ADOBE CONSERVATION

A PRESERVATION HANDBOOK

by

THE TECHNICAL STAFF

of

CORNERSTONES COMMUNITY PARTNERSHIPS

with illustrations by

FRANCISCO UVIÑA CONTRERAS

santa fe

Adobe Conservation - a Preservation Handbook has been compiled by Cornerstones Community Partnerships, a 501(c)3 organization based in Santa Fe, New Mexico. Since 1986, Cornerstones Community Partnerships has worked to preserve architectural heritage and community traditions in New Mexico and the Southwest. Cornerstones has assisted more than 300 rural communities preserve historic earthen structures by teaching tradi- tional building skills and engaging youth and elders in the process of understanding and maintaining their cultural connection to earthen architecture. Youth training and applied learning have proven to be key factors in historic preservation in New Mexico and the Southwest, where the labor-intensive nature of traditional building methods poses unique challenges. Cornerstones is committed to working in partnership with communities to preserve historic resources, encourage traditional building practices and affirm cultural values. Tax-deductible contributions may be sent to Cornerstones Community Partnerships, P.O. Box 2341, Santa Fe, New Mexico, 87501-2341. Funding for this publication was generously provided by the Historic Preservation Division of the New Mexico Department of Cultural Affairs, by the Santa Fe Community Foundation and by the New Mexico Historical Society.

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In memory of VIRGINIA L-S (GINNY) COWLES 1924-2006

and dedicated to WILLIAM COWLES

Generous friends of Cornerstones
and passionate protectors of the youth,
the architectural heritage, and the cultural
traditions of New Mexico

PART ONE TERMINOLOGY AND TOOLS

Architectural Style and Materials Architectural Terminology
Tools, Equipment, Materials and Supplies Archaeological Sites and Burial Grounds
Safety on the Job

PART TWO ALL ABOUT ADOBE

Interpreting Sources, Processes and Effects of Deterioration Emergency Shoring
Moisture Testing in Adobe Walls Monitoring Cracks in Adobe Walls
Adobe Material Selection, Mixing and Testing Making Adobe Bricks

PART THREE HOW TO PROCEED

Installing a Subsurface Drainage System Removing Cement Plaster
Removing a Concrete *Contra Pared* Repairing and Restoring Adobe Walls Basal
Repairs and Stabilization
Repairing Erosion and Structural Cracks in Adobe Walls Reconstructing Adobe Walls
Lintel Repair, Replacement and Installation Mud Plastering
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Earthen and Lime Finishes
Repairing, Removing and Installing Wood Floors Installing Earthen Floors
Inspecting *Vigas* and Corbels Repairing *Vigas* and Corbels Cleaning the Attic
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PREFACE

Cornerstones and its community partners required more than six years to complete the preservation of *Nuestra Señora de la Limpia Concepción* – the great adobe mission church in Socorro, Texas, that is discussed in many sections of this new edition of our adobe conservation handbook. Like most Cornerstones projects, the effort at Socorro involved people from a variety of age groups and many walks of life. It also involved making more than 22,000 traditional adobe bricks by hand!

By comparison, it has taken more than three years just to revise and update this work, which illustrates the commitment made by Cornerstones' entire staff to carry out this important task carefully rather than quickly. This long period of revision, which caused a good deal of frustration among the stewards of adobe buildings eager for its re-release, is also testament to the pressing commitments of our organization's Technical Staff, all of whom had to balance limited time between duties in the field in New Mexico, across the American Southwest and along the Mexican *Frontera*, with the demands of reviewing, analyzing, revising and illustrating the technical issues discussed here.

In some respects blame for our delay in getting this handbook to the publisher must be shared with Socorro Mission itself. Indeed, many of the technical aspects of adobe conservation examined here, and which were developed and tested at Cornerstones projects, both large and small, over the past two decades, were fine-tuned at the multi-faceted Socorro Mission Preservation Project. We believe the additional experience gained at Socorro to be invaluable for the conservation of traditional adobe buildings of any age or size. We were determined to take the time to include information on the Socorro project in this new edition. We are, therefore, indebted to many people for their patience with us and we sincerely hope that the result has been worth the wait.

The release of *Adobe Conservation – a Preservation Handbook* just precedes Cornerstones Community Partnerships' twenty-first anniversary. This is an important occasion we will celebrate in 2007 as our *Coming of Age* year. It is a salute to the emphasis we place on youth education and training, a long-standing principal of Cornerstones' nationally honored mission. The first version of this handbook was pulled together "on a shoestring" as a way to provide communities across the Southwest, and especially their youngest members, with practical advice on how to continue the stewardship of the historic resources to which their ancestors had been dedicated, in many instances for centuries. It is our hope that this new edition, which benefits from the latest publishing-on-demand technologies, will continue to serve this crucial constituency of young people on a more timely and accurate basis for many years to come.

