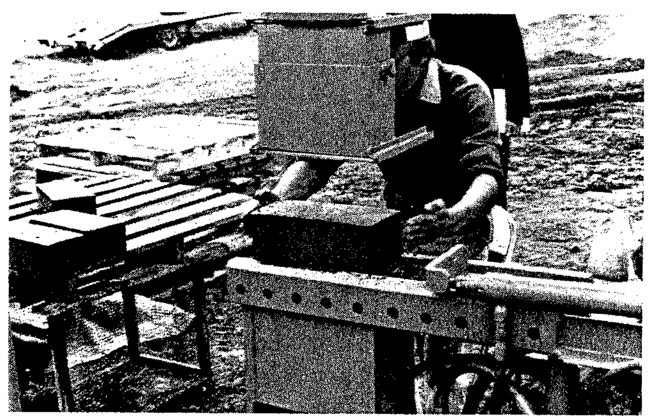
Weight	140 lbs
Height and base width	10 x 16 x 26 inches
Application force of lever	80 lbs
Bearing strength (cured brick)	200—500 psi
Size of brick	3^{1}/2 x 5^{1}/2 x 11 ½ inches
Size of tile	1 ^{1}/2 x 5½ x 11½ inches
Average weight of bricks	20 lbs
Average number of bricks per 100 lbs of cement	150
Average number of bricks per 5 gal of asphalt emulsion and water mixture	40



A-MIXED ADOBE MUD IS PLACED BY FRONT-END LOADER INTO HOPPER OVER MOLD.



B-ADOBE SOIL IS PLACED IN MOLD TO PRODUCE A 6 x 6 x 12-INCH PRESSED-ADOBE BRICK.



C-PRESSED-ADOBE BRICK IS EJECTED FROM MOLD AND PLACED ON WOODEN PALLET TO DRY.

FIGURE 75-PRESSED-ADOBE PRODUCTION AT SOIL-CRETE SOLAR COMPANY. NAVAJO DAM.

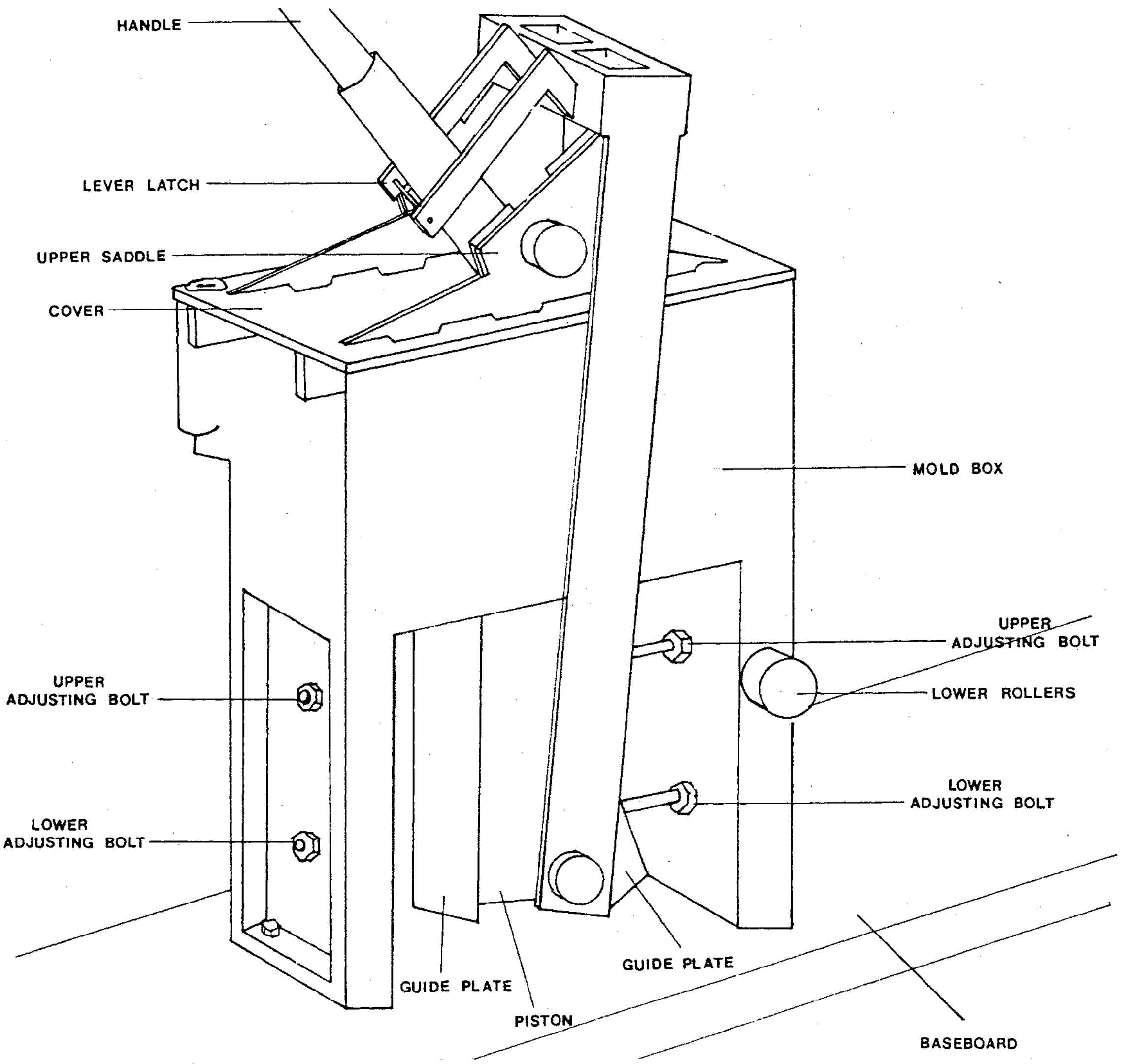


FIGURE 76-DIAGRAM OF CINVA-RAM BRICK PRESS AND ITS PARTS.

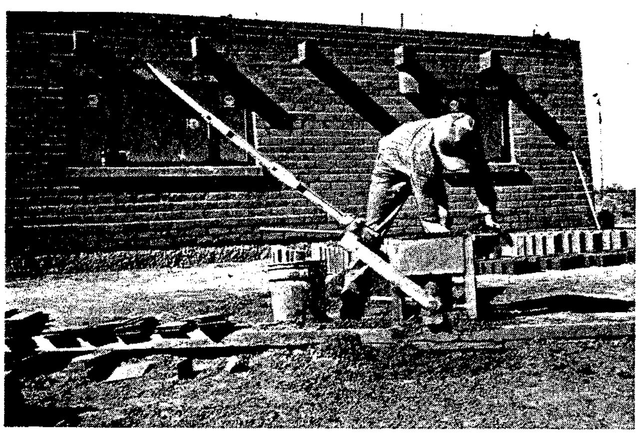
During the summer of 1980, a CINVA-Ram adobe press was used by W. S. Carson to construct a 3,000-ft^2 two-story adobe house. Equipment at the construction site and adobe yard included a CINVA-Ram press, a small gravel-screening plant, a front-end loader, a cement mixer, and various containers to mix and hold the water and asphalt emulsion. The adobe soil, sand, and gravel were secured from a nearby arroyo and hauled to the production site where the material was stockpiled adjacent to the cement mixer. The procedure used in the production of the bricks is detailed as follows:

1) The cement-mixer operator shovels the screened adobe soil and gravel material into the cement mixer and adds a measured amount of water and asphalt emulsion. As the correct amount of moisture (10%) is critical, the operator usually tests the moist soil by hand to assure the correct uniform mixture. The moist mud is mixed for several minutes and then is dumped into a wheelbarrow and transported to the press location. Here the CINVA-Ram is mounted to a board 9 ft long, 8 inches wide, and 2 inches thick, which prevents the machine from tipping sidewise.
2) The cover on the press is opened and the piston is moved to the bottom of the mold box. The adobero places a flat $^1/_8$ -inch steel $5^1/2$ x $11^1/2$-inch plate in the bottom of the mold (fig. 77A). The adobe-mud mixture is shoveled into the mold and tamped with the shovel to level off the loose material (fig. 77B). The operator then wets the bottom of the press cover and replaces the cover over the mold box (fig. 77C).
3) The lever is moved to the vertical position which permits the rollers to fall into place (fig. 77D). The lever latch is disengaged, and the lever is moved to a horizontal position on the side opposite the lower rollers for the compressive cycle (fig. 77E). The lever is moved down with two or three pushes (80–130 lbs of pressure). The lever is moved back to the vertical position, the lever latch is engaged, the lever then is returned to its rest position on the lower rollers and the cover is removed.
4) The lever is depressed at a steady rate to eject the brick, and the brick is lifted from the machine by hand and carried to the drying yard (fig. 77F).

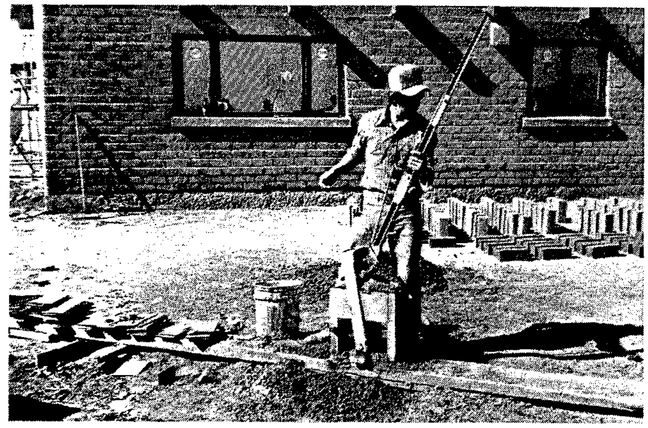
The Carson adobe operation employed a crew of two, which included the supervisor of the cement mixer and mud supplies, as well as the CINVA-Ram press operator. During a normal 8-hr working day, an average of 180 pressed-adobe bricks $3^3/4$ x $5^1/2$ x $11^1/2$ inches in size were manufactured.

A-ADOBERO PLACES FLAT STEEL PLATE IN BOTTOM OF CINVA-RAM MOLD.

B-ADOBE SOIL IS SHOVELED INTO CINVA-RAM MOLD AND TAMPED WITH SHOVEL.

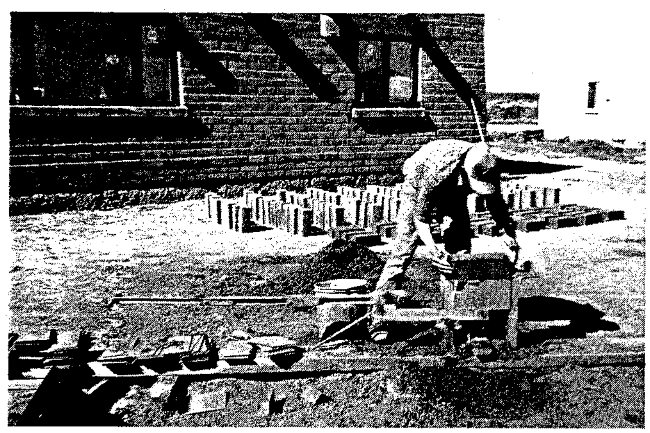


C-TOP PLATE COVER IS BRUSHED WITH WATER



D-HAND LEVER IS MOVED TO VERTICAL POSITION TO PERMIT ROLLERS TO FALL IN PLACE.

E-ADOBERO MOVES LEVER TO HORIZONTAL POSITION TO COMPLETE COMPRESSION CYCLE.



F-HAND LEVER IS RETURNED TO ITS REST POSITION WHICH EJECTS BRICK, AND ADOBERO REMOVES ADOBE FOR DRYING.

FIGURE 77-CONSTRUCTION OF THE W. S. CARSON HOME WITH CINVA- RAM PRESSED-ADOBE BRICKS, COLUMBUS.

The bricks cure similarly to traditional adobe bricks but may be laid up in a wall within a few days where they continue to dry. CINVA-Ram adobe-brick construction on the W. S. Carson house in Columbus, New Mexico, is shown in fig. 78.

Mechanized adobe production

This technique of adobe-brick production is usually associated with the large-scale manufacturing of bricks and the maximum use of mechanical equipment. A total of four operators in New Mexico who were classified in this category were using front-end loaders, pugmills or a ready-mix truck, and a machine-powered mechanical adobe layer.

The mechanized operations use from 2,000 to 15,000 yards-3 of soil per year to produce up to 1,000,000 bricks annually. The soil is usually excavated from a pit located at the adobe site or by land leveling of the adobe yard. Two of the producers purchased crusher fines from local sand and gravel operations at a cost varying from $1.50 to $8.00 per yard^3. The sizes of the adobe yards varied from 4 to 18 acres and the yards were capable of handling a daily pro-

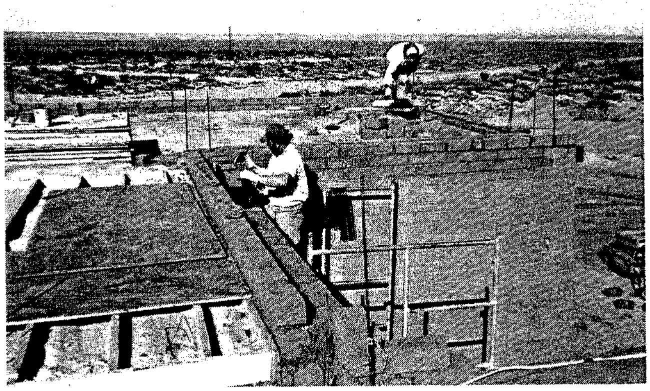


FIGURE 78-LAYING A DOUBLE WALL OF CINVA-RAM-MADE PRESSED ADOBES AT THE W. S. CARSON HOUSE IN COLUMBUS.

FIGURE 79-EIGHT NORTHERN INDIAN PUEBLOS COUNCIL ADOBE YARD. SAN JUAN PUEBLO.

duction of 5,000—7,000 adobes. A total of 1,066,000 semi-stabilized and stabilized adobe bricks of the 10 x 4 x 14-inch standard size were produced by the four fully mechanized New Mexico manufacturers in 1980 (table 9).

Included in this section is the production technique used at the Hans Sumpf Company of Madera, California. This company, in operation for 45 yrs, is known as the father of the mechanized stabilized-adobe industry. Production at their Madera operation averages between 1,500,000 and 2,000,000 bricks per yr, with a total of 1,376,000 bricks produced in 1980.

Eight Northern Indian Pueblos Council (San Juan Pueblo)

The Eight Northern Indian Pueblos Council adobe-brick manufacturing operation was established in 1976 and is presently managed by Dennis Duran of the Council's Native Products Division. It is located on 17.68 acres at San Juan Pueblo, New Mexico, approximately 5 mi north of Española, on the east side of the Taos Highway, US—64 (fig. 79). The adobe site has an average elevation of 5,800 ft and a semiarid climate. The average annual rainfall is 9—11 inches and the mean annual temperature is 51 ° F, as recorded at the Alcalde, New Mexico, station. Normally the frost-free period lasts for 150 days, extending from May to October. The soils used to make adobe bricks at the production site are from Quaternary alluvial deposits that have been derived mainly from the Tertiary Tesuque Formation (Kelley, 1978) and are associated with old stream channels,

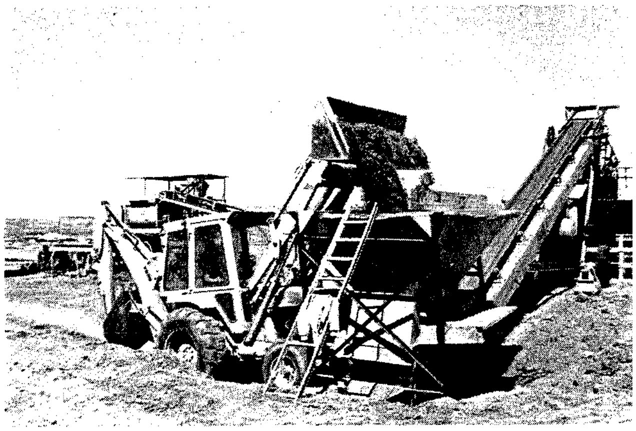
TABLE 9-ADOBE MANUFACTURERS USING MECHANIZED METHOD OF PRODUCTION (10 x 4 x 14-inch adobe); production totals and average prices for 1980. * indicates 1980 as the first year of production. t indicates a 12 x 4 x 16-inch adobe brick. ** indicates a 7½ x 4 x 16-inch adobe brick.

Name	Location	Approximate annual production	Average price/adobe	
			Semistabilized	Stabilized
Western Adobe	Albuquerque	250,000	28¢	40¢
The Adobe Patch	La Luz	350,000	0	45¢
Eight Northern Indian Pueblos Council	San Juan Pueblo	436,000	30¢	35¢
*Adobeworks	Artesia	30,000	0	40¢
Hans Sumpf	Madera, Calif.	1,376,790	0	63.3¢ t 39.5¢ **

floodplains, terraces, and alluvial fans. The soil type is identified by the U.S. Department of Agriculture and the Bureau of Indian Affairs as a stratified variant of Fruitland sandy loam.

Three major types of adobe bricks, traditional, semi-stabilized, and stabilized, were manufactured in 1980 in five sizes. A total of 436,000 bricks was produced, and the majority of bricks sold were semistabilized adobes. The procedure used by the Eight Northern Indian Pueblos Council for the large-scale production of adobe bricks is detailed as follows:

1) The sandy-loam alluvial soil is removed by grading and leveling of the adobe yard using a D-9 Cater-pillar bulldozer and is placed in several nearby stockpiles. The material is removed from the stock-pile by a 1-yard^3 model 550 Ford front-end loader and transported to a 7 x 7-ft storage hopper at the screening plant (fig. 80A).
2) The adobe soil is screened to remove large rocks and clay clods and is dumped into a three-bin storage area from which it is conveyed into one end of a 5-ft pugmill trough. The trough holds approximately 1.5 yards^3 of soil and contains two shafts, studded with paddles, that rotate to mix a measured amount of soil, water, and asphalt emulsion (fig. 80B).
3) The materials are uniformly mixed for 5 min and are then bottom-dumped into a cement-lined 10 x 20-ft mudpit (fig. 80C). A second 1-yard^3-capacity Ford front-end loader removes the adobe mud from the pit and carries the mud mix to the molding machine (adobe layer) located in the leveled adobe yard (fig. 80D). This self-propelled mechanized adobe layer, mounted on wheels, molds 25 10 x 4 x 14-inch adobe bricks at one time (fig. 80E). The machine, which was developed by the Hans Sumpf Company of California, is manufactured by Steel Structures, Inc., of Fresno, California, and consists of a steel mold, mounted so that it can be raised and lowered, and a movable hopper that feeds the adobe mix into the mold compartments. The operator moves the machine in a straight line over the smoothly scraped surface of the adobe-drying field. The bottomless mold is lowered onto the scraped surface, and the adobe mix is then fed into the mold from the hopper. The scrapers level the top of the mix, and the mold

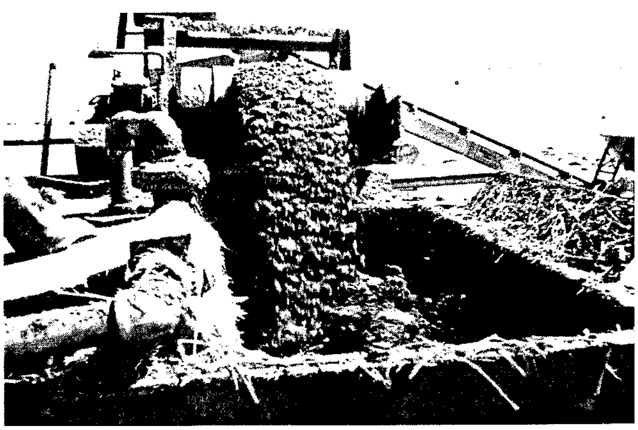


A-ADOBE SOIL BEING PLACED INTO MATERIAL HOPPER WHICH MOVES SOIL TO SCREENING PLANT.