Twenty-one is a significant number for another reason. It represents the amount of time, at least in the American Southwest, that preservationists have had to figure out the physical dynamics that are characteristic of earthen architecture. Readers familiar with the earlier version of this handbook will notice that many of the guiding principles for traditional adobe maintenance and conservation have remained the same since we first went to press nearly a decade ago. These are common-sense rules based on traditional folk-knowledge Cornerstones has gathered since 1986. We have consulted elders in communities, at first primarily in northern New Mexico and eventually all the way from southern Colorado to Chihuahua, Mexico, and beyond, that needed assistance with their old adobe buildings. Despite the loss of knowledge of traditional building techniques among the younger generations in the region, Cornerstones has been fortunate to find community members who remembered "the old way of doing things." At times, just the acknowledgement that new methods are not always the best methods was all that was needed to bring this "forgotten" knowledge back to life.

At the same time, we must admit that in other cases it has taken a significant effort to demonstrate the problems of modern materials to some older community members. Faced with loss of population in their parishes, towns and villages, and therefore loss of the labor force necessary to maintain adobe buildings using traditional materials and methods, these caretakers sought to safeguard them by applying impermeable cement-based stuccos, or installing concrete slab floors and aprons *(contra paredes)* in and around them. Unfortunately, the central threat faced by an historic adobe building is the use of these well-intentioned, but drastically damaging modern construction materials. When a traditional adobe building is encased in cement, its ability to breathe – its natural capacity to rid itself of the moisture that wicks up into its walls as a result of capillary action – is eliminated. Over a relatively short period of entrapment by cement-based renders, adobe bricks that have maintained structural integrity for decades, if not centuries, begin to slump and turn to dust. If there is any single point Cornerstones would like to impress upon the readers of this handbook it is this: please let your adobe buildings breathe! (If only the City of Santa Fe, Cornerstones' home town, would heed this advice. Despite having what is considered one of America's most restrictive historic design ordinances, the City's laws do nothing to protect the city's remaining historic adobe buildings from this dire threat!)

Years of workshops, symposiums and cross-border collaborations between Mexico and the U.S. have allowed us and the communities we have worked with (more than 300 to-date) to re-learn traditional techniques from people who, in many cases, never switched to contemporary construction materials. The techniques in this handbook reflect many different trials and errors and shared experiences.

Revisions to this handbook became necessary to reflect what has been learned in the field at projects like Socorro Mission, as well as at preservation projects at the venerable adobe buildings of Acoma, Taos, Isleta, Laguna and Zuni pueblos, at the remarkable collection of 18th, 19th and early-20th century adobe missions high up in New Mexico's Mora Valley, at monuments in the Mexican states of Chihuahua, Sonora, Durango and Zacatecas, and at earthen buildings of almost every shape, size, age and function in between.

Revisions to the information contained here will continue to be made; that is the nature of adobe architecture and the long vernacular tradition to which it belongs. Please take the skills and techniques described here, follow the standard principles we recommend and make them work to suit your particular situation. Then let us know what you have learned and what you would like us to share with others. Preservation – particularly when it involves adobe – is an art as much as it is a science.

James Hare, *Executive Director*
Antonio Martinez, *Technical Coordinator*
Jean Fulton, *Preservation Programs Coordinator*
Aubry Raus, *Applied Education Director*
Pat Taylor, *Southern Program Manager*
Francisco Uviña, *Architectural/Technical Manager*

ACKNOWLEDGEMENTS

Cornerstones Community Partnerships has culled the technical information in *Adobe Conservation – a Preservation Handbook* from many sources. The most interesting and no doubt the best information has been passed down in an oral tradition from generation to generation. It is impossible to acknowledge all the communities and individuals who have contributed to this body of learning. The indigenous knowledge of earthen technologies has provided us with a repository of information that we are passing along with the deepest gratitude and appreciation to those, both here and across borders, who have taught us. Working together to conserve the earthen architecture of the Southwest and northern Mexico erases political boundaries.

The content of this handbook is the product, as well, of the collaboration of the entire staff of Cornerstones, and in particular the organization's Technical Staff, who worked diligently to review and refine information gathered in the previous edition of this work and to compile important new information. As with the first handbook, we are indebted to Francisco Uviña for the many illustrations he created to make technical information both graphically appealing and comprehensible. Cornerstones' intern, Hanna Robertson, did the initial organization for this revision, and Robyn Powell and Linda Gegick of the New Mexico Historic Preservation Division assisted with early technical edits. Jean Bowley did double duty cataloging photographs and illustrations and reviewing content for clarity and accuracy. We also owe a debt of gratitude to friends of Cornerstones who generously shared photographs for use in this publication; particularly Ed Crocker, Jim Gautier and Alexandra Ward. We would be remiss not to express our sincere appreciation to the many professional partners Cornerstones has among the staffs of the Instituto Nacional de Antropología e Historia (INAH); the International Council on Monuments and Sites (ICOMOS); the National Trust for Historic Preservation; the National Park Service; and New Mexico Historic Preservation Division, Department of Cultural Affairs.

This edition of *Adobe Conservation – a Preservation Handbook* has been made possible in part through the generous financial support of the Santa Fe Community Foundation; The Historical Society of New Mexico; the New Mexico Historic Preservation Division, Department of Cultural Affairs; and Sunstone Press. We feel it continues to be important to acknowledge the support that brought earlier versions of this project to life by again thanking Cynthia Grenfell; the Albuquerque Community Foundation; the Graham Foundation for Advanced Studies in the Fine Arts; the Lila Wallace-Reader's

Digest Community Folklife Program administered by the Fund for Folk Culture and underwritten by the Lila Wallace-Reader's Digest Fund; the McCune Charitable Foundation; the Design Program of the National Endowment for the Arts, *The Santa Fe New Mexican*; and the Eugene V. and Clare E. Thaw Charitable Trust.

Of course, it would be impossible to do the work upon which this handbook is based were it not for the constant encouragement and assistance provided by members of Cornerstones' Board of Directors, both past and present, and former staff members of the organization. We are sincerely thankful for the many generous benefactors that Cornerstones has in New Mexico and the Southwest and indeed, all across the United States, who make it possible on a daily basis for our organization to help preserve the architectural heritage and community traditions of this very special part of the world.

En contraposición a este movimiento existe un principio de permanencia, la fuerza centrípeta que evita que la inercia del cambio acabe con la civilización, manteniendo el equilibrio que permite que el movimiento cíclico de la cultura continúe. Este concepto es la tradición, cimiento sobre el que se construye toda innovación y al mismo tiempo refugio seguro y estable ante la posibilidad de que los cambios fracasen.

The concept of permanence, however, stands in opposition to this trend. It creates a cen- tripetal force that prevents the inertia of change from bringing civilization to a halt. It also maintains the balance that permits the cyclical motion of culture to continue. This concept is tradition, the foundation on which all innovation is built, and the sure and steady refuge that protects change from failure.

Luis Fernando Guerrero Baca
Arquitectura de Tierra en Mexico

Interior staircase, convento
San Esteban del Rey
Pueblo of Acoma
(Jim Gautier, 2004)

INTRODUCTION

New Mexico has one of the richest architectural histories in the United States. However, it is most celebrated not for its diversity of styles and influences, but for the continuity of its traditions. With one of the oldest building histories in the United States, ancient architectural styles still influence modern building practices and aesthetics in New Mexico.

Long before the arrival of colonists, both Europeans and indigenous peoples of Mexico, Puebloan peoples in the Southwest were building with earth. It is this ancient technique that has persisted throughout the centuries as a thread to the past. Presently, an astonishing one-third of all humans live in dwellings made of earth. In developing countries, the figure is closer to one-half. There are varying methods of earthen architecture worldwide, from *pisé* in France to *bajareque* in Costa Rica. In New Mexico, the most common method of earthen construction is sun-dried mud bricks. In Spanish this technique is referred to as adobe. Adobe as a building technique probably began in Mesopotamia over 9,000 years ago. Mud bricks were used to construct villages throughout the ancient Middle East, China, Africa, the Mediterranean and India. Egyptian hieroglyphics document early use of adobes and Biblical accounts make reference to the use of mud-bricks for construction in the ancient world. The earliest monumental building uncovered to-date in Italy, the Etruscan complex at Poggio Civitate (Murlo, Siena) was built with mud brick (Phillips: 14).

The history of the regional architectural styles covered in this handbook begins over two millennia ago, when the Basket Maker III culture began to build pit-house settlements. Over time, these rudimentary shelters evolved into the large multi-story communal buildings referred to as pueblos by the Spanish explorers. In the early 1600s, Franciscan missionaries imported their own knowledge of earthen architecture, which peoples of the Iberian Peninsula had inherited from the Moors, and most probably, the Romans and Phoenicians before them. Spanish methods of adobe construction were similar to those used by the pre-conquest pueblos. By the 16th century, however, the majority of the earthen

structures in southern Spain were modest in comparison to those being erected by the Puebloans. When the Franciscans arrived in Mexico and the American Southwest they encountered a tradition of earthen architecture that was certainly as robust as their own.