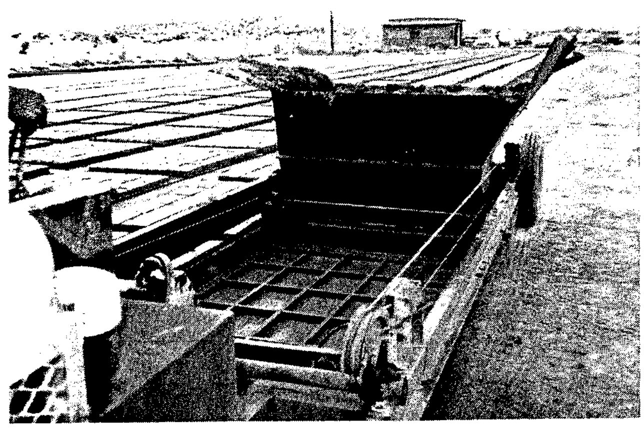
D-FRONT-END LOADER PICKS UP ADOBE MUD AND MOVES ADOBE MATERIAL TO MECHANICAL ADOBE LAYER.

B-SCREENED MATERIAL DUMPED INTO PUGMILL FOR MIXING.

E-MECHANICAL ADOBE LAYER RECEIVES LOAD OF ADOBE MUD IN HOPPER LOCATED AT END OF LAYING FORM.



C-1.5-YARD3 PUGMILL IN OPERATION.



F-MUD HOPPER IS RETURNED TO END OF MOLDING FORM, AND FORM IS LIFTED FROM BRICKS.

FIGURE 80-EIGHT NORTHERN INDIAN PUEBLOS COUNCIL MECHANIZED ADOBE PRODUCTION. SAN JUAN PUEBLO.

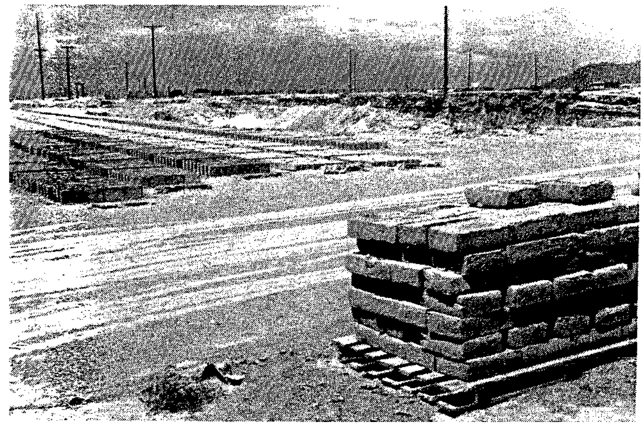
is raised leaving the bricks on the ground (fig. 80F). The whole machine then is moved forward, and the mold is washed with a water spray and lowered for the next filling. The front-end loader shuttles between the pugmill and the molding machine as the bricks are laid out in long rows. Different molds of various sizes and brick shapes can be mounted on the machine.

4) After 3—5 days of drying, the bricks are turned up on edge, cleaned and scraped, and left in this position to dry thoroughly until needed for shipment. A supply of several months' production is stockpiled for future sales. The operation at San Juan Pueblo can produce from 5,000 to 8,000 adobes per 8-hr day in good weather with a minimum of mechanical breakdowns.

Western Adobe (Albuquerque)

At Dean Leach's Western Adobe in Albuquerque (fig. 81), a total of 250,000 semistabilized adobe bricks of

FIGURE 81-WESTERN ADOBE YARD, ALBUQUERQUE.

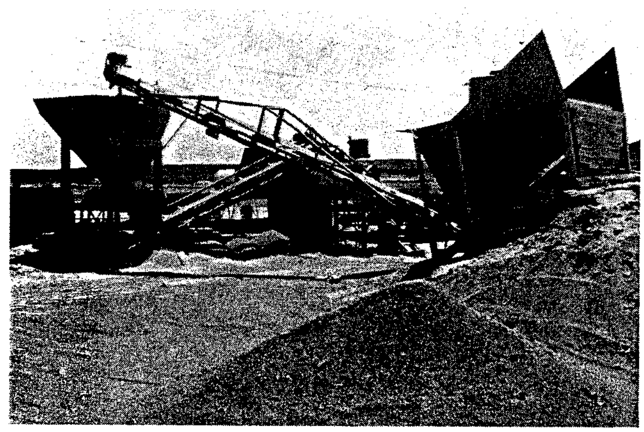


A-STACKED ADOBES, DRYING YARD, AND SOIL PIT.

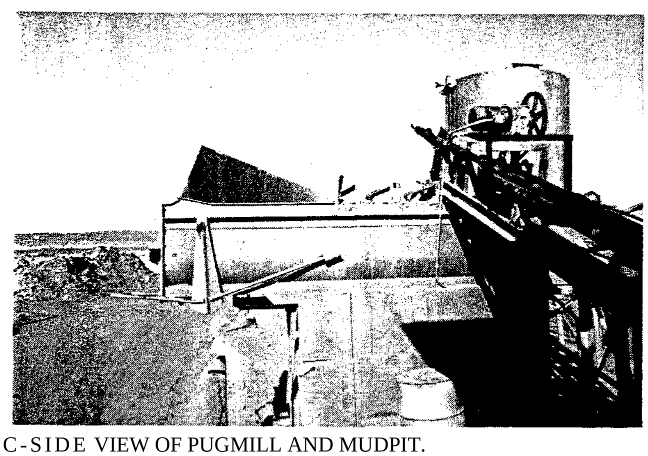
10 x 4 x 14-inch size were produced in 1980 using the following procedure:

1) The local sandy loam soil is obtained from the recent alluvial-slope deposit which is located at the eastern end of the adobe-laying yard (fig. 82A). The soil is excavated by a 1.5-yard^3 model A62 Ford front-end loader and is transported by the loader to the electrically powered screening plant where the soil is screened and conveyed into a 10 x 10-ft storage hopper (fig. 82B).
2) The equipment operator mechanically loads the 4 x 12 ft pugmill trough with approximately 1.5 yard^3 of adobe soil and adds a measured amount of water (60 gal) and asphalt emulsion (5 gal) prior to the mixing process (fig. 82C). The two shafts, studded with paddles, rotate in the trough of the pugmill and mix the mud for approximately 5 min (fig. 82D). The mud is then dumped into a large mudpit that measures 26 x 85 ft and is 12 ft deep at its deepest end.
3) The front-end loader removes the adobe mud from the pit and dumps the material into the mud hopper located on the Hans Sumpf-type molding machine (fig.. 82E). This self-propelled adobe layer, operated by one person, travels across the level adobe yard depositing 32 standard 10 x 4 x 14-inch molded bricks at a time.
4) The newly laid bricks, which cover a large area of the adobe yard, are allowed to dry for 2—3 days, depending upon the weather, after which they are turned on their side by hand, trimmed of any excess material, and allowed to dry for a minimum of 3—4 weeks under normal conditions (fig. 82F).
5) When the bricks have dried sufficiently, they are stacked directly on a 2-ton flatbed truck for delivery or are placed on wooden pallets that hold 100 adobes per pallet. The stacked pallets are easily lifted onto a truck by a forklift when required and can be delivered to the construction site.

The Western Adobe plant has several different-sized adobe molds available that can be mounted on the mechanical adobe layer and that are capable of producing many different brick shapes and dimensions. With good weather conditions and a minimum of mechanical breakdowns, the operation can produce an average of 5,000—7,000 bricks per 8-hr day with a crew of two employees.



B-SCREENING EQUIPMENT, STORAGE BINS, AND CONVEYOR SYSTEM.



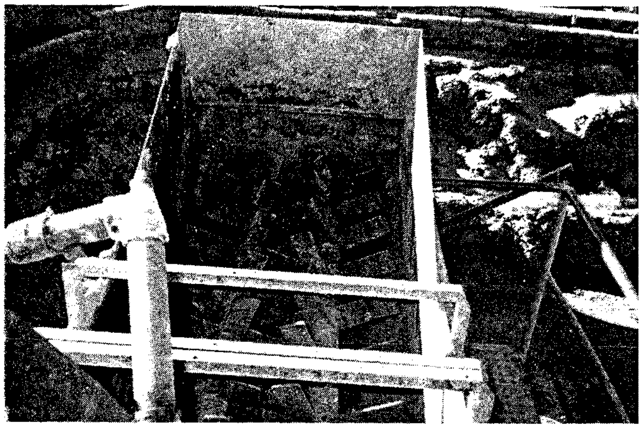
C-SIDE VIEW OF PUGMILL AND MUDPIT.

FIGURE 82—MECHANIZED ADOBE PRODUCTION AT WESTERN ADOBE, ALBUQUERQUE.

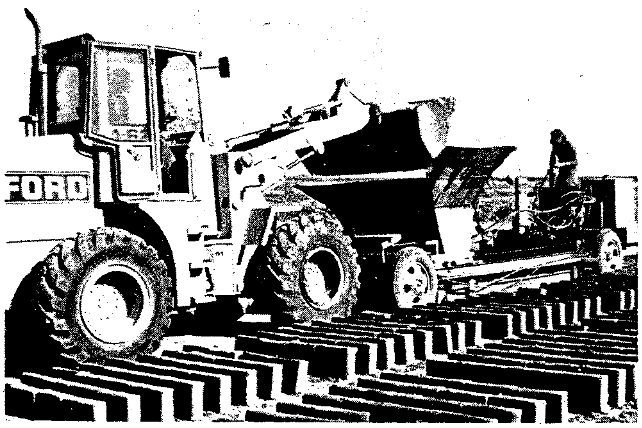
The Adobe Patch (La Luz)

The only large-scale producer of stabilized adobe bricks in the eastern part of New Mexico, located approximately 1 mi north of Alamogordo, is The Adobe Patch, owned by Robert Godby and Howard Scoggins, La Luz, New Mexico, which produced over 400,000 bricks during the 1980 season (fig. 83). Their fully mechanized and quality-control method of adobe production has resulted in the manufacture of a superior adobe brick (see table 8).

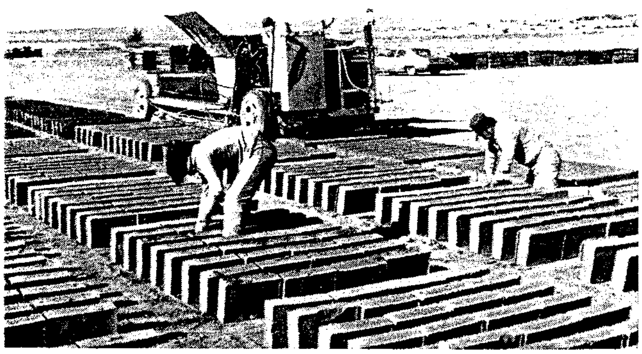
The geographic location of The Adobe Patch permits an



D - TWO SHAFTS STUDDED WITH PADDLES ROTATE IN PUGMILL TROUGH TO MIX ADOBE MUD.



E-FRONT-END LOADER REMOVES ADOBE MUD FROM MUDPIT FOR DELIVERY TO HANS SUMPF-TYPE ADOBE LAYER.



F-AFTER BRICKS HAVE DRIED FOR 2 OR 3 DAYS, THEY ARE TURNED ON EDGE AND TRIMMED OF EXCESS MATERIAL.

adobe-production season of approximately 300 frost-free days. However, because of the mild 1980 New Mexico winter, several thousand additional bricks were produced during part of December. Their adobe soil (crusher fines) is purchased from a sand and gravel operation located in Alamo Canyon. The soil is alluvial-fan material usually consisting of coarse sand, silt, and clay that passes a inch screen. The clay content of the crusher fines is estimated to be 15—18% and produces strong stabilized-adobe bricks.

The equipment used at the adobe yard includes one Ford front-end loader, three 7.5-yard^3 ready-mix trucks, one me-

FIGURE 83-HOWARD SCOGGINS IN ADOBE YARD, THE ADOBE PATCH, LA LUZ.

chanical adobe layer, one sand spreader, one 5,000-gal water tank, one 5,000-gal asphalt-emulsion tank, and one diesel semiflatbed truck and trailer for adobe deliveries.

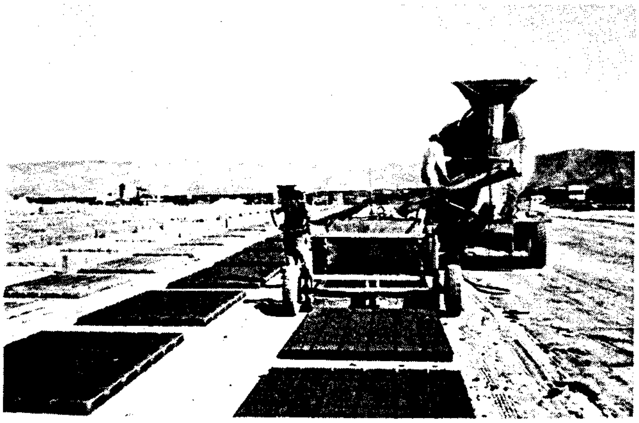
The details of The Adobe Patch production system are as follows:

1) 7 yards of adobe soil and a mixture of 340 gal of water and 80 gal of asphalt emulsion are added to a 7.5-yard^3 ready-mix truck (fig. 84A). The mud, water, and asphalt emulsion are mixed in the cement mixer for an average of 45 min and then delivered to a special mechanical adobe layer that is attached to the rear of the ready-mix truck. The adobe layer is operated hydraulically and runs off of the truck's power equipment.
2) The mixer on the truck empties the adobe mud into the hopper of the adobe layer, which feeds into a steel mold that produces 42 adobes at a time. The scrapers attached to the mud hopper level the top of the mud mix, and the mold is raised, leaving the formed bricks on the ground (figs. 84B and C).
3) The ready-mix truck and the attached adobe layer are moved forward. The mold is washed with a water spray and lowered for the next filling. The procedure is repeated until the ready-mixer is emptied after producing approximately 630 adobe bricks per load. The operation at La Luz produces 2,000—3,000 adobe bricks per day with a crew of two employees.
4) After 2—3 days of drying, the bricks are turned on edge, cleaned and scraped, and left in this position to dry thoroughly (15—20 days) or until needed for shipment. In the present operation, the drying adobe bricks are stacked on pallets with a holding capacity of 77 bricks. The loaded pallets are lifted by a Spyder forklift onto the flatbed of the company truck (figs. 84D and E). The forklift is then fitted into a cradle built into the end of the flatbed where it is carried to the construction site and is used to unload the palletized adobe bricks (fig. 84F). The Spyder forklift weighs 2,350 lbs and requires only 3—5 min to load and unload from the carrying cradle.

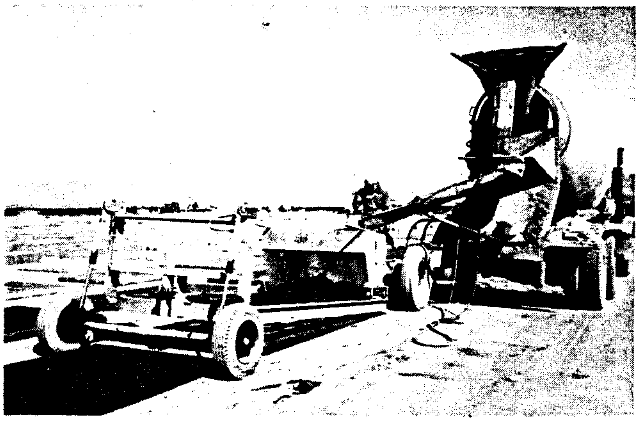
Adobeworks (Artesia)

The Adobeworks was established in 1980 by Jerry and Gladys Holt of Artesia, New Mexico. Their operation is

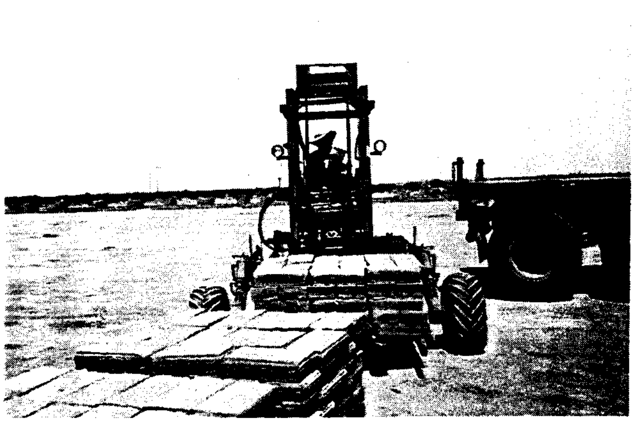
A—FRONT-END LOADER PLACING ADOBE SOIL INTO HOPPER OF CEMENT MIXER.



B—ADOBE MUD IS POURED INTO HOPPER OF ADOBE LAYER.

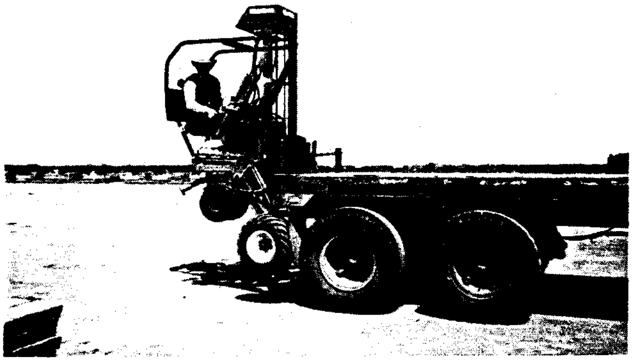


C—ADOBE MOLDING FORM IS HYDRAULICALLY LIFTED FROM ADOBES.



D—FORKLIFT MOVING STACKED ADOBES TO FLATBED OF TRUCK.

E—STACKED ADOBES ON TRUCK.