The pre-colonial architecture of the Pueblo III period in the Southwest was primarily domestic. The Spanish Franciscan missionaries spurred a new wave of architectural activity focused on religious structures of monumental proportions. They oversaw construction of immense churches and *conventos*, the majority of which were later severely damaged or destroyed during the Pueblo Revolt of 1680. A new era began after the Reconquest of 1692 as the Spanish population increased and the Spanish Crown awarded important land grants. Despite frequent attacks from Apache, Comanche, Ute, and later Navajo tribes, both Spanish/Mexican villages and Indian Pueblos flourished along the Rio Grande.

The raids significantly influenced the architecture and layout of both the Pueblos and the Spanish villages. Churches, houses, and other buildings were constructed with defensive purposes in mind. After the Reconquest, construction methods remained much the same until the invasion of the American Army in 1846. During their short reign, from 1821 to 1845, the Mexicans allowed the Santa Fe Trail to be developed. This important east-west trade route accounted for the accelerated influence of foreign architectural styles and supplies.

By the beginning of the 19th century the Franciscan presence had greatly declined, and there was a drastic shortage of priests in the region. This situation spurred the growth of *La Cofradia de Nuestro Padre Jesús Nazareno* or the *Hermanos Penitentes*, a lay brotherhood of men who took on many of the responsibilities of the absent clergy. They built small chapels called *Moradas*, and developed many devotional rituals that helped meet the religious needs of the people and keep the faith alive during the first half of the 19th century. In the 1850s the Archdiocese of Santa Fe was established, and Archbishop Jean Baptiste Lamy arrived with a large contingent of French priests to serve as pastors of parishes throughout New Mexico. The architectural changes introduced by Lamy reflected popular French Gothic styles. Many existing adobe churches were remodeled with Gothic Revival elements such as arched windows and an increased usage of stone. The introduction of new materials by the Americans facilitated Lamy's more grandiose projects, including the Cathedral of Saint Francis in Santa Fe.

The American occupation, beginning in 1848, and the Railroad Era, commencing in 1880, brought new materials and styles. Brick copings on the wall parapets appeared, and many flat roofs were pitched and covered with terne plate and later galvanized corrugated metal. Metal hinges replaced wooden pintle hinges. The American occupation also brought a growing interest in archaeological ruins and the historic structures that were in increasing danger of collapse.

In 1859, the Historical Society of New Mexico was established. Other important milestones in the field of historic preservation followed. Federal protection for archaeological sites began in 1889, and The Act for the Protection of American Antiquities was passed in 1906. John Gaw Meem, a pioneer of the historic preservation movement came to New Mexico in 1920. Meem contributed to the architectural revival, helping to establish the Committee for the Preservation and Restoration of the New Mexico Mission Churches. Meem was also one of the founders of the Old Santa Fe Association, whose stated mission was:

> To preserve and maintain the ancient landmarks, historical structures and traditions of Old Santa Fe; to guide its growth and development in such a way as to sacrifice as little as possible of that unique charm, born of age, tradition and environment which are the priceless assets and heritage of Old Santa Fe.
>
> (Chauvenet: 21)

Over the past century, significant charters have been established, setting an international standard for the conservation, preservation and restoration of historic structures. The Athens Charter in 1931 established for the first time that each country is responsible for applying principles of preservation according to its own culture and traditions. The Venice Charter of 1964 expanded upon the Athens Charter to acknowledge the significance of not only the historic structure itself but also the setting in which the structure exists. In doing this, the Venice Charter established the principle that historic structures are both historical evidence and works of art, and also affirmed the importance of the preservation of original fabric and the use of traditional building techniques.

The growth of interest in historic preservation and the emergence of the Spanish-Pueblo Revival style were accompanied by a desire to give traditional adobe structures a greater sense of permanence. In the 1930s concrete and cement plaster became the materials of choice to preserve the unique style of adobe buildings and prevent further deterioration. As economic opportunities encouraged emigration of the younger generation from New Mexican villages, the older population was left behind to care for their homes and churches. Because adobe structures needed regular and frequent care, the elders in these communities were quick to adopt seemingly more durable materials like cement plaster in order to extend the maintenance cycle demanded by traditional mud plasters. Though done in good faith, the application of impervious cement was disastrous for many structures. It forced adobe walls to retain any moisture that penetrated behind the substrate. Unable to "breathe" they accumulated moisture until structural stability was lost.

It has not been until recently that the young people who moved away in the 1940s, 50s and 60s began returning to their native towns and villages. Often, they found churches and homes that were in severe disrepair or, in the worst cases, already collapsed or demolished. In 1986, Cornerstones Community Partnerships, an organization initiated by the New Mexico Community Foundation and known initially as *Churches: Symbols of Community*, received funding to survey and document the historic churches of New Mexico. This investigation, which was a joint project with the New Mexico Historic Preservation Division (the NM State Historic Preservation Office) revealed that 684 historic religious structures existed statewide, of which 363 were constructed of adobe. With the baseline information collected in the survey, Cornerstones began to assist communities in the restoration and conservation of their historic churches. Cornerstones continues to assist communities in carrying on the traditions of their ancestors in the care and maintenance of historic vernacular structures central to community life.

In *Arquitectura de Tierra en Mexico,* Luis Fernando Guerrero discusses the importance of vernacular architecture and its tradition worldwide. We see these principles alive in the commu-

Cañoncito de la Cueva in the Mora Valley of northern New Mexico before and after preservation by the community and Cornerstones Community Partnerships.
Photo left: Cornerstones archives; right, Francisco Uviña (1998)

nities of New Mexico. Structures are built out of necessity with local materials, expressing a unity with the surrounding environment. Builders are most often anonymous community members who have learned their knowledge from past generations. They create unique structures that are harmonious with an aesthetic that has been established by the community.

Most importantly, perhaps, is the way vernacular architecture evolves organically without adopting any pre-established formalities of design. In this way, the community considers vernacular architecture to be a symbolic expression of the continuity of tradition.

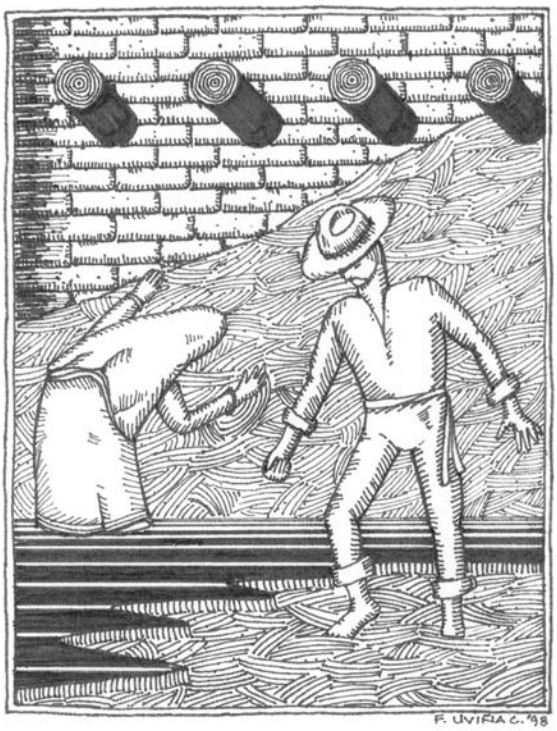
The purpose of this handbook is to provide access to the knowledge of traditional and contemporary techniques for use in the care and maintenance of historic adobe structures. It is written for *mayordomos* (lay church caretakers), community members, volunteers, contractors and preservationists who assist in the maintenance and conservation of their buildings. It encourages the revival of traditional methods of construction, some extinct and others on the verge of disappearing. Self-explanatory graphics and photographs are used to demonstrate the various techniques of adobe conservation. The sections are structured to give the reader a basic understanding of why many adobe buildings are threatened and how they can be preserved, restored and maintained for future generations.

These technologies are vital to preserving important symbols of New Mexico's culture and traditions. Many of the traditional techniques illustrated herein have been locally forgotten. It is our hope that this manual will help to sustain interest in the use of such methods in both conservation and new construction for the survival of an extraordinary architectural heritage and a distinctive cultural landscape.

En efecto, la mayor parte de la arquitectura del mundo está constituída por edificios de pequeñas proporciones, construídos con un mínimo de recursos, destinados principalmente a vivienda o trabajo y creados con las propias manos del usuario o su comunidad. Estas obras, además de ser magníficas respuestas morfofuncionales a las necesidades locales, encierran en cada rincón rastros de la sabiduría milenaria que es productor de ensayos y errores ancestrales, en un esfuerzo de adaptación a un medio ambiente adverso y hostil

In fact, most of the architecture in the world consists of small buildings that are constructed with a minimum of resources. They are destined primarily for work or domestic use and are created by the hands of the users or their communities. Magnificent responses to diverse local needs, these structures capture, in every nook and cranny, traces of age-old wisdom, and the results of the trials and errors of preceeding generations attempting to adapt to an adverse and hostile environment.

Luis Fernando Guerrero Baca
Arquitectura de Tierra en Mexico



PART ONE

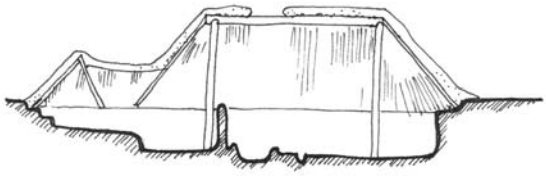
TERMINOLOGY AND TOOLS

ARCHITECTURAL STYLES AND MATERIALS

Anasazi and Ancestral Puebloan Architecture

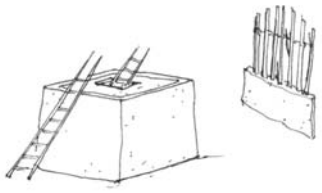
Basket Maker III, 350 to 700 A.D.