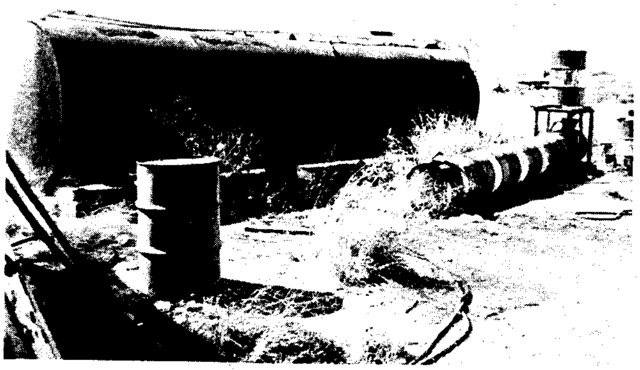
F—LIFTING WHEELS ON FORKLIFT WHILE IN TRUCK CRADLE.

FIGURE 84—MECHANIZED PRODUCTION METHOD OF THE ADOBE PATCH, LA LUZ.

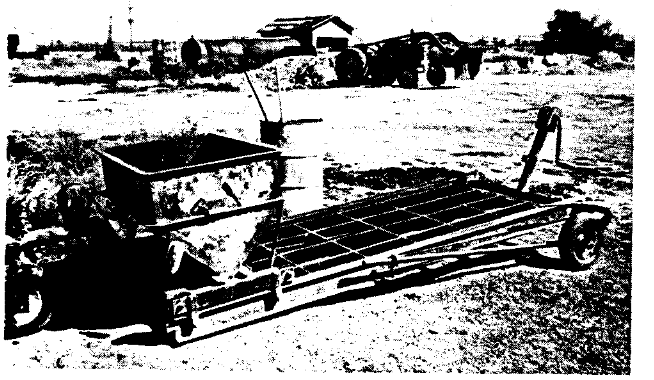
similar to The Adobe Patch of La Luz and is located approximately 5 mi north of Artesia on 10 acres of leveled and fenced land. Although they manufactured only 30,000 stabilized adobes their first year, the Holts' adobes were of good quality, and the operation will be capable of producing several hundred thousand adobe bricks per year in the future.

At the time of my visit in August of 1980, the equipment was not in operation. However, several thousand stabilized adobes were drying in the adobe yard. The Adobeworks' equipment and production techniques are detailed as follows:

1) Adobe soil is purchased from a local sand and gravel operation and is classified as crusher-fine material. The fines are usually blended with clay to secure the proper mixture. Both materials are delivered to the Adobeworks' yard and stockpiled adjacent to the oil and water supply. A front-end loader is used to place the adobe soil into the 7.5-yard^3 cement mixer located on a ready-mix truck.
2) A mixture of 330 gal of water and 80 gal asphalt emulsion is pumped into the cement mixer from a series of holding tanks constructed of oil barrels (fig. 85A). The material is mechanically mixed for an average of 30–45 min and is then delivered to



A—ASPHALT EMULSION AND WATER ARE PRE-MIXED IN A SERIES OF WELDED 55-GAL DRUMS.



B—MECHANICAL ADOBE LAYER THAT ATTACHES TO READY-MIX TRUCK.

FIGURE 85—ADOBEWORKS OF ARTESIA.

a hand-operated mechanical adobe layer that is attached to the rear of the ready-mix truck (fig. 85B). The mixed adobe mud is emptied into the hopper of the adobe layer that feeds into the steel mold that produces 24 bricks at a time.

3) The mold is raised, leaving the formed bricks on the ground, the ready-mix truck and the attached adobe layer are moved forward, and the mold is washed with a water spray. The mold is again lowered for the next pouring, and the procedure is repeated until the ready-mixer is emptied after producing an average of 500–600 bricks per load.
4) After several days of drying, the bricks are turned on edge, cleaned and trimmed, and left to dry for 2–3 weeks. The owner uses a lowboy trailer to deliver stockpiled adobes to construction sites. The system, using the hand-operated hopper method, is capable of producing 1,500–2,500 adobe bricks per 8-hr work day with a crew of three employees.

Hans Sumpf Company (Madera, California)

The Hans Sumpf Company of Madera, California, was established in 1936 and is known throughout the adobe-brick industry as the leader and father of mechanized stabilized-adobe manufacturing. At first the business was a mobile operation moving from one site to another, but, in 1954, a permanent location was established southeast of Madera, California, which remained the company's production location for 26 yrs.

Throughout the years the company has developed its own special mixing equipment, a mud-buggy system for delivering the adobe mix and a specially designed, self-propelled mechanical adobe layer. In 1979 the company produced a total of 1,718,000 adobe bricks of various sizes in a total of 73 production days, and, during 1980, a total of 1,376,790 adobe bricks was produced in 59 production days.

The present Hans Sumpf adobe operation is under the direction of Tom Harley, Vice-President and General Manager, who in 1980 moved the production facilities to a new location 9 mi from the old site. The new site is located on 320 acres of dry farming land, which is also the source of the San Joaquin sandy loam used to produce their high quality adobe bricks. Adobe-brick samples from this operation were tested in 1980 at the Twining Laboratories in Fresno, California, and their results are shown in table 8.

In New Mexico at the time of this survey, a total of six mechanical adobe layers developed and patented by the Hans Sumpf Company were owned or in use at five large-scale adobe manufacturers. The influence of the California adobe operation was noted in other types of equipment and production techniques. For this reason I have included the following information on the Hans Sumpf technique of adobe production.

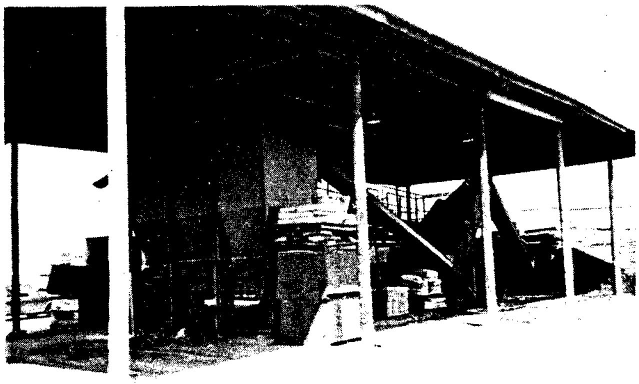
The production equipment, consisting of a grizzly, conveyors, a shaker screener, a roller crusher, soil-storage bins, and a pugmill, is located near the center of a 40-acre adobe yard. A maintenance shop and field office are adjacent to the adobe yard, and a total of 320 acres are available for future development. An overall view of the adobe yard and stacked adobe bricks is shown in fig. 86A.

In general the procedure used in the production of stabilized adobe bricks is as follows:

1) The adobe soil is obtained by leveling the farmland. An elevator scraper removes the soil from a stockpile that is near the mixing equipment and dumps it into the grizzly, which screens out the large rocks. The conveyor moves the material to the shaker screener and roller crusher (fig. 86B).
2) The screened material is conveyed to the storage bins located by the pugmill, where an operator controls the amount of adobe soil, water, and asphalt emulsion added to the pugmill trough (fig. 86C). Two shafts, studded with paddles, rotate in the trough of the pugmill, which holds approximately 3–4 $yards^3$ of soil, and mix the mud for several minutes prior to dumping it into a specially designed mud buggy (fig. 86D).
3) Two mud buggies, which hold approximately 1 ton of adobe mud each, travel between the pugmill and the Hans Sumpf mechanical adobe layer. The layer molds 35 7½ × 4 × 16-inch adobe bricks per form and lays the bricks on kraft paper to prevent dirt from sticking to the wet adobes. The adobe bricks are allowed to dry for 2–3 days at which time they are turned on edge to dry for an additional 3–4 weeks, depending upon the weather. After the adobes have dried, the bricks are stacked for delivery on pallets with a holding capacity of 110 adobes.

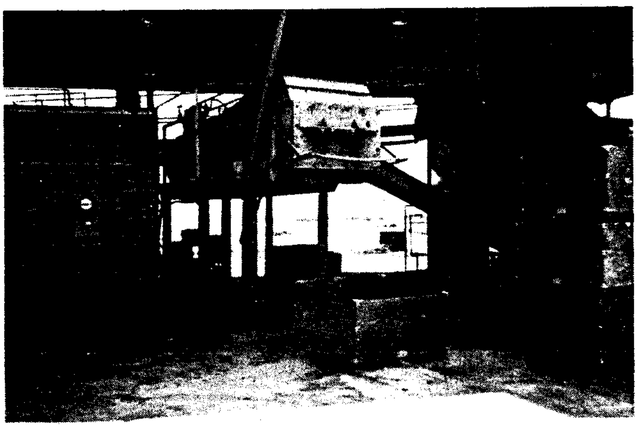
A—Adobe bricks stacked on pallets and drying adobes.

D—One-ton mud buggy developed by Hans Sumpf Company for carrying mixed adobe mud from pugmill to adobe layer.



B—Conveyor, screening equipment, and storage bins.

E—Stabilized adobe bricks—garden and patio pavers, 6 × 2½ × 12-inch—in patio of Hans Sumpf Company.



C—Adobe-soil storage bins and pugmill.

F—Adobe-brick restaurant complex attached to Ramada Inn, Fresno, California.

FIGURE 86—Hans Sumpf Company, Madera, California.

The Hans Sumpf operation has a production capacity of over 4,000,000 bricks per yr and on a daily basis is capable of producing 18,000–20,000 bricks of 7½ × 4 × 16-inch size. The company also produced a 12 × 2½ × 12-inch garden or patio paving brick, which is widely used throughout the local area (fig. 86E). Outstanding examples of the use of adobe bricks made at the Hans Sumpf operation were noted in private homes, offices, and other commercial buildings, particularly the two-story Ramada Inn Motel in Fresno, California (fig. 86F).

Summary and conclusions

The use of adobes by the Spanish and Indian population of the Southwest has long been of historical and cultural importance. Today the adobe industry continues to expand with New Mexico's population growth, interest in solar-adobe structures, and the desire to build houses of traditional adobe design. The continued growth of the adobe-brick industry in the state depends upon three basic factors: 1) the ability to locate and secure supplies of low-cost adobe-soil materials from federal, state, or private lands; 2) the economic considerations related to production, transportation, and marketing of adobe bricks; and 3) the acceptance by federal agencies (HUD and others) of the good physical qualities and advantages of adobe bricks.

Soil resources

Results of this study show that adobe-soil materials are abundant in New Mexico with extensive deposits located in the floodplains and alluvial first-terrace deposits of the Albuquerque and Española Basin areas of the Rio Grande valley. Noting that 67% of the 1980 adobe-brick production consisted of semistabilized and stabilized adobe bricks using asphalt emulsion as the water-resistant stabilizing material is important. The use of a water-resistant stabilizing material may expand the present market for adobe.

Production, transportation, and marketing

Adobe bricks can be produced in large quantities (150,000–1,000,000) at reasonable costs with limited equipment and at low operation costs using the semimechanized and mechanized methods of production. Information obtained from adobe producers, architects, builders, and others shows that wide acceptance of adobe bricks exists in the state, with the total production of the manufacturers usually sold by the end of November of each year. The 1980 summer-market value for the three major types of adobes averaged $266.00 per thousand for the traditional adobe bricks, $278.00 per thousand for the semistabilized adobes, and $369.00 per thousand for the stabilized adobes. Transportation costs averaged $100–$200 per thousand for delivery within a 100-mi radius of the adobe-production yard. Clearly, with the growing interest, an extensive untapped market exists for adobe bricks of all types in this state and throughout the Southwest.

Acceptance by federal agencies

Tests indicate that the New Mexico adobe bricks have adequate physical properties to meet federal and state building codes. Recently considerable discussion with regulating agencies of the state and federal governments centering around the wages paid to adobe layers has taken place because of the Davis–Bacon Act and the subsequent overall costs of adobe construction. Adobe has largely been considered too expensive for many government projects, because labor wages to construct the buildings have been calculated for highly skilled masons (Davis–Bacon Act—$13/hr). However, unlike laying brick or cement block, adobe construction does not require such a highly skilled labor classification. For purposes of cost calculation, the highest category of unskilled laborer (Davis–Bacon Act—$6–7/hr) is perfectly adequate for building with adobe. Obviously, when utilizing this more appropriate labor classification, adobe-construction costs drop dramatically and become competitive with both frame and block construction.

Another of the major stumbling blocks to governmental acceptance of adobe is in the area of thermal performance. To answer some of the major questions regarding thermal characteristics, the Department of Energy, HUD, the University of New Mexico's Energy Institute, Tesuque Pueblo, and the Eight Northern Indian Pueblos Council in 1980 funded the Southwest Thermal Mass Study, Adobe Research Facility Phase, located at Tesuque Pueblo. This project will identify the characteristics of thermal mass with an emphasis on adobe. Objectives of the project are:

1) to measure thermal performance of mass walls as components in buildings;
2) to measure energy consumption of mass walls coupled with thermostat setpoints and ventilation;
3) to measure U-values of stabilized, semistabilized, and traditional adobe including changes because of curing differences; and
4) to compare experimental results with predictions in such areas as effective U-values, M-factors, and steady-state U-values.

Results of the study will be published sometime in 1982.

Clearly adobe will gain wider and wider acceptance as a preferred building material in this part of the country. Especially as the emphasis on non-energy-intensive, indigenous building materials grows, adobe will emerge as an attractive and viable building alternative for people in all income brackets.

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Glossary

ABSORPTION—the taking in of water or other liquid into a soil mass (Wolfskill and others, 1970).

ADOBE FORMS—a single or multiple mold of a particular size usually made of wood into which the mixed adobe soil is placed to produce a uniform brick.

ADOBE SOIL—a mixture of clay and silt deposits found in the basin areas of the southwest United States and used to produce sun-dried bricks.

ADOBERO—(from the Spanish) a person engaged in the production of adobe bricks and the construction of adobe buildings.

ALLUVIAL FAN—a fan-shaped deposit of sand, gravel, and fine materials dropped by a stream where its gradient lessens abruptly.

ALLUVIUM—soil material that has been deposited on land by streams and local wash.

ASPHALT EMULSION—asphalt globules of microscopic size which are surrounded by and suspended in a water medium (International Institute of Housing Technology and California State University, Fresno Foundation, 1972).

ATTERBERG LIMITS—in a sediment, the water-content boundaries between the semiliquid and plastic states (known as the *liquid limit*) and between the plastic and semisolid states (known as the *plastic limit*).

BASIN—in southwest United States, a depression in the surface of the land, usually caused by subsidence, which may contain extensive sedimentary deposits of adobe material.

BRITISH THERMAL UNIT (Btu)—a measurement representing the amount of heat necessary to raise 1 lb of water (1 pint) 1° F.

CALICHE—a cemented deposit of calcium carbonate found in many soils of the southwest United States.

CLAY—a fine-grained, natural, earthy material composed primarily of hydrous aluminum silicates with grain diameters less than .004 mm.

COAGULATION—the coalescence of fine particles to form larger particles (ASTM STP no. 148–D, 1959).

COHESION—the ability of various particles to stick together (Wolfskill and others, 1970).

COLLOIDAL—a subdivision of suspended matter in which the particle size ranges between 5 and 200 millionths of a millimeter (Bateman, 1951).

COMPRESSIVE STRENGTH—a physical property of a material that indicates its ability to withstand compressive forces, usually expressed in pounds per square inch (psi).

CRUSHER FINES—finely crushed or powdered material such as rock, silt, and clay but not necessarily in the correct ratio for adobe-brick production; an engineering term for the clay- and silt-sized soil particles (diameters less than 0.074 mm) passing U.S. standard sieve no. 200.

CURING—a time period during which the action of water in a stabilized soil mass causes the mass to be cemented together by the stabilizer (Wolfskill and others, 1970).

DURABILITY—the resistance of a material to weathering and erosion.

EFFECTIVE U-VALUE—value determined (in masonry-mass walls) as a factor of the resistance to the transfer of heat and of the capacity to hold heat.

EROSION—the physical and chemical processes by which a material is removed. It includes the processes of weathering, mechanical wear, and transportation of the material.

GRIZZLY—a device for the coarse screening of bulk materials.

IMPERMEABLE—the ability of a soil material to restrict the flow or seepage of water to a negligible amount (Wolfskill and others, 1970).

KILN—an oven, furnace, or heated enclosure used for processing bricks by burning or firing.

K-VALUE—value representing the thermal conductivity of a material, which is expressed as the quantity of heat in Btu's that flows in a unit time (1 hr) through a unit area (1 ft^2) of unit thickness (1 inch) for a unit difference in temperature.

LIQUID LIMIT—the moisture content in percent of dry soil weight at which the soil changes from a plastic to a liquid state (Wolfskill and others, 1970).

LOAM—a rich, permeable soil composed of a crumbly mixture of relatively equal and moderate proportions of clay, silt, and sand particles, and usually containing organic matter; it usually implies fertility; topsoil.

MECHANICAL ADOBE LAYER—a self-propelled and hydraulically operated machine developed by the Hans Sumpf Company of California for molding adobe bricks. The adobe layer uses various metal molds to produce adobe bricks of different sizes.

MECHANICAL ANALYSIS—the determination of the grain-size distribution of a soil material; also known as a sieve analysis (Wolfskill and others, 1970).

MECHANIZED METHOD OF ADOBE PRODUCTION—the use of powered mixers, front-end loaders, and mechanical adobe layers to produce adobes on a large scale.

MINERALOGY—the science of the study of minerals.

MODULUS OF RUPTURE—a physical-property figure indicating the relative cohesion of the materials that make up the adobe and the ability of the material to resist tension or shear forces, usually expressed in pounds per square inch (psi).

MOISTURE CONTENT—the amount of water contained in soil material expressed as the weight of the water divided by the weight of the dry soil material in percent (Wolfskill and others, 1970).

MORPHOLOGY—the study of the forms and shapes of lands.

MOSQUE—a temple of worship in the religion of Islam.

NEW MEXICO STATE BUILDING CODE—used in conjunction with the broad principles outlined in the Uniform Building Code. This set of amendments was adopted in its most recently revised form by the New Mexico Construction Industries Commission in 1977. The local code addresses construction concerns about building materials and conditions specific to the State of New Mexico. Regulations concerning the use of adobe, for example, are handled in Section 2405 of the most recent code. See also UNIFORM BUILDING CODE.

PALLET—a flat wooden board base used to stack and store adobe bricks. The pallet is designed to permit a fork-lift vehicle to lift the adobes and pallet on and off a flatbed truck.

PISÉ—from the French, "pisé-de-terre" meaning rammed-earth-type adobe construction (Wolfskill and others, 1970).

PLASTIC LIMIT—the lowest water content at which the soil becomes plastic.

PLASTICITY—the ability of a moist soil to be deformed and hold its shape. This indicates that the soil has cohesion and contains clay particles (Wolfskill and others, 1970).

PLASTICITY INDEX—the numerical difference between the liquid limit and the plastic limit (Wolfskill and others, 1970).

PRESSED ADOBE—a type of adobe brick made from traditional or stabilized adobe material pressed into dense bricks of various sizes using either a hydraulically operated power machine or a hand-operated press called the "CINVA-Ram."