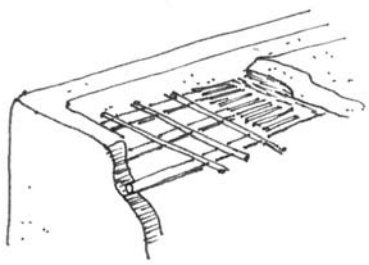
Early Basket Makers did not make pottery, but as their name implies, were excellent basket weavers. Their predecessors lived mostly in caves and natural rock shelters during the period known as Basket Maker II, however, a significant change occurred around the year 350 A.D., at which time a knowledge of agriculture and the pottery making was acquired. This period, known as Basket Maker III, was also characterized by the development of an architectural form referred to as the 'Pit House'. Pit houses were subterranean and semi-subterranean constructions of square or circular shape. They featured earth roofs that were supported on a framework of slender poles.



Pueblo I Period, 700 to 900 A.D.

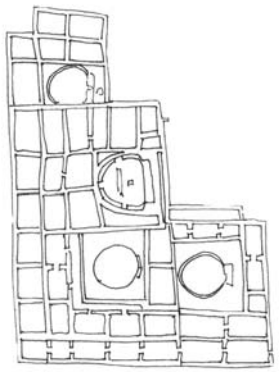
For the most part, buildings of this period were erected above ground. Early Pueblo I peoples used *jacál* construction—a technique of infilling woven vertical wood posts with mud. Single room units were sometimes joined into a series of blocks. In addition to *jacal*, wattle-and-daub and stone laid with mud mortar were other construction methods used during this period. Roofs were constructed of continuous poles covered with brush and earth.





Pueblo II Period, 900 to 1050 A.D.

During this period, most pueblos were constructed of stone masonry and hand-molded adobes. The *kiva*, a ceremonial chamber, became a standard feature. Units

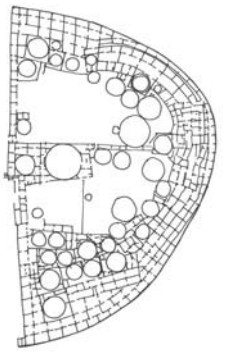


Timeline

A.D. 1 to 350	350	700	900	1050	1350
Basket Maker II period.	*Initiation of the Basket Maker III period.*	*Initiation of the Pueblo I period.*	*Initiation of the Pueblo II period.*	*Initiation of the Pueblo III period.*	*Initiation of the Pueblo IV period.*

were grouped together on all sides and were built in multiple stories. Lower level units were often storage spaces.

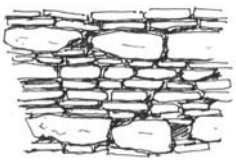
Jacál construction was still used, though principally for storage structures. Roof construction remained basically the same as that used by the Pueblo I peoples.



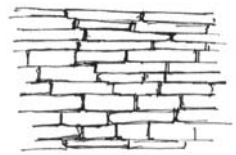
Pueblo III, 1050 to 1300 A.D.

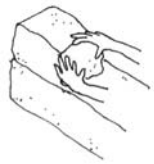
Archaeologists have generally considered Pueblo III to be the 'classic' period of Anasazi architecture. Buildings of this period, the remains of which are concentrated in the Four Corners area of New Mexico, Colorado, Arizona and Utah, became larger and were frequently fortified. Very large, or 'great' *kivas* are characteristic of the period. Stone masonry, earthen architecture and stone tool methodologies became highly refined as did engineered solutions to irrigation and water storage. Some Pueblos were four stories tall, the walls being three feet thick at the base narrowing to one foot on upper stories.

Three examples of stone masonry construction used in Pueblo Bonito at Chaco Canyon, New Mexico are illustrated to the right. At Chaco, stones were either laid dry or set in mud mortar.



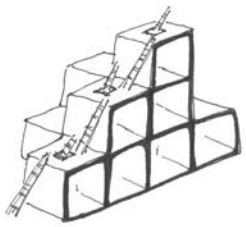
In addition to stone masonry, 'puddled adobe' was also a common method of earthen construction during the Pueblo III period onward. Builders laid and shaped bands of puddled earth in rows by hand. In New Mexico, a pueblo known as Mariana Mesa, which was occupied from 1150 to 1300 A.D., features some of the most well-preserved, hand-molded, pre-Spanish adobe bricks in the Southwest.





Pueblo IV, 1350 to around 1700 A.D.

During the 1300s, a period of drought, social unrest, and migration of nomadic groups encouraged the establishment of riverine settlements. The period was one of cultural evolution, cross-cultural contact and dramatic population shifts. A number of pueblos that have survived until the present day were established at this time.