PUDDLED ADOBE—adobe mud patted by hand into a wall shape without the use of wooden forms.

QUEMADO (BURNT ADOBE)—a sun-dried adobe brick that has undergone a modified low-firing process.

RAMMED EARTH—damp or moist earth that is tamped into a wall between temporary, movable formwork (Middleton, 1976); also known as "pisé" construction.

R-VALUE—a measure of the ability to retard heat flow, rather than the ability to transmit heat. R is the numerical reciprocal of U, thus $R = 1/U$. R is used in combination with numerals to designate thermal-resistance units. R-11 equals 11 resistance units. The higher the R, the higher the insulating factor. All insulation products having the same R-value, regardless of material and thickness, are equal in insulating value (New Mexico Energy Institute, 1977).

SAND—individual rock or mineral fragments in a soil that range in diameter from 0.05 to 2.0 mm (Folks, 1975).

SEMIMECHANIZED METHOD OF ADOBE PRODUCTION—a method similar to the traditional handcrafted method except for the addition of some mechanical equipment, usually a front-end loader, and a series of gang molds.

SEMISTABILIZED ADOBE—classified as a water-resistant adobe brick because of the addition of a small amount of asphalt emulsion (4% or less by weight).

SHRINKAGE—the decrease in volume of soil material caused by evaporation of water (Wolfskill and others, 1970).

SILT—individual mineral particles in a soil that range in diameter from the upper limit of clay (.004 mm) to the lower limit of fine sand (.05 mm; Folks, 1975).

SLURRY—a mixture of soil and water that results in a soupy liquid that is easily poured into the wooden forms.

STABILIZATION—the improvement of soil properties by the addition of materials which will either cement the soils, waterproof the soil, or reduce volume changes (Wolfskill and others, 1970).

STABILIZED ADOBE—the fully stabilized adobe (referred to by the New Mexico Building Code as a "treated adobe"); defined as containing a sufficient amount of stabilizer to limit a brick's water absorption to less than 2.5% in 7 days.

STABILIZER—a material such as asphalt emulsion, portland cement, lime, or one of many other chemicals that is added to the soil material to waterproof or increase the weathering resistance of the adobe brick.

STEADY-STATE CONDITION—the state when heat energy is passing uninterrupted from one side of the wall to the other at a constant rate.

STRENGTH—the ability of a material to resist applied forces. The strength of soil mixes is normally considered the strength in shear stress and is expressed in pounds per square inch (psi; Wolfskill and others, 1970).

TERRÓN—a Spanish word meaning "a flat clod of earth": refers to the type of adobe brick made of cut sod or turf material found in the floodplain areas of the Rio Grande.

TRADITIONAL ADOBE—a sun-dried adobe brick made with soil composed of a uniform mixture of clay, sand, and silt; usually straw is added to the adobe soil.

TRADITIONAL HANDCRAFTED METHOD OF ADOBE PRODUCTION—the process of making adobe bricks by hand, without the use of any mechanized equipment.

U-VALUE—coefficient of heat transmission expressed in units of Btu per hr per ft^2 per °F. It is the time rate of heat flow. The U-value applies to combinations of different materials used in series along the heat-flow path, such as single materials that comprise a building station, cavity air spaces, and surface air film on both sides of a building element (New Mexico Energy Institute, 1977).

UNIFORM BUILDING CODE—a standard code of building specifications established by the International Conference of Building Officials and adopted by local construction-regulating agencies in most states. The code is founded on broad-based performance principles and is dedicated to the development of better building construction and greater safety to the public by establishing uniformity in building laws.

Appendix 1—Clay-size fraction analyses

Analyses of clay-size fraction (particles less than 2 micrometers) of New Mexico adobe-clay material; semiquantitative (parts in 10) analyses of contained clay minerals. Symbols: tr, trace amount; —, nothing present.

Map no.	Adobe producer	Brick sample no.[1]	Smectite[2]	Illite[3]	Mixed-layer illite-smectite[4]	Kaolinite[5]	Chlorite	Other[6]
1	New Mexico Earth	NM-19	2	2	4	2	—	quartz and calcite
2	Western Adobe (bag sample)	WA	2	2	3	3	—	calcite and quartz
3	Manuel Ruiz	MR-3	1	2	4	3	—	quartz and calcite
4	Frank Gutierrez	FG-13	1	3	2	4	—	quartz and calcite
5	Pete Garcia	PG-13	—	3	4	3	—	quartz and calcite
6	Adobe Enterprises, Inc.	AE-15	2	3	—	5	—	calcite, quartz, and feldspar
7	Lawrence Tenorio	LT-19	1	2	4	3	—	calcite, quartz, and feldspar
8	Aragon/Garcia Adobes	no sample						
9	Adobeworks	no sample						
10	Hachita Adobe	HA-14	3	2	3	2	—	quartz
11	David Griego	DE-3	tr	3	3	4	—	quartz
12	Robert Garcia	no sample						
13	The Adobe Patch	no sample						
14	Eight Northern Indian Pueblos Council	MNIP-31	6	2	—	2	—	calcite, quartz, and feldspar
15	Robert Ortega	RO-1	3	tr	5	1	1	quartz and calcite
16	Medina's Adobe Factory	MM-19	2	3	2	3	—	calcite and quartz
17	Antonio Serrano	AS-3	tr	7	2	1	—	quartz and calcite
18	Felix Valdez	FV-17	8	1	—	1	—	quartz, calcite, and feldspar
19	Andy Trujillo	AT-12	5	2	2	1	—	quartz, calcite, and feldspar
20	Big "M" Sand and Cinder	TM-18	2	2	3	3	—	calcite and quartz
21	D. Sandoval/E. Trujillo	DS-15	1	3	2	4	—	quartz and calcite
	D. Sandoval/E. Trujillo	DS-25	1	3	3	3	—	calcite, quartz, and feldspar
22	D. T. Wiley	DW-12	4	1	2	3	—	quartz
23	Marino Romero	L-MR-12	—	4	2	4	—	quartz and calcite
24	Danny Porter	DP-6	tr	2	3	5	—	quartz
25	Robert Leyba	RL-8	tr	3	4	3	—	calcite and quartz
26	Adobe Farms	no sample						
27	Oliver Trujillo	OT-9	6	3	—	1	—	calcite and quartz
28	Charles C de Baca	CB-3	1	2	3	4	—	calcite and quartz
29	Edward Sandoval	ES-2$_x$	2	1	6	1	—	calcite and quartz
30	Roman Valdez/James Lujan	RV-9	4	4	tr	2	—	quartz and calcite
31	Adrian Madrid	AM-14	2	3	2	3	—	calcite and quartz
32	Victor Montano	VM-5	1	3	3	3	—	calcite and quartz
33	Eloy Montano	EM-38	1	3	3	3	—	calcite, quartz, and feldspar
	Eloy Montano	EM-18	2	2	3	3	—	calcite, quartz, and feldspar
34	Al Montano	LAM-3	4	1	4	1	—	calcite and quartz
35	Albert E. Baca	NAB-16	2	3	4	1	—	calcite and quartz
	Albert E. Baca	HMB-4	2	3	4	1	—	quartz and calcite
36	Rodriguez Brothers	GJR-1	2	3	1	4	—	quartz and calcite
37	Tod Brown	no sample						
38	Montoya Adobes	no sample						
39	Emilio Abeyta	EA-6	1	2	4	3	—	quartz and calcite
40	Taos Pueblo	TP-26	tr	3	4	3	—	quartz and calcite
41	Joe Trujillo	JT-12	2	2	3	3	—	quartz and calcite
42	Ralph Mondragon	RM-3$_x$	3	3	2	2	—	calcite and quartz
43	Joe Pacheco	JP-11	—	4	4	2	—	calcite and quartz
44	Humberto Camacho	HC-9	—	3	3	4	—	quartz and calcite
	Humberto Camacho	HC-9 (rerun)	—	3	4	3	—	calcite and quartz
45	Rio Abajo Adobe Works	no sample						
46	Otero Brothers	no sample						
47	Alfonso Carrillo	C-MEX-7	—	3	5	2	—	calcite and quartz
48	Leonardo Duran	D-MEX-10	—	3	5	2	—	quartz, calcite, and feldspar
	W. S. Carson (adobes produced for individual construction project)	WC-12	—	4	3	3	—	quartz

(continued on p. 68)

(continued from p. 67)

Map no.	Adobe producer	Brick sample no.[1]	Smectite[2]	Illite[3]	Mixed-layer illite-smectite[4]	Kaolinite[5]	Chlorite	Other[6]
	Cruz Perez (no production in 1980)	CP-15	3	3	3	1	—	calcite and quartz
	Maggie Martinez (no production in 1980)	AMM-6	tr	3	3	4	—	quartz
	P. Arango (145-yr-old terrón used for individual construction project)	T-PA-5	tr	3	4	3	—	calcite and quartz
	Chamisal (45–50-yr-old adobe from Chamisal, New Mexico)	TCS-19	4	2	3	1	—	quartz and calcite
	San Juan Pueblo (100-yr-old adobe from San Juan Pueblo, New Mexico	SJ-14	4	2	3	1	—	calcite and quartz
	R. Vigil	ERV-4	1	3	3	3	—	calcite and quartz

1 "Brick sample number" refers to adobe brick from a particular locality (letters indicate locality) and the number indicates a particular brick. For details of name and location of various adobe producers see fig. 1 and table 1.

2 "Smectite" indicates member of the smectite group of clay minerals which are expandable (expansive) to 17 Å thickness in ethylene glycol atmosphere. All samples, with exception of those marked by a subscript "x," had a "c" dimension of 14.7–15.0 Å in the unglycolated and unheated state. Those with the "x" subscript had a "c" dimension of 14.2–14.5 Å in the same state. All expand to 17 Å when exposed to ethylene glycol atmosphere. Both smectites are of the calcium-rich type, although they apparently do have some small amount of the sodium-rich variety of smectite because of the smaller-than-15.4-Å spacing indicative of a 100% calcium smectite.

3 "Illite" refers to 10-Å-thick, nonexpandable (nonexpansive), K-rich clay minerals, sometimes called "hydromica."

4 "Mixed-layer illite-smectite" refers to an intimate mixing of 10-Å-thick, nonexpandable clay minerals and 17-Å-thick expandable clay minerals which have no regular ordering of these layers or domains (ordered mixed-layer illite-smectites exist, but none seem to be present in these samples).

5 "Kaolinite" refers to the 7-Å-thick, Al-rich clay mineral in the kaolinite group.

6 Other nonclay minerals in less-than-2-micrometer fraction are shown in order of decreasing abundance.

Appendix 2—New Mexico State Building Code, Section 2405

In most regions of the United States where adobe is widely used in construction, locally adopted amendments to the Uniform Building Code establish standard building specifications. In New Mexico, specifications for adobe are covered in Section 2405 of the code; the most recent version was approved and adopted by the New Mexico Construction Industries Commission on July 22, 1977. Prior to this revision, which was developed under the auspices of the adobe industry and written by a team of four New Mexican adobe experts, the section on adobe had been regarded as severely limited and inconsistent in its coverage of the material and its specifications.

The method by which building codes in general are put together combines objective data gathering and subjective interpretation of that data. Information derived from extensive engineering and construction experience and statistics collected from standardized laboratory tests all contribute to the store of practical and scientific knowledge about how a material behaves under a variety of conditions. However, the transition from raw data and information to a meaningful and workable building code relies on an interpretive and analytical process and ultimately on the quality of judgment of those individuals who produce the final written code.

Adobe codes have traditionally suffered from deficiencies in both of the areas of objective data gathering and subjective interpretation of the data. The amount of "official" data concerning adobe has (until recently) been quite small relative to that on many other building materials. The Construction Industries Commission has often resisted attempts to solicit the aid of skilled members from within the adobe industry in producing the codes to which these members of the adobe industry are expected to comply. This situation has resulted in extensive criticism of the existing codes in many areas of the country; in fact, just such criticism finally led to the adoption of the revised and more responsive adobe code now on the books in New Mexico. In many states codes are now beginning to respond realistically to the needs of the modern adobe construction industry.

Among the major revisions in the 1977 edition of the New Mexico State Building Code are the legalization of unstabilized (traditional) adobes, already used throughout the state, and the removal of the requirement that buildings constructed with sufficiently stabilized adobe and mortar be coated with some other protective substance. In addition many other minor revisions are included, such as the allowance of the use of wooden "gringo" blocks and soil for mortar, as well as changes in the required thicknesses of load-bearing walls. A more detailed breakdown of the components of the new code can be found in *Adobe Today*, issue 22, 1978 (Albuquerque, New Mexico,), in an article written by H. T. Hinrichs, an engineer, adobe producer, and one of the authors of the New Mexico Code's revised Section 2405.

Section 2405 of the New Mexico Uniform Building Code (Construction Industries Division, 1979) is reprinted below in its entirety. Any further questions concerning the code should be addressed to the Construction Industries Division, Bataan Memorial Building, Santa Fe, New Mexico 87503 (telephone: 505/827–5571).

AMENDMENT 6: CHAPTER 24 • MASONRY

UNBURNED CLAY MASONRY

Sec. 2405. (a) **General.** Masonry of unburned clay units shall not be used in any building more than (2) stories in height. The height of every laterally unsupported wall of unburned clay units shall be not more than 10 times the thickness of such walls. **Exterior** walls, which are laterally supported with those supports located no more than 24 feet apart, are allowed a minimum thickness of 10 inches for single story and a minimum thickness of 14 inches for the bottom story of a two story with the upper story allowed a minimum thickness of 10 inches. **Interior bearing** walls are allowed a minimum thickness of 8 inches.

(b) **Compressive Strength.** The units shall have an average compressive strength of 300 pounds per square inch when tested in accordance with ASTM C-67. One sample out of five may have a compressive strength of not less than 250 pounds per square inch.

(c) **Module of Rupture.** The unit shall average 50 pounds per square inch to modulus of rupture when tested according to the following procedure:

PROCEDURES:

(1) A cured unit shall be laid over (cylindrical) supports two inches (2") in diameter, located two inches (2") from each end, and extending across the full width of the unit.

(2) A cylinder two inches (2") in diameter shall be laid midway between and parallel to the supports.

(3) Load shall be applied to the cylinder at the rate of 500 pounds per minute until r[u]pture occurs.

(4) The modulus of rupture is equal to $\frac{3WL}{2Bd}$ 2

W = Load of rupture
L = Distance between supports
B = Width of brick
d = Thickness of brick

(d) **Soil.** The soil used shall contain not less than 25 percent and not more than 45 percent of material passing a No. 200-mesh sieve. The soil shall contain sufficient clay to bind the particles together and shall not contain more than 0.2 percent of water-soluble salts.

Most clayey loams, except those with a high clay content, are suitable, but it is not practicable to make a selection on the basis of soil analysis only. Soil[s] having a high clay content shrink or crack badly when drying, and sandy soils do not have sufficient b[o]nding material to prevent crumbling. Neither of these soils should be used alone for brick, but a very good building material can be obtained by mixing the two soils together in proportions that will overcome the undesirable qualities of each. The best way to determine the fitness of a soil is to make a sample brick and allow it to cure in the open, protected from moisture. It should dry without serious warping or cracking.

(e) **Classes of Adobe.**

ADOBE TYPES: (1) Treated Adobes. The term "treated" is defined to mean adobes made of soil to which certain admixtures are added in the manufacturing process in order to limit the adobe's water absorption in order for it to comply with paragraph (h) below. Exterior walls constructed of treated adobe require **no** additional protection. Stucco is not required. In order for the wall to so comply, the mortar must be of Type 5 of adobe soil treated with an additive to make the mortar comply with the same water absorption requirement in paragraph (h) below.

(2) Untreated Adobes. Untrea[t]ed adobes are adobes which do not meet the water absorption specifications of paragraph (h) below. This shall hold even if some water absorption protection agent has been added. The determination as to whether an adobe is treated or untreated is to test for compliance with paragraph (h) below. Exterior walls of untreated adobe are allowed but must comply with paragraphs (o) requiring Portland cement plaster applied to the outside. Use of untreated adobes is prohibited within 4 inches above the finished floor grade. Treated adobes may be used for the first 4 inches above finished floor grade. Mortar must be Type 5 (or masonry mortar) or adobe soil (either treated or untreated).

(f) **Sampling.** Each of the tests prescribed in this Section shall be applied to five sample units selected at random from each 25,000 bricks to be used.

(g) **Moisture Content.** The moisture content of the unit shall be not more than four percent by weight.

(h) **Absorption.** A dried four-inch (4") cube cut from a sample unit shall absorb not more than two and one-half percent moisture by weight when placed upon a constantly water saturated porous surface for seven (7) days.

(i) **Shrinkage Cracks.** No units shall contain more than three shrinkage cracks, and no shrinkage crack shall exceed three inches (3") in length or one-eighth inch (1/8") in width.

(j) **Use.** No adobe shall be laid in the wall for at least three (3) weeks after making, dependent on weather conditions.

(k) **Foundations.** Adobes shall not be used for foundation or basement walls. All adobe walls, except as noted under Group M Buildings, shall have a continuous concrete footing at least eight inches (8") thick and not less than two inches (2") wider on each side than the foundation walls above. All foundation walls which support adobe units shall extend to an elevation not less than six inches (6") above the finish grade.

Foundation walls shall be at least as thick as the exterior wall as specified in Section 2405 (1). Where stem wall insulation is used, a variance is allowed for the stem wall width to be two inches (2") smaller than the width of the adobe wall it supports.

(l) **Exterior Walls.** All walls of adobe (treated or untreated) shall not have thicknesses less than that allowed in paragraph (a) above. Mortar shall be in accordance with paragraph[s] (e1) and (e2) above depending on the class of adobe being used. All adobe brick shall be laid up with full slush (bed) joints and shall be bonded (overlapped) not less than 4 inches. Walls of treated adobe which do not require a protective outer coating must also be laid up with full head (end) joints. All exterior adobe walls shall be topped with a continuous belt course or tie beam (except patio walls less than 6' high above stem). At the time of laying, all units shall be clean and damp at the surface.

(m) **Concrete Tie Beam.** Shall be minimum size six inches (6") by width of wall up to a ten inch (10") width. For walls thicker than ten inches, a ten inch (10") tie beam will suffice. All concrete tie beams shall be reinforced with a minimum of two No. 4 reinforcing rods each floor and ceiling plate line.

(n) **Wood Lintels or Tie Beams.** Shall be minimum size six inches (6") by wall width up to a ten inch (10") width. For walls thicker than ten inches, a tie beam of ten inch (10") thickness shall suffice. The wooden tie beam shall be overlapped, or spliced, at least six inches (6") at all joints. All joints shall have a wall bearing of at least twelve inches (12"). Wood tie beams may be solid in the six inch (6") dimension or may be [built up by applying layers of lumber. No layer shall be] less than one inch (1"). Wood joints, vigas or beams shall be spiked to the wood tie beam with large nails or large screws. All lintels, wood or concrete, in excess of nine feet (9') shall have specific approval of the building official.

(o) **Plastering.** All **untreated** adobe shall have all exterior walls plastered on the outside with Portland cement plaster, minimum thickness 3/4" in accordance with Chapter 47. Protective coatings other than plaster are allowed, provided such coating is equivalent to Portland cement plaster in protecting the untreated adobes against deterioration and/or loss of strength due to water. Metal wire mesh minimum 20 gauge by one inch (1") opening shall be securely attached to the exterior adobe wall surface by nails or staples with minimum penetration of one and one-half inches (1½"). Such mesh fasteners shall have a maximum spacing of sixteen inches (16") from each other. All exposed wood surfaces in adobe walls shall be treated with an approved wood preservative before the application of wire mesh. No adobe bricks shall be used for isolated piers, porch columns or wall section of less than 28" × 10". A minimum twelve inch (12") wall section will be permitted between openings provided a continuous lintel of concrete or timber be installed spanning both openings and wall section.

EXCEPTION:

(1) Exterior patio, yard walls, etc., need not have Portland cement coating.

(p) **Floors and Roofs.** Floors and roofs may be constructed of wood, the sizes and spans to be in accordance with Chapter 25.

(q) **Floor Area.** Allowable floor area shall not exceed that specified under Occupancy (Part III). Adobe construction shall be allowed the same area as given in Table No. 5-C, Type V construction, Column N.

(r) **Wood Partitions.** Partitions of wood shall be constructed as specified in Chapter 25, wood partitions shall be nailed to nailing blocks laid up in the adobe wall or bolted through the adobe wall the height of the partition with ½" bolts @ 24" on center with large washers or plates.

(s) **Stop Work.** The Building Official shall have the power to stop work whenever adobes have not been thoroughly cured and shall give prior approval to the use of any hardeners, stabilizers or other so-called preservatives.

Appendix 3—Construction specifications for adobe

Recommended specifications for adobe and construction details

INTRODUCTION—Specifications are written instructions that accompany drawings on a construction project and are issued to further explain the intent of the drawings. Specifications spell out exactly how a material or system is to be handled and installed and indicate the size, type, and quality of materials to be used.

In the following suggested adobe specifications, the instructions are generalized for use with most adobe projects, and more explicit instructions should be written for each project as necessary. The general notes and drawings are provided only as a guide to assure that basic elements relating to the adobe construction are considered. Additional notes accompany some drawings where not all conditions are shown. Many variations and local customs differ from the ones shown; however, the details have been reviewed and reflect the latest in energy efficiency coupled with the simplicity of adobe. All drawings and specifications should be the responsibility of the person who prepares the construction documents, the owner, the designer, the architect, or the engineer.

ACKNOWLEDGMENTS—Construction details (figs. 87–102) were drawn by Dale Zinn, an architect with Architecture Planning Group, Santa Fe. Architects William Lumpkins also of Santa Fe and Allen McNown of Nambé reviewed the drawings.

General notes

All adobe walls should be erected on solid bearing foundations. The foundations should be at least 16 inches wide and rest on undisturbed earth or rock at a point below the frost line. Check with the building official for the depth of the frost line in the project vicinity. All foundation walls should extend above the ground at least 6 inches to protect the adobe walls from erosion. Earth around the structure should slope away from the walls.

For minimum foundation reinforcement two ½-inch continuously running reinforcing bars should be placed horizontally side by side and 6 inches apart in the footing 2 inches above the earth. Vertical ½-inch bars should extend from the bottom of the footing up through the foundation wall every 4 ft. Another horizontal bar should be run continuously at the top of the stem wall and should be tied to the verticals. All splices should be overlapped 24 bar diameters or a 12-inch minimum. The concrete for the footing and the foundation wall or to fill the cells of a concrete-block foundation should have a minimum of 2,500 psi compressive strength.

Perimeter insulation is required by the New Mexico State Energy Code. This is a rigid-board insulation that is moisture protected or impervious to moisture. The perimeter insulation is most effective if it is 2 inches thick and if it is placed on the outside of the foundation walls extending at least 2 ft down into the earth.

The New Mexico Energy Code requires that walls meet the criteria for insulative qualities. Adobe walls that are to be insulated should have the insulation fitted to the exterior to preserve the thermal-mass effect of the adobe shell. The insulation can be a sprayed-on material, or board stock can be mechanically attached to the outside. The outside should be additionally protected by a stucco or other finish. This finish must be anchored through the insulation into the adobe.

Either cement or adobe-mud mortar can be used effectively for adobe construction. Cement mortar is more expensive; however, the cement sets up faster and stronger so that work can progress more quickly. Mud mortar is inexpensive, but walls may take weeks and even months to dry completely. Working too fast with adobe mud mortar can cause structural failure.

Horizontal joint reinforcing can be used to add strength to the walls. Usually 9-gauge wire in a ladder or truss configuration is laid in every sixth-course mortar joint. Wider walls require wider reinforcing. A ⅜-inch reinforcing bar also may be used in the joint.

The height of adobe walls is limited by code. The maximum height of a bearing wall of adobe is 10 times the width of the unit being used. Therefore a 10-inch-wide adobe wall can be laid 8 ft 4 inches high, and a 14-inch-wide wall can be 11 ft 8 inches high. Higher walls should be designed by an architect or engineer. Most walls of a house are not over 20 ft long without an intersecting wall. A wall that is over two times the allowable length should have an intersecting wall, reinforcing pilaster, or adobe post built into the wall for lateral bracing.

All openings in adobe walls have to be spanned with a supporting member. The member can be steel, reinforced concrete cast in place or precast, or wood. The lintels should extend 12 inches past the opening on both sides and be the full width of the wall. The depth of the member depends on the width of the opening and the strength of the material. In wood an 8-inch-deep member can be used in an opening up to 6 ft wide. A 12-inch-deep member can be used in an opening up to 10 ft wide. The supporting structure of wider openings should be designed by an architect or engineer.

Structural damage from water runoff is the worst and most frequent problem with adobe construction. All details of the roof, whether it is pitched or semiflat, should take into consideration that the runoff of rain water should be carried away from the outside adobe walls by canales, scuppers, gutters, or roof overhangs.

Bond beams

The bond beam is a continuous member placed at the top of a wall where the roof structure is to be anchored. The bond beam as called for on the drawings can be either concrete or treated wood as specified in the Uniform Building Code. The bond beam shall be set on adobe-mortared walls only after the wall has dried for at least 7 days; cement-mortared walls can be ready for the bond beam after only 1 day. The size of the bond beam as required by code is a minimum of 6 inches deep and equal to the wall width. A wood bond beam may be made up of layers of boards not less than 1 inch thick; however, wood joints shall be lapped at least 6 inches and spiked together. All bond beams should be anchored into the adobe wall. This can be done with ⅝-inch steel reinforcing bars (or bolts) cut long enough to extend down through the bond beam and into the adobe for at least four courses (± 16 inches). These anchors should be placed every 6 ft and solidly grouted into the wall.

Wall finishes

Upon completion of the work, rake out all defects in joints of exposed surfaces, fill with mortar, retool, and rub. Leave all surfaces clean, free of mortar daubs, and with tight mortar joints throughout. Exterior and interior walls may be left unfinished. The following wall-finish alternatives are quoted from the California Research Corporation report (1963).

1) SMOOTHING AND WASHING—The wall surface shall be cleaned by wetting and rubbing smooth with wet burlap, then washing [with an adobe mortar wash].
2) PAINT COAT, PRIME COAT, TRANSPARENT SEALER—
   a) *Paint*. The following paints are satisfactory when applied on emulsified asphalt treated soil brick dry surfaces to serve as finish paint coat, exterior or interior. No prime coat is required . . . [Alcyd resin, an oil base exterior masonry paint, or acrylic latex flat exterior finish may be used.]
   b) *Asphalt base aluminum prime*. After the walls are smoothed and cleaned 1) and are thoroughly dry, a good grade of *asphalt base* aluminum paint, formulated with drying oils, shall be used as prime. When the coating is dry, one or more coats of a good grade of exterior or interior paint may be applied. (Note: Aluminum paint is not recommended to be applied during wet seasons, or on walls when damp. When wall is damp, use instead cement wash, Par. "c," below.)
   c) *Cement wash*. The clean wall surface shall be wetted, then primed with a cement wash consisting of one sack of Medusa or equal White Cement mixed with about 6 gallons of water to a paint consistency, applied by vigorous brushing. After initial set, the prime coat shall be fogged with water several times daily for 5 or 6 days, until the cement is fully set and hardened.

      A second application of cement wash, tinted with pigment if desired, may be applied as final coat; or after setting, the cement-primed surface may be painted with a good grade of exterior or interior paint. (Cement wash coats are best applied when damp; cloudy weather aids moist curing.)
   d) *Transparent protective sealer*. A nonglossy protective finish, not altering natural color of the bricks, may be obtained by applying on the clean wall surface . . . [a clear acrylic sealer or a silicone masonry sealer, either clear or tinted].
   e) *Linseed oil, for interior finish only*. For harder, tougher interior surfaces a prime coat or a transparent protective seal coat may be provided by painting with raw linseed oil (imparting to the brick surface a richer, darker color). When used as prime coat, allow to cure thoroughly, at least two weeks, then paint with 50% raw linseed oil, 50% . . . [alcyd resin, an oil base interior masonry paint].
3) PLASTER—Expanded metal lath or 1-inch 18-gage galvanized wire shall be fastened to the walls with furring nails driven into the bricks. Cement stucco or hardwall plaster is then applied in scratch, brown, and finish coats according to standard practice.

Estimating quantities of adobes

Several methods are used for estimating the number of adobe bricks necessary to build a wall or partition. The method described here known as the *wall-area method* is the simplest and is as accurate as any. The quantities shown are based on an adobe brick of 10 × 14 × 4-inch nominal dimensions. If the adobe is other than this size the quantities will not be accurate.

Estimating procedure

Given the modular (standard and consistent size) nature of adobes made in quantity, the wall-area method of estimating adobe quantities assumes that a consistent number of adobe bricks are contained in any 1 ft^2 of wall area. In estimating quantities of other masonry units for a specific area, such as bricks, the size and consistency of the mortar units are very important. The adobe unit is much larger than a fired brick; therefore, consistency and size of the joints are less critical in the determination of the quantity of units in the adobe wall. The quantities below reflect an assumption that the joints are approximately ½–¾-inch thick.

The first step is to estimate the amount of area for each wall thickness. For example, take the length of a 10-inch-thick wall and multiply by the height, excluding bond beams. Subtract the window and door areas. This will be the *net wall area*. Repeat this procedure for all other 10-inch-thick walls until the net wall areas of all 10-inch-thick adobe walls are calculated. Estimate the net wall area in the same manner for other thicknesses of walls. Multiply the net areas by the units per ft^2 given below for each of the different wall thicknesses. This number will be the preliminary quantity of adobes needed. An estimation of the breakage and waste must be made and then added to this quantity. At least 10% should be added; however, various factors will increase this percentage. Some of these factors are quality of the adobes, the exposure that the stacked units are subjected to, the amount of handling necessary to bring the units to the construction site, and the number of doors and windows in a wall panel. Following are the units per ft^2 for different wall thicknesses:

10-inch-thick wall = 2.60 units/ft^2
14-inch-thick wall = 3.63 units/ft^2
24-inch-thick wall = 5.52 units/ft^2

To determine the amount of mortar required for ½-inch joints, multiply ⅙ of the net wall area by the wall thickness in feet, then divide by 27. The result is the $yards^3$ of mortar required with some allowance for wastage.

General specifications

SCOPE—Furnish and install all adobe masonry where shown on drawings and where required by the project manual, complete with all necessary accessories.

HANDLING—Stack adobe units on planks or platforms and protect adobes from moisture by covering with tarps, felt paper, or polyethylene sheets. Broken units and those with damage (2-inch maximum break or more than three surface cracks ⅛ inch in width and 3 inches long) shall be discarded from the stack and not used.

CODES—Local, state, and national codes in effect at the site of the work shall be observed during all phases of the work.

WEATHER CONDITIONS—Discontinue adobe-masonry construction when the ambient temperature is below 40° F (4° C) or when the probability of such conditions could occur within 48 hrs. Special conditions for cold-weather laying shall be subject to prior approval by the architect or building official. Do not build upon frozen materials. Remove any work that has become frozen prior to resuming construction. In hot weather, protect concrete and cement mortar from drying too rapidly.

TESTING—The adobe manufacturer shall attest by certificate or otherwise guarantee that the adobes furnished meet or exceed the physical requirements stated in the building code adopted by the state of New Mexico.

Materials

SEMISTABILIZED ADOBES—Nominal 4 × 14 × 10-inch units shall be made from adobe clay soil that shall contain not less than 25% and not more than 45% clay/silt material passing a no. 200 sieve. The soil shall contain sufficient clay to bind the particles together and shall contain not more than 0.2% water-soluble salts. Each adobe unit shall contain from 2 to 4% asphaltic emulsion stabilizer. The remainder of materials shall be a combination of fine sands and silts containing no particles larger than ⅜ inch and shall be free of large organic objects. The water used to mix the material shall be potable (drinkable). All units shall be formed in standard wood or metal molding forms. No units shall be used that are less than 30 days old.

TRADITIONAL ADOBES—Nonstabilized adobe shall be made in the same manner as the semistabilized units with the exception that the asphalt shall be deleted, and small quantities of straw can be used as a binder in the mix.

STABILIZED ADOBES—Stabilized units shall be made in the same manner as the semistabilized units except that the adobe asphalt content shall be 5–8%.

STABILIZERS—Type CSS-1 or CSS-1h asphaltic emulsion or the following cement, lime, and sand mixture—*portland cement*, ASTM C-150 Type II-2500 psi; *hydrated lime*, ASTM C-207 Type S; *sand*, clean sharp, ASTM C-144; *water*, clean, nonalkali, and potable; and *joint reinforcing*, ASTM A-82, Truss Type 9 gauge.

ANCHORS AND TIES—Galvinized, 20 gauge minimum, and of approved design or expanded metal, 3.4 lbs/yard^2. All metals shall be free of loose rust or scale.

GRINGO BLOCKS OR WOOD SLEEPERS—Wood blocks in the same shape as the adobe unit shall be made of 2 × 4-ft stock material and treated with an approved wood preservative.

MORTAR—Mortar shall be mixed as follows—1 part cement, 1 part lime, and not more than 6 parts sand with adequate water to produce a workable mix.

ADOBE MORTAR—Adobe mortar where allowed by the building official shall be mixed of the same materials as the adobe units. Mortar joints should be waterproof to prevent expansion and contraction as a result of moisture variations and should be about ½ inch thick (California Research Corporation, 1963). Soil found suitable for use in mortar is best mixed in a small powered plaster or cement mixer. Usually approximately ½–¾ gal of stabilizer (asphalt emulsion) per ft^3 of dry loose soil is required. To produce a 5–8% mix use a 55-gal oil drum, pour in 5–5½ gal of asphalt emulsion, fill the drum with water, stir, and then add the mixture into the plaster or concrete mixer with soil in the ratio mentioned above to make a workable adobe mortar.

The proportions suggested by the Hans Sumpf Company (personal communication, 1980) are as follows: 1 part cement, 2 parts adobe soil, 3 parts sand, and 1½ gal emulsified asphalt per sack of cement used in the mortar mix.

ALTERNATIVE MORTAR—The alternative mortar proportions suggested by the Hans Sumpf Company (personal communication, 1980) shall be 1 part cement and 2½ parts sand into which emulsified asphalt shall be incorporated at a ratio of 1½ gal to each sack of cement.

Execution

WALL CONSTRUCTION—The contractor shall inspect the foundation for suitability for laying of the adobes. Do not proceed if the earth is within 6 inches of the first course of adobe or if any other condition exists that would be detrimental to the adobe.

Mix cement mortar in a mechanical mixer for at least 10 mins, not more than 2½ hrs before it is to be used. Retempering (rewetting) of cement mortar shall not be allowed.

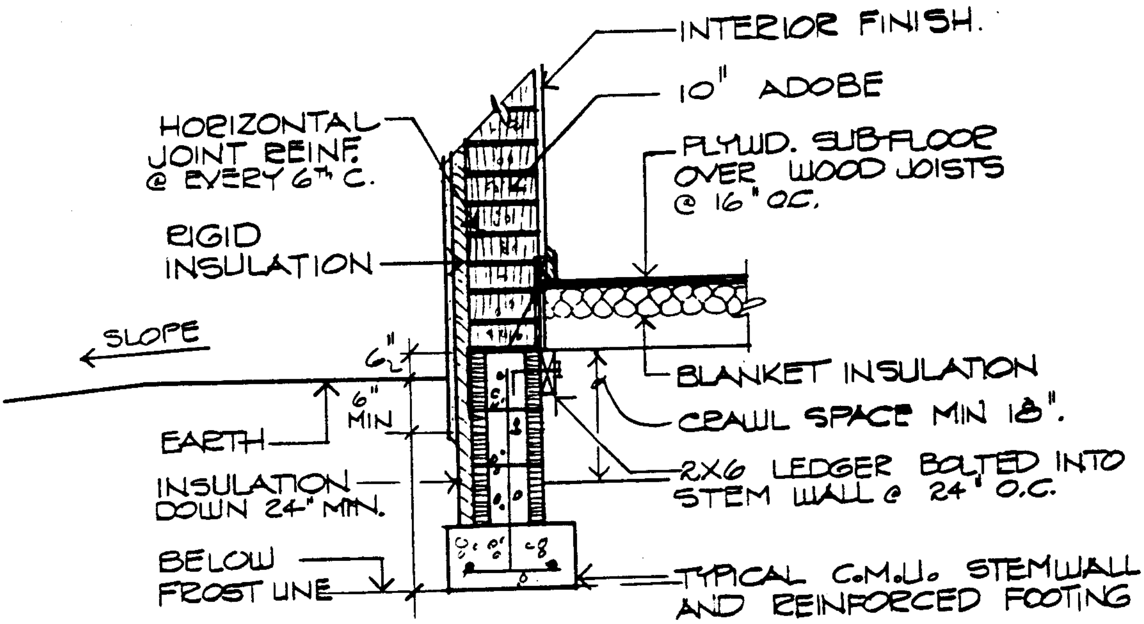
Lay adobe units in running bond with a minimum 4-inch overlap of the vertical joints between the bricks of adjacent courses. Mortar joints shall be flush with a ½–¾-inch maximum thickness. Tool mortar joints slightly concave on interior surfaces scheduled for an exposed finish. Rub with burlap prior to subsequent finishing. Any unit that has been disturbed after the mortar has stiffened shall be removed and relaid in fresh mortar.

Install horizontal joint reinforcements as indicated on drawings, or if not called for, place reinforcements in every sixth course and in the first joint above lintels. Extend reinforcements 2 ft on both sides of all openings. Lap reinforcement 6 inches minimum at all splices and maintain a ⅝-inch mortar coverage on the weather side of the joint.