Architecturally, Pueblo I construction methods, such as those demonstrated at Paquimé in northern Mexico around 1250 A.D., continued to be employed. During this period, pueblos were constructed by building units stacked in irregular pyramidal forms organized around internal plazas or that featured encircling walls for protection.

Contrary to the popular belief that the Spanish introduced molded adobe bricks to the Pueblo people, archaeologists have recently discovered 14th century form-molded adobe bricks at a site near the Arizona/New Mexico border. This discovery proves that Pueblo communities already used form-molded technology before the period of European contact. Forms use by the

1492
Columbus' first expedition to the New World.

1519
Cortés invades Mexico.

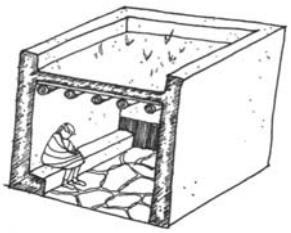
1539
Fray Marcos de Niza and his scout, Estévan the Moor (Estevánico), lead an entrada*, or expedition, into New Mexico.*

1540-42
Coronado explores New Mexico and the Southwest.

1573
The Ordinances of Discovery, also known as the Laws of the Indies, are promulgated by the Spanish Crown to govern the establishment of new cities and towns throughout the Spanish empire.

1581
Rodríguez/ Chamuscado entrada *into New Mexico.*

Pueblo people, however, were not constructed with wood or metal; rather, they were dug into the ground. Housing units during this period lacked furniture, as we know it, but in many cases had built-in *bancos* (benches). Generally, interiors were mud plastered and walls were finished with a light colored earth or whitewash and a dark earth dado. Floors were earthen. Common features of the period were corner fireplaces, clay pot chimneys and piki bread ovens.



Corner fireplaces (left) and clay pot chimney

Pueblo V, 1700 to recent times

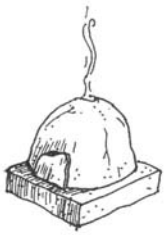
During the twelve years following the Pueblo Revolt of 1680, many communities were abandoned. Out of fear of Spanish reprisals, the inhabitants of some pueblos fled to high, inaccessible areas. After the Spanish Reconquest of 1692, some abandoned pre-revolt pueblos were reconstructed using Spanish-influenced methods of construction.

The common trade route during this period linking New Spain's colonial capital in Mexico with the frontier towns of the north was the *Camino Real de Tierra Adentro*—the Royal Road of the Interior. The *Camino Real* was well established in New Mexico by the end of the Pueblo IV period, and gained wider use after the Spanish Reconquest. It remained in use until late in the 19th century. The trail passes through many New Mexican pueblos and was the primary route of the Franciscan friars who brought the Catholic religious and mission architecture to the Pueblos.

Spanish Colonial Architecture, 1539-1821

The Spanish brought with them new tools and architectural ideas. With the introduction of metal tools, local communities were able to further modify their buildings. This influence was especially evident in the introduction of finely carved windows, corbels, and doors.

During the pre-revolt decades, the Spanish introduced simple stone footings, outdoor baking ovens borrowed from the Moors, and the corner fireplace or *fogón*. The Spanish colonists also standardized the use of form-molded adobes by introducing wooden adobe forms. They also reintroduced selenite use for windows. Some evidence suggests that selenite was used during the Pueblo III period but had fallen into disuse by the time of the Spanish invasion. Clerestories built during this period to illuminate the altars of mission churches utilized selenite material as window glazing. The mission churches built by Franciscan friars were the most monumental architectural contribution made by the Spanish before the rebellion of 1680. Although most of these churches were destroyed during the rebellion, elements of scale and pro-



1598
Don Juán de Oñate leads an entrada *into New Mexico and begins the construction of a church, San Juan de los Caballeros, at San Juan Pueblo before relocating to nearby San Gabriel.*

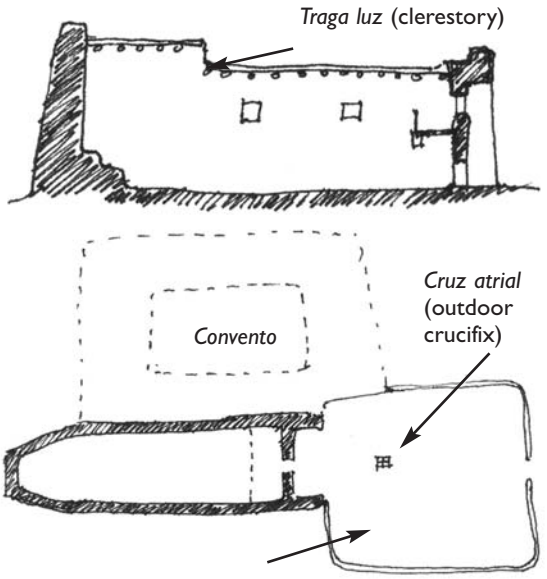
1610
Spanish abandon San Gabriel and establish Santa Fé as the seat of government.