Install built-in items such as wood sleepers, blocking, door frames, anchors, lintels, or other framing members as required as the work progresses. Space around frames and anchors shall be filled solidly with mortar.

Step back unfinished walls for joining with new work. Cover all partially completed work with a waterproof material and anchor securely. Protect surfaces of walls from damage and keep free of excess mortar. Walls may be channeled to embed pipes or conduit up to ½ inch maximum diameter. Adobe walls may be thickened to embed larger diameters. Pipes or conduits may pass through the walls.

CLEAN UP—Remove all debris created by the work in this section from the job site.



10' STEM WALL-JOIST FLOOR

NOTE: ALL FOOTINGS AND FOUNDATION WALLS ARE SHOWN FOR AVERAGE SOIL AND LOADING CONDITIONS. ALL FOOTINGS SHOULD BE DESIGNED FOR THE SPECIFIC CONDITIONS OF EACH PROJECT.

THE THICKNESS OF INSULATION REQUIRED BY ENERGY CODES VARIES WITH PROJECT, SITE, CLIMATE AND THE R-VALUE OF THE INSULATION TO BE USED.

FIGURE 87—TYPICAL FOUNDATION FOR 10-INCH ADOBE WALL.

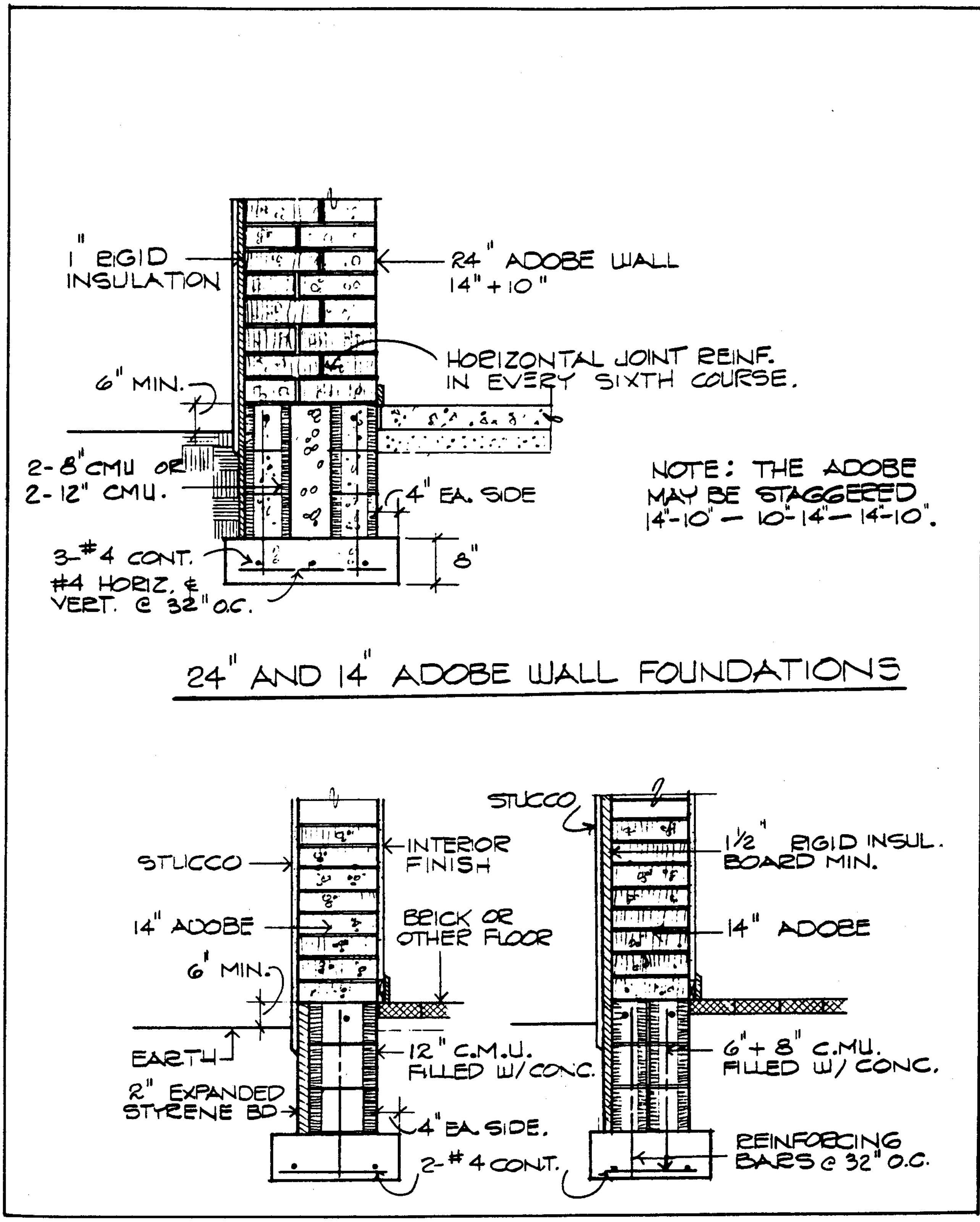


FIGURE 88—TYPICAL FOUNDATIONS FOR 14-INCH AND 24-INCH WALLS.

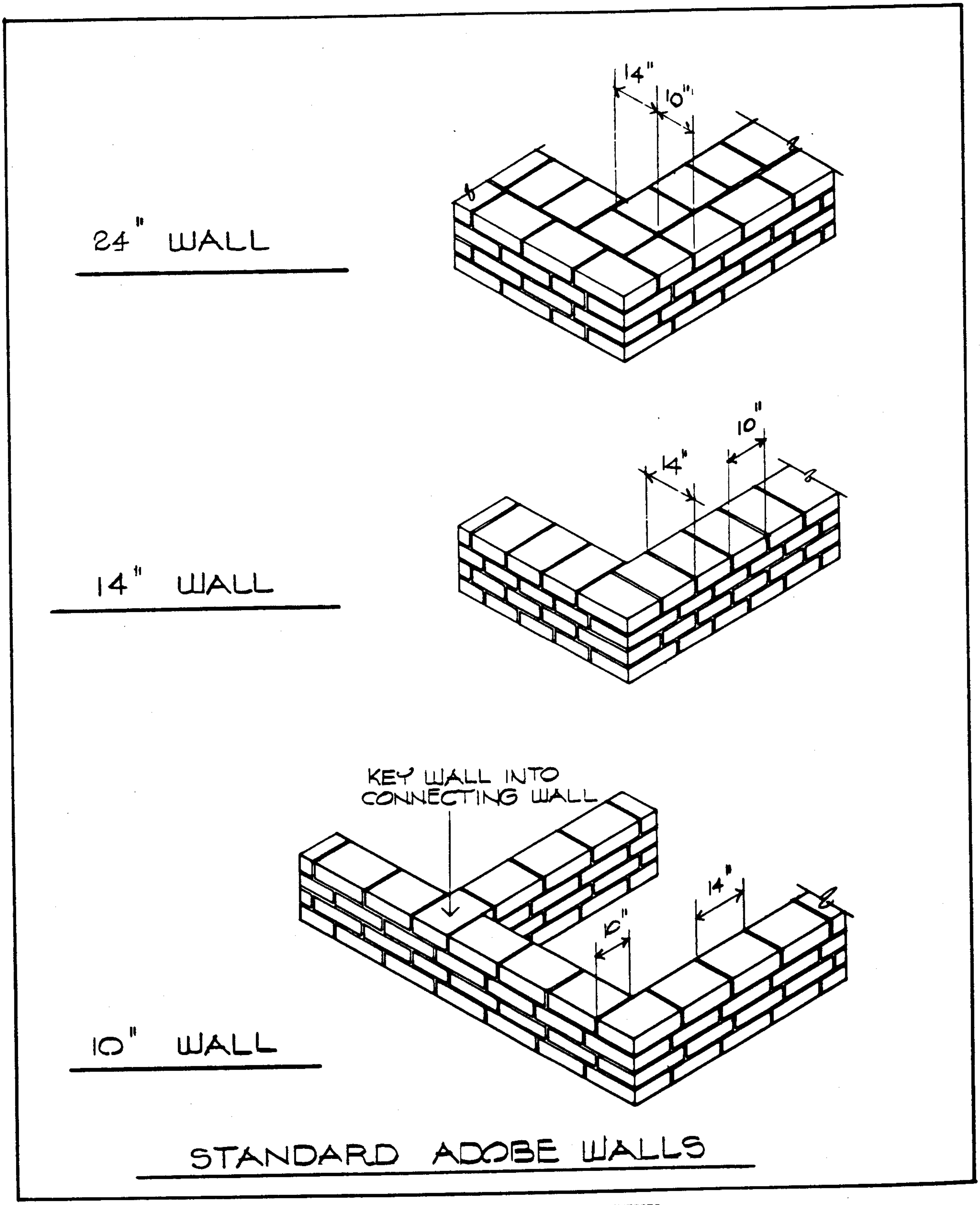


FIGURE 89—STANDARD ADOBE-WALL THICKNESSES.

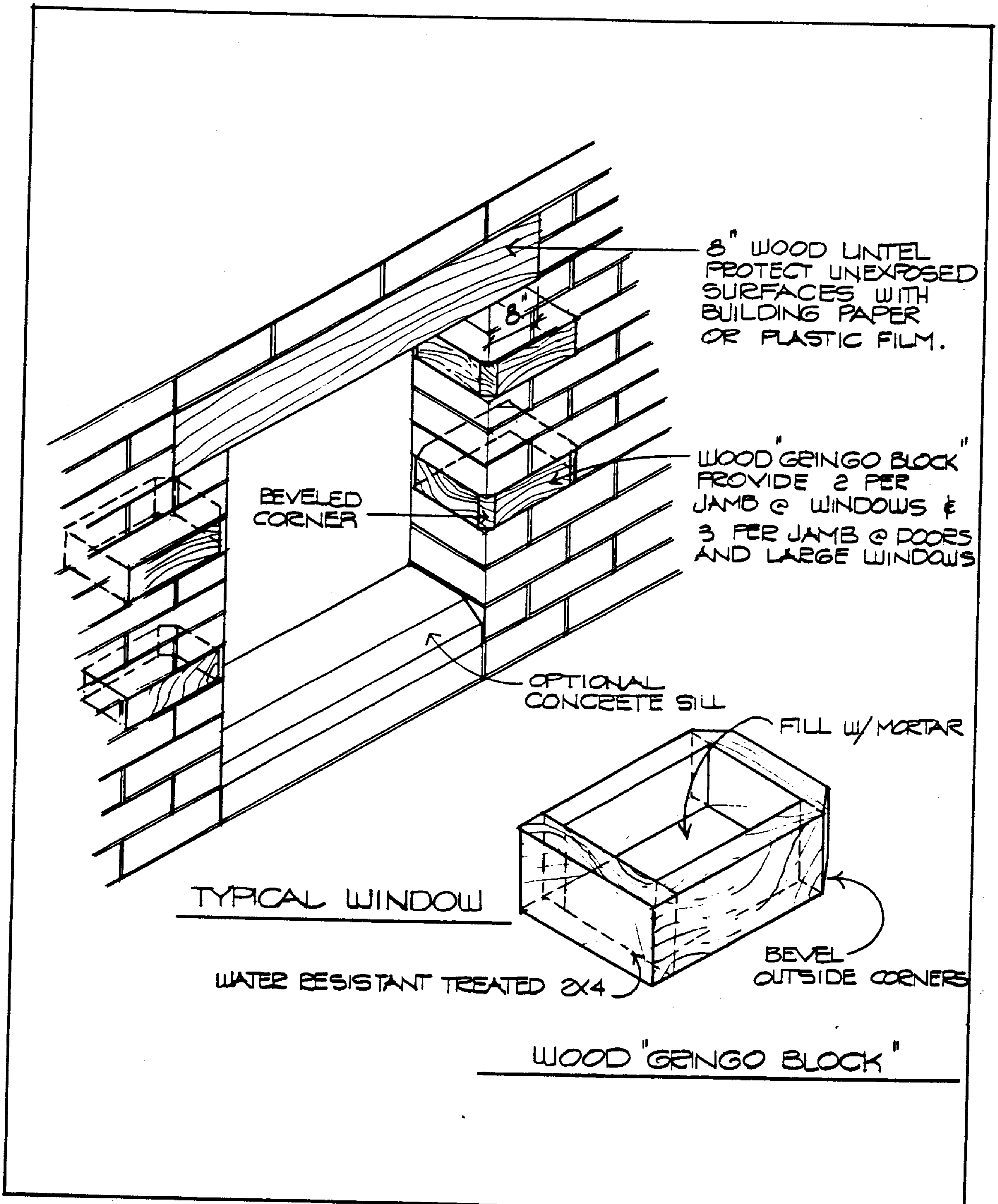


FIGURE 90—Wood "gringo" blocking detail.

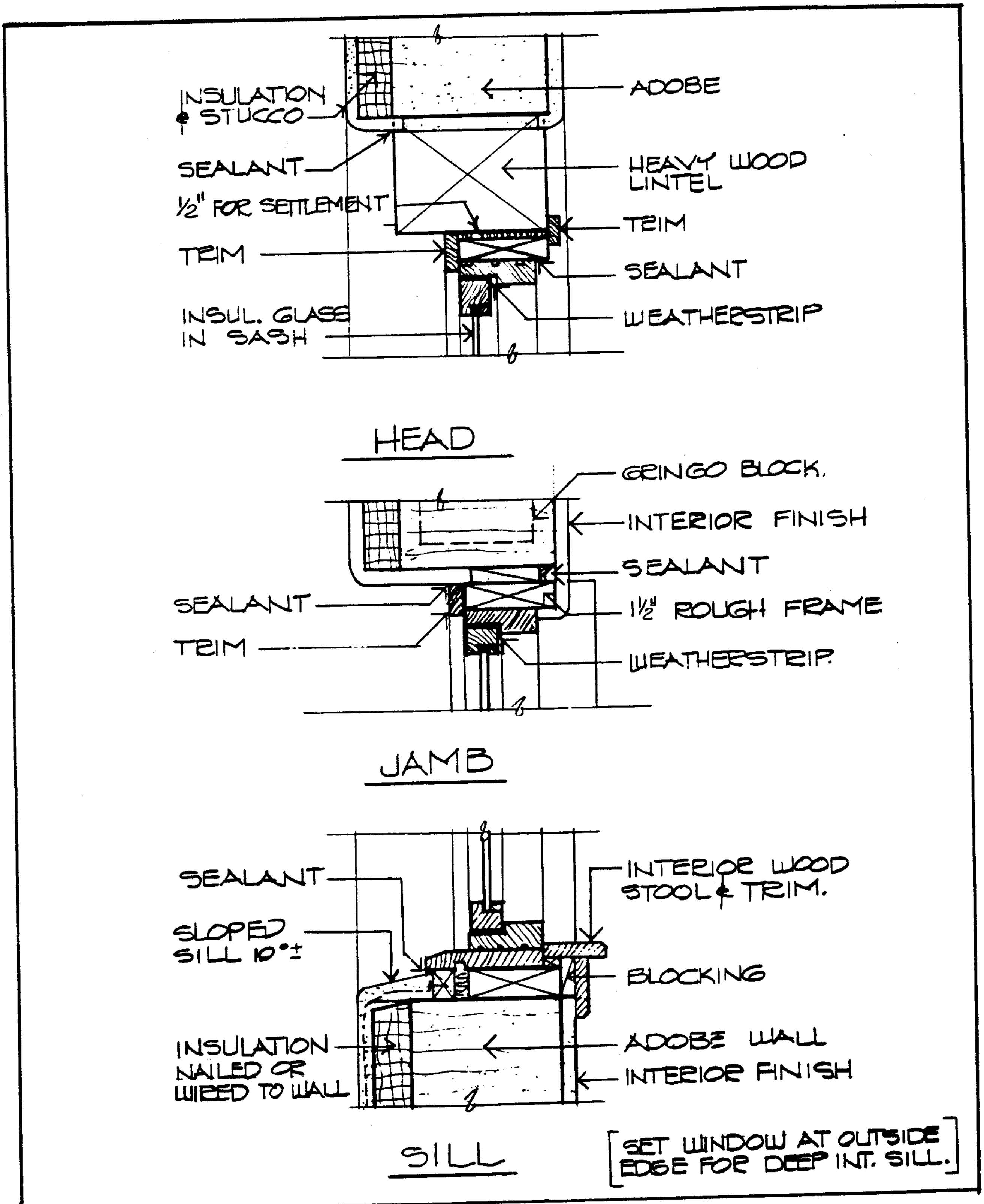


FIGURE 91—TYPICAL WOOD WINDOW DETAIL IN ADOBE WALL.

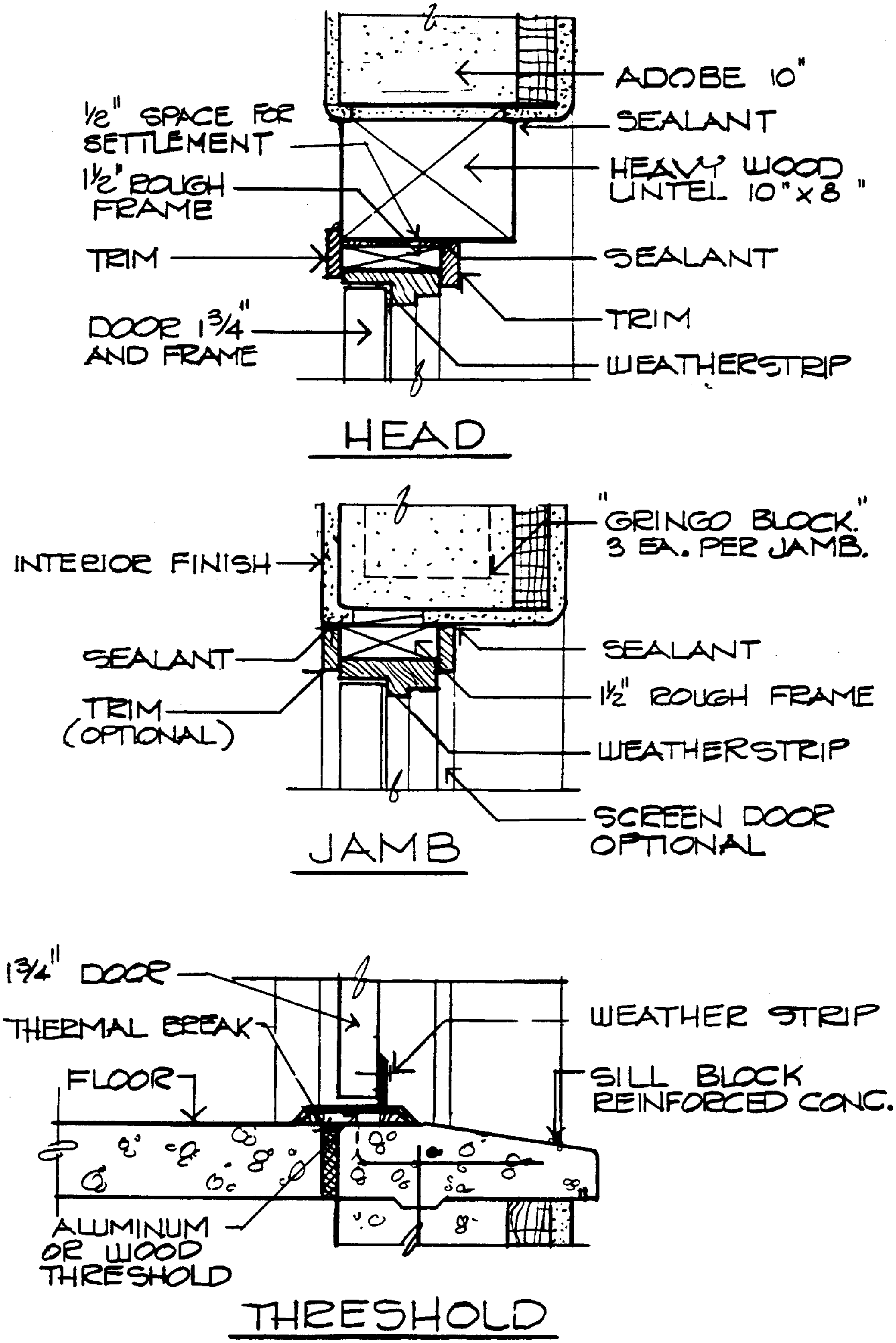


FIGURE 92—TYPICAL EXTERIOR WOOD DOOR DETAILS.

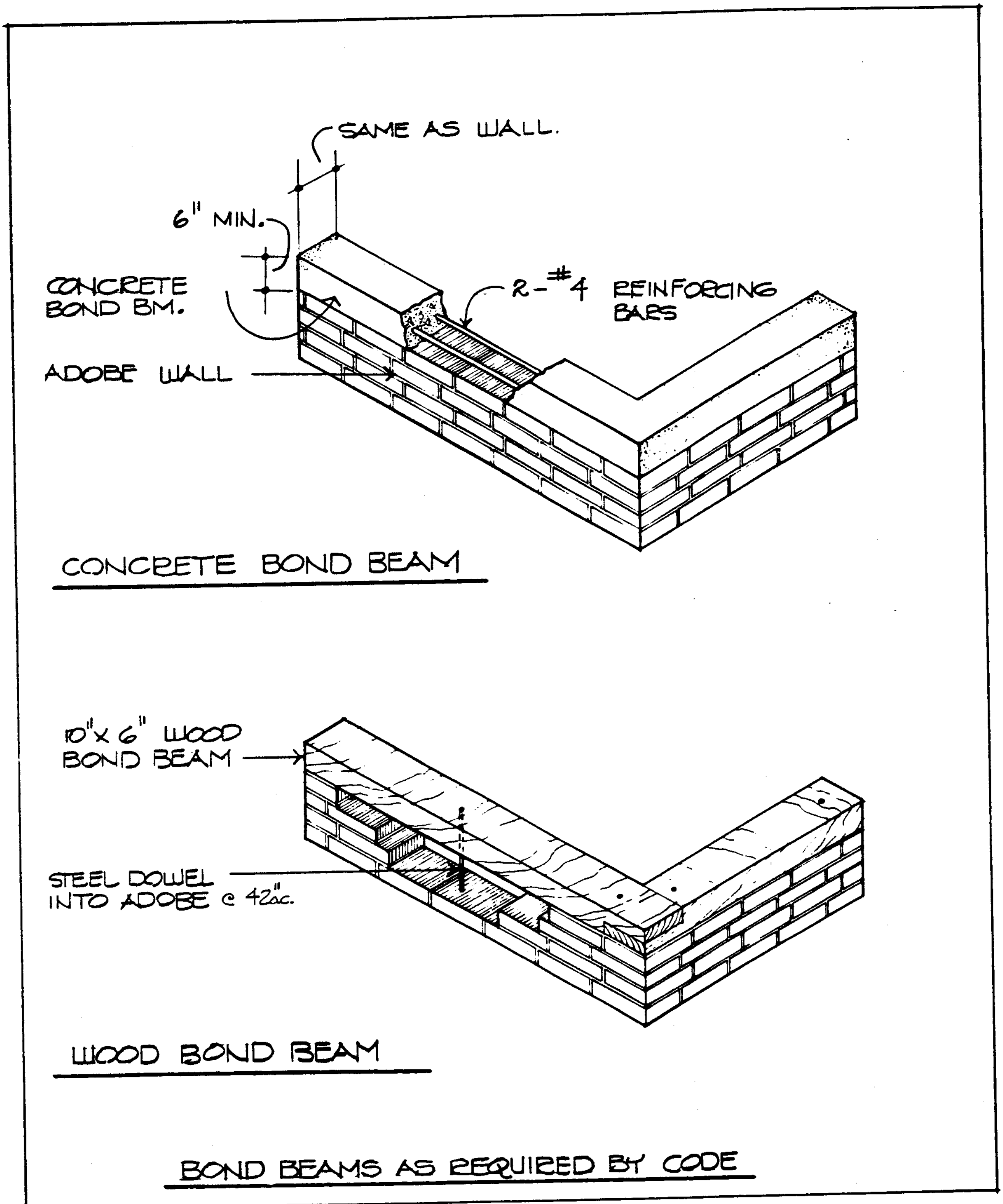


FIGURE 93—BOND BEAMS AS REQUIRED BY CODE, WOOD TIMBER AND CONCRETE.

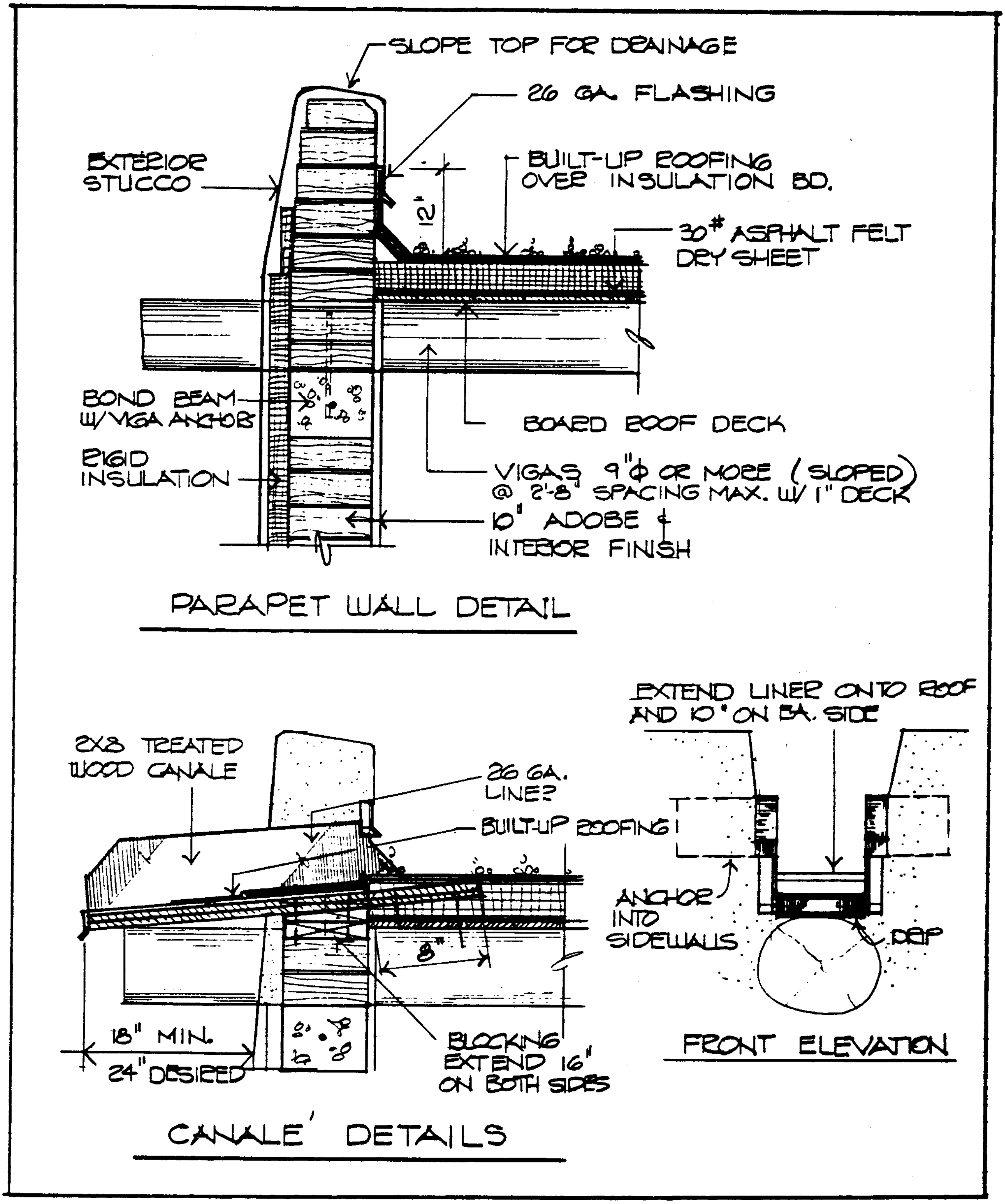


FIGURE 94—ROOF PARAPET AND CANALE DETAIL.

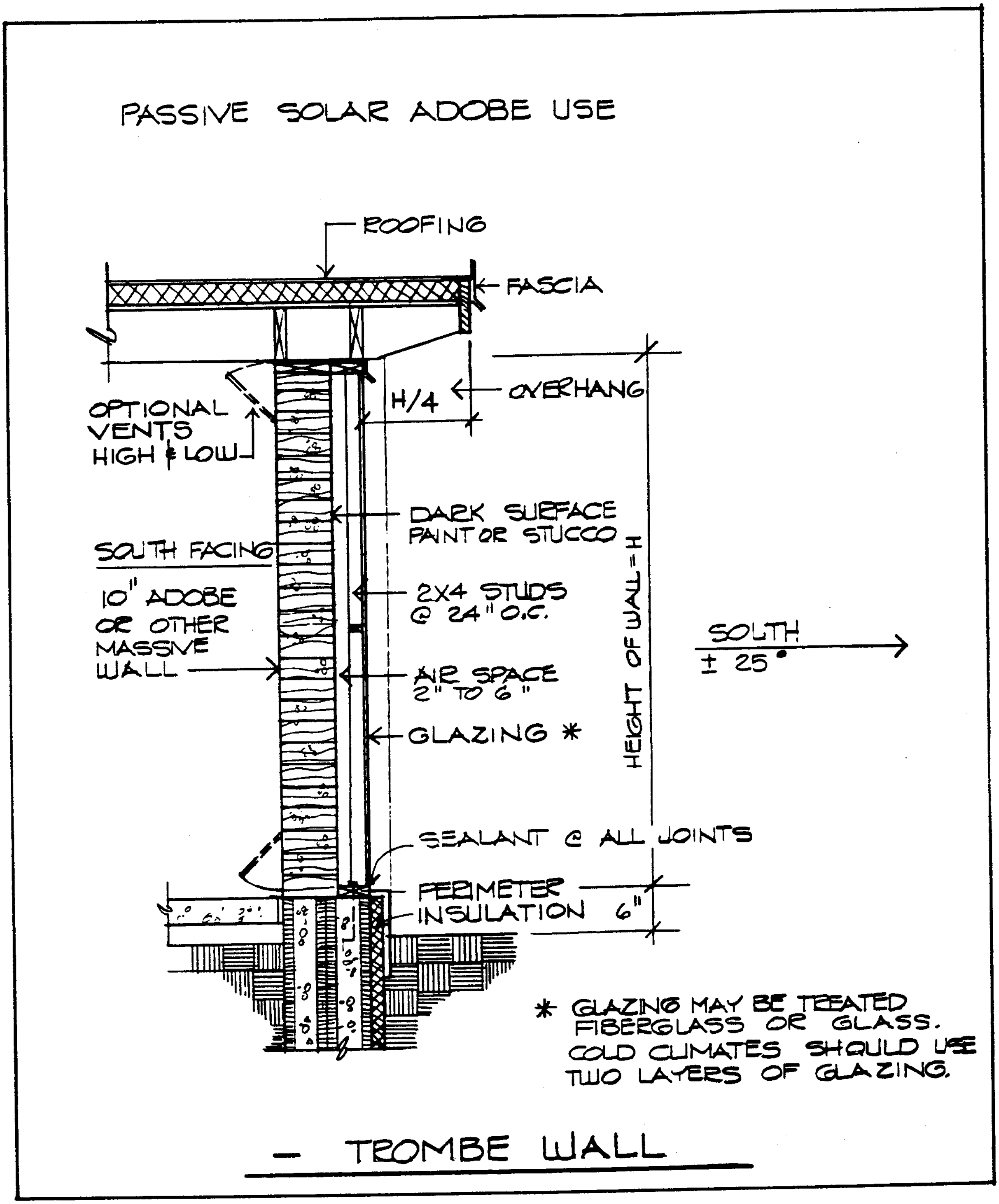


FIGURE 95—PASSIVE SOLAR TROMBE-WALL DETAIL.

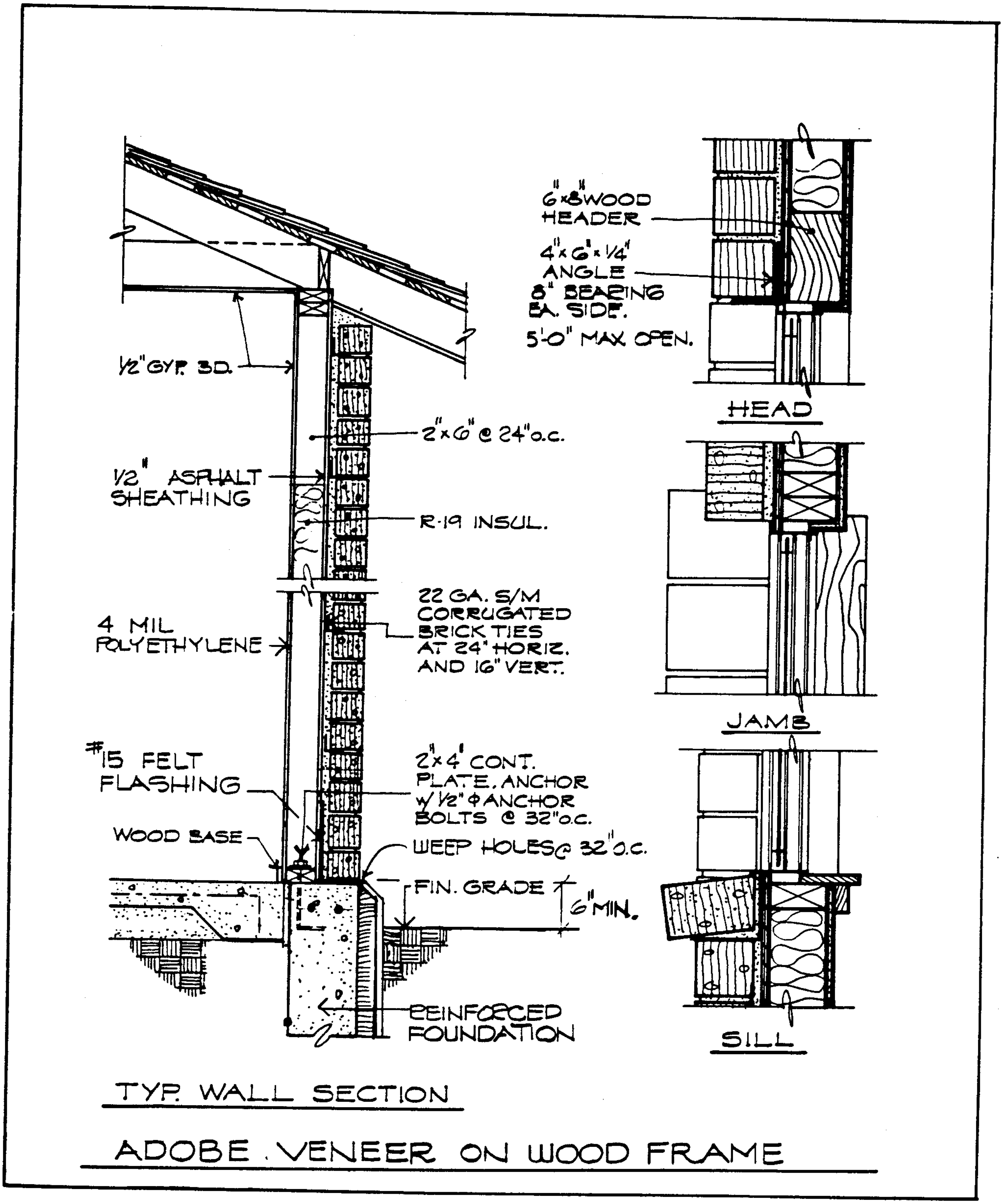


FIGURE 96—ADOBE VENEER OVER STUD WALL SECTION.

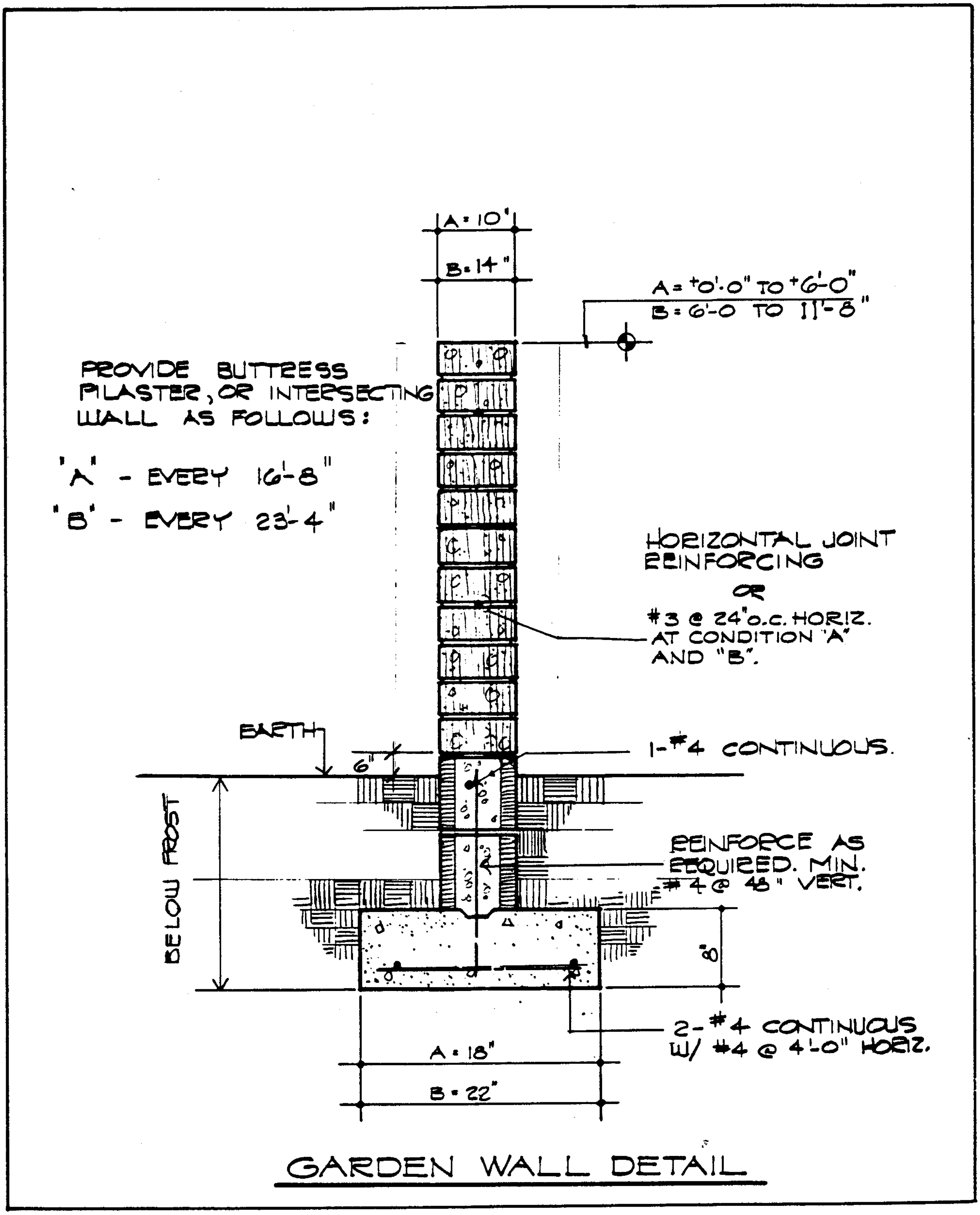


FIGURE 97—GARDEN-WALL DETAIL.

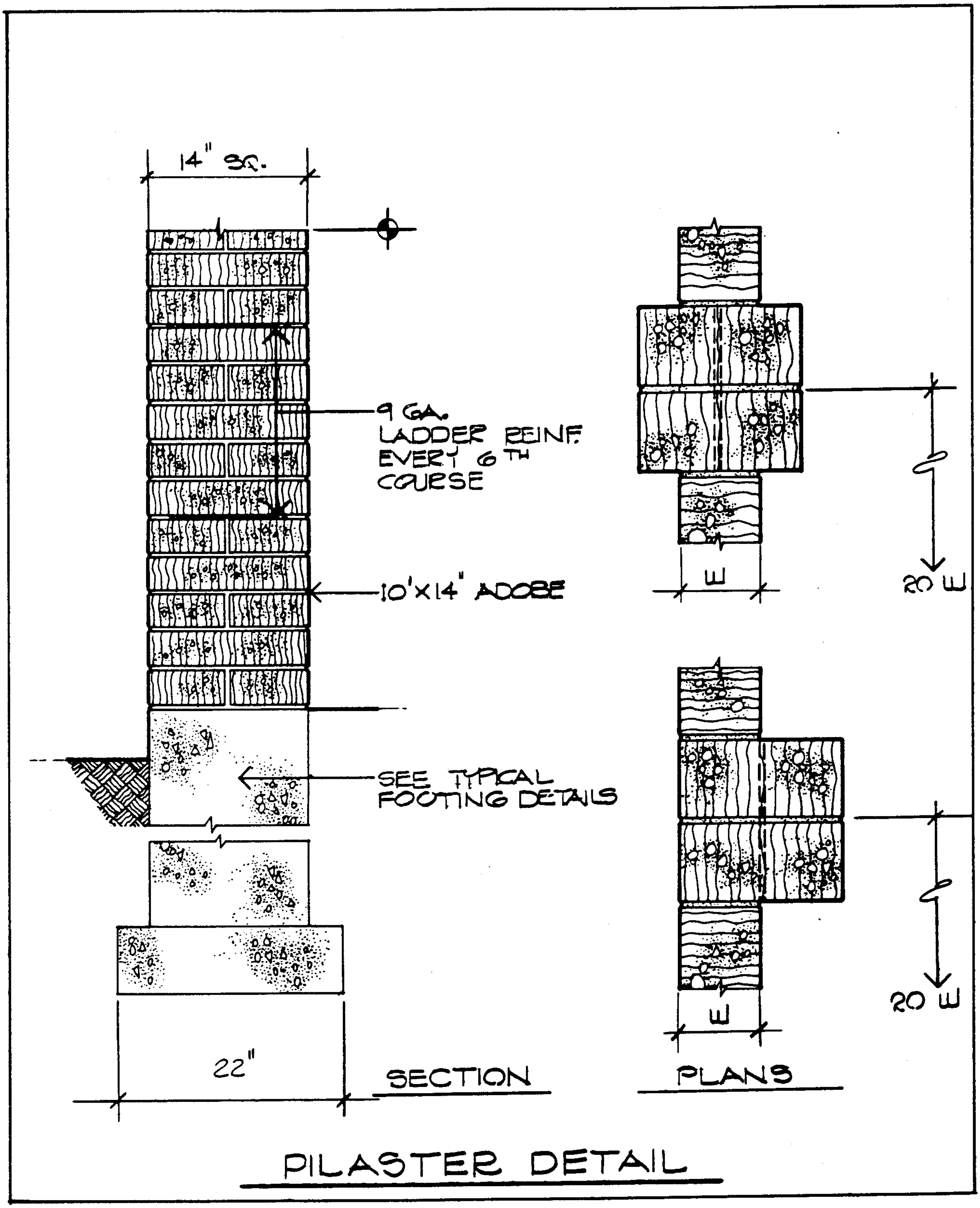


FIGURE 98—ADOBE POST OR PILASTER DETAIL.

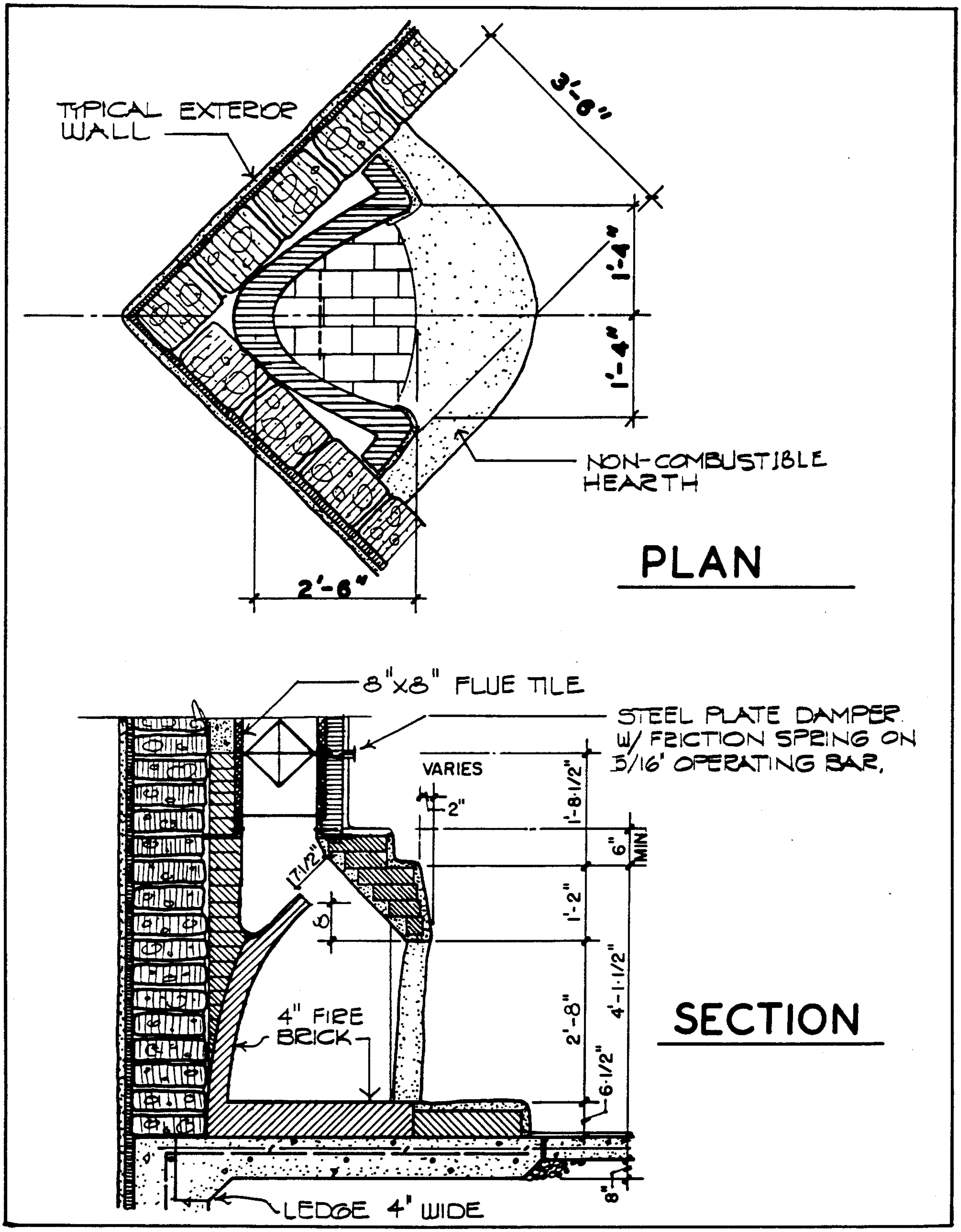
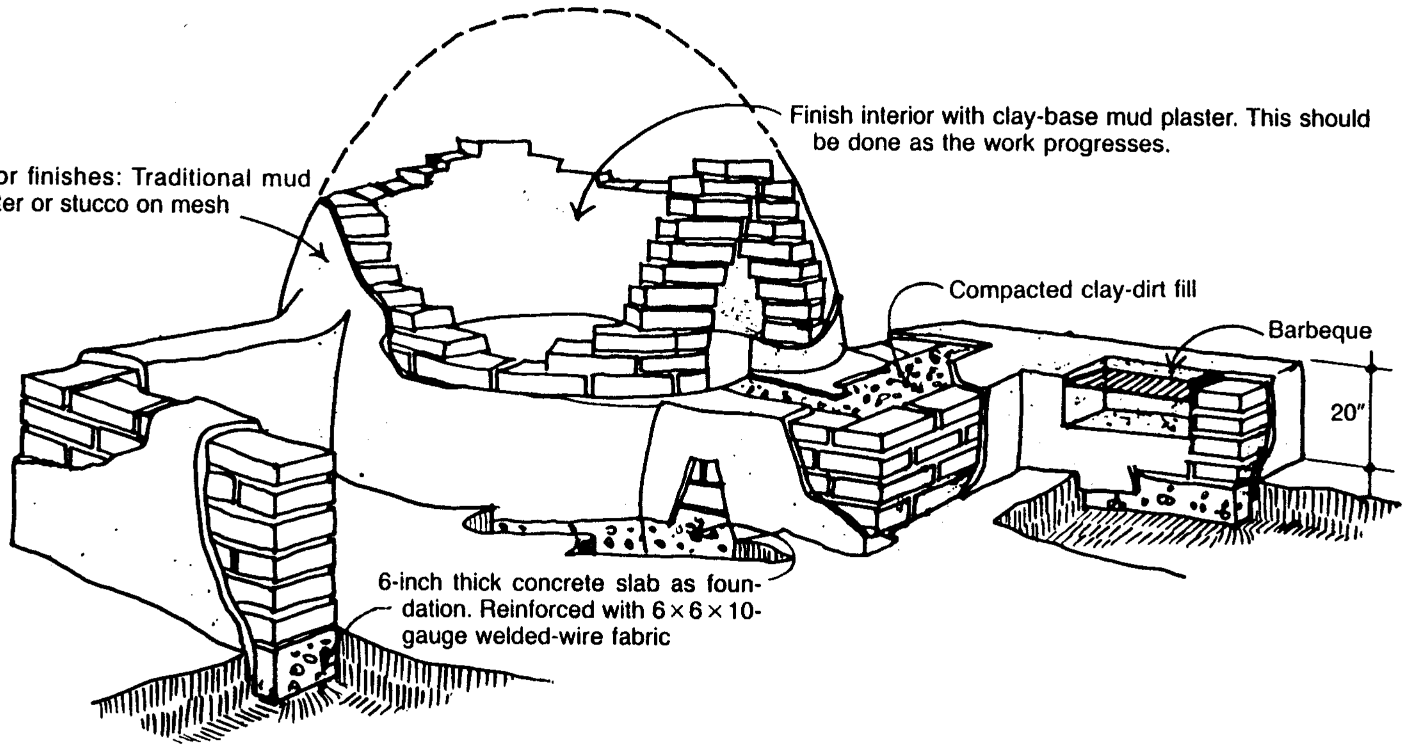


FIGURE 99—ADOBE CORNER FIREPLACE.



Adobe "horno" or Indian oven

Note: All adobe fill should be allowed to dry out completely before finishing the work.

FIGURE 100—ADOBE HORNO OR INDIAN OVEN.

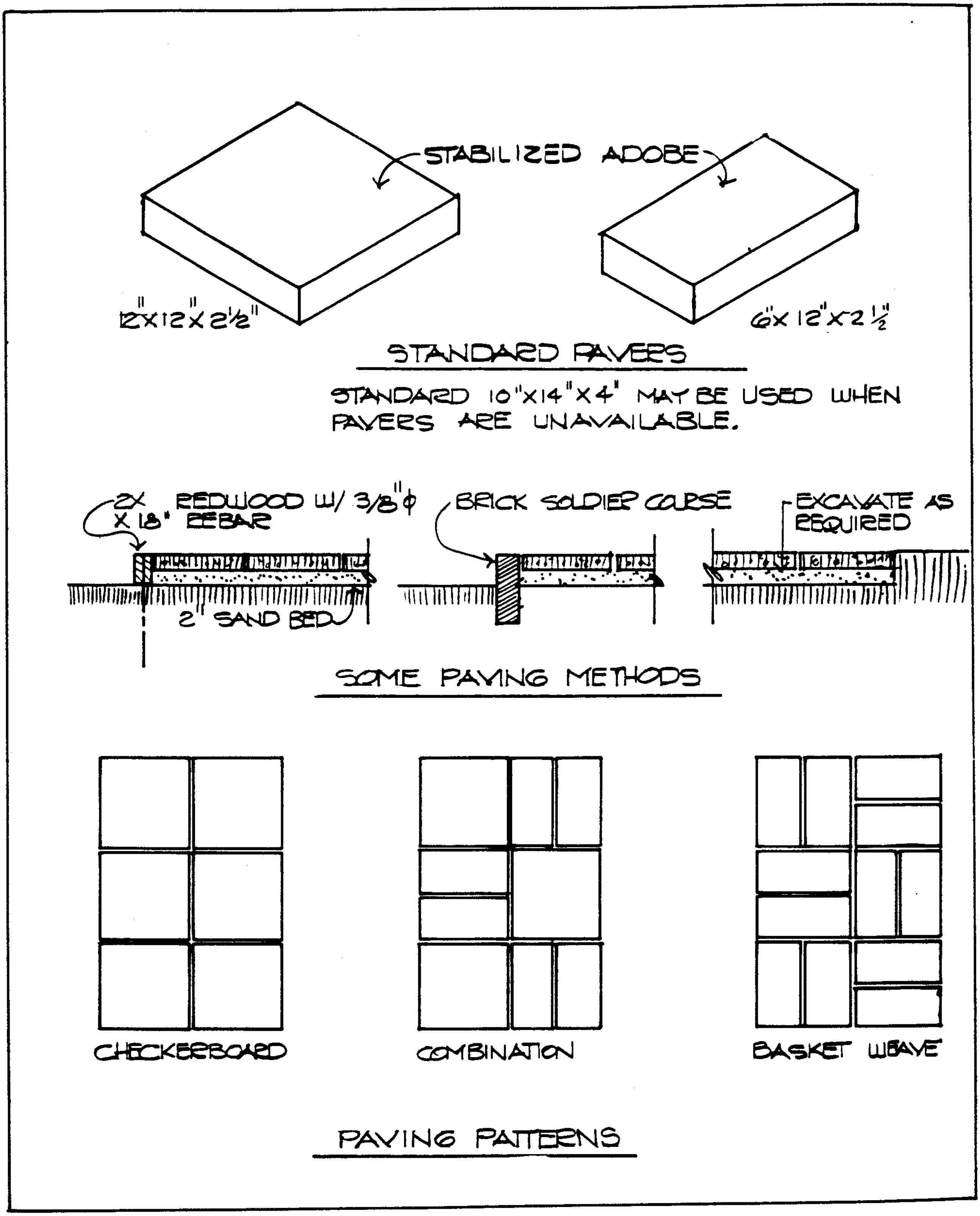
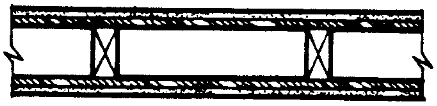
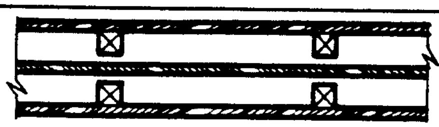
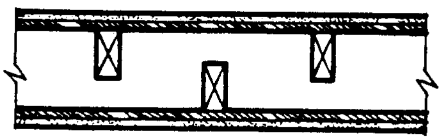
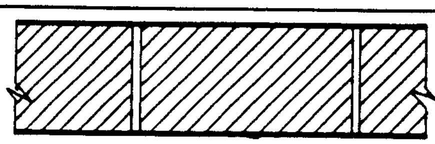


FIGURE 101—ADOBE-BRICK PAVING FOR WALKWAYS AND PATIOS.

Test no.	Construction	Weight lbs/ft²	Sound transmission dBu	Class
1*	 ½-inch insulating board on 2×4 studs @ 16-inch on center	3.8	32.2	Fair
2*	 2×4 studs @ 16-inch on center with ⅜-inch gypsum lath and ½-inch plaster	15.0	34.9	Fair to good
3*	 2×4 studs @ 16-inch on center on a 2×6 plate with ¾-inch insulating board. ½-inch insulating board loose between studs.	6.2	42.8	Very good
4*	 2×4 studs staggered 16 inches on center on 2×6 plate with ½-inch lath and plaster	13.1	53.7	Excellent
5	 10-inch thick adobe brick	109	63	Excellent

*Tests shown with (*) are results of tests sponsored by the Insulation Board Institute.
From a report dated Sept. 14, 1956, Examination 308691, after Hans Sumpf Company, Inc.

FIGURE 102—Sound-transmission test results.