1629
Thirty-three conventos and 150 churches and chapels are documented in New Mexico.

1644
The great mission church of San Esteban del Rey is completed at Acoma Pueblo.

1680
Pueblo Revolt. The Spanish are expelled from New Mexico. They and many Christianized Indians relocate to El Paso del Norte (Ciudad Juaréz, Mexico). Most of the churches that were built after Oñate's expedition are severely damaged or destroyed during the Pueblo Revolt.

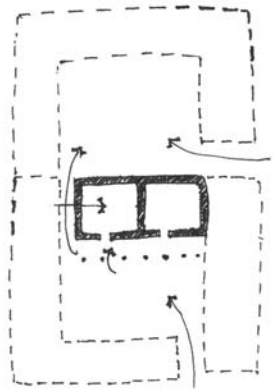
portion based on European Renaissance principles are apparent in the remaining great buildings of the period, most notably Acoma Pueblo's great mission, San Esteban del Rey.

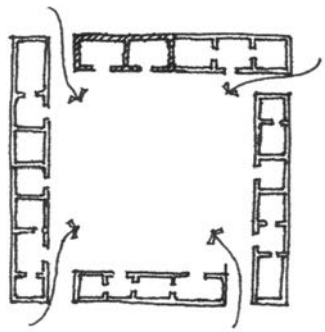


Camposantos/cemeteries were introduced to bury the dead within church grounds

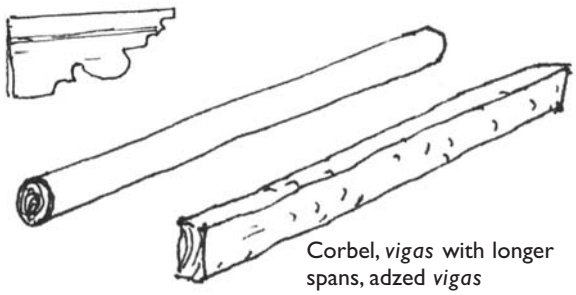
The post-rebellion period saw even greater changes for local communities and the appearance of architectural details that persist today. Spaniards introduced squared, hand-adzed roof beams and cabinetwork, as well as free-standing furniture. *Jacál* or wattle and daub construction was also used to house stables close to the home, as livestock became more integrated to the domestic compound. Pintled wooden shutters now covered door and window openings.

In contrast to the irregular, stacked form of pueblo architecture, Spanish colonial floor plans were only one room deep in a single file. Spanish towns took the form of enclosed and fortified compounds surrounding interior plazas. Typically, a large gate gave access to an interior covered portico known as a *zaguán*. Domestic structures were predominantly one story with the exception of the *torreón* – a two-story tower used for defensive purposes.





It is important to note that Spanish influence did not completely destroy the Pueblo peoples' spatial concepts. "Today the Pueblos still represent the most persistent architectural heritage in North America" (Nabokov & Easton: 353).



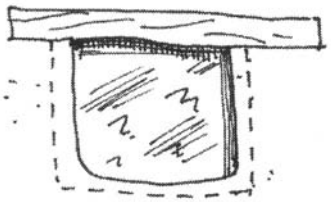
Corbel, *vigas* with longer spans, adzed *vigas*

Bell-shaped *fogón*

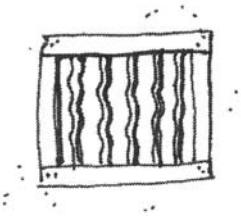
Interior walls have *jaspe* (whitewash) finish over mud plaster and earth floors are sealed with animal blood

1692-93	1698	1700	1710	1730	1760	1771
De Vargas re-conquers the region.	*Rebuilding of churches begins. There are approximately 1,000 Spaniards and 25,000 Indians in New Mexico.*	*Initiation of the Pueblo V period.*	*The chapel of San Miguel in Santa Fe's Barrio de Analco is rebuilt.*	*Bishop Benito Crespo makes an Episcopal visit to New Mexico.*	*Bishop Pedro Tamarón y Romeral makes an Episcopal visit to New Mexico.*	*Domínguez and Escalante search for a route to California.*

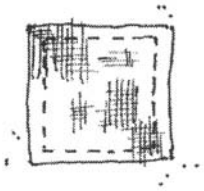
TYPICAL SPANISH ARCHITECTURAL FEATURES



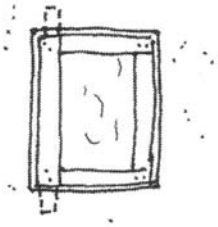
Translucent selenite slabs embedded in masonry to enable entry of light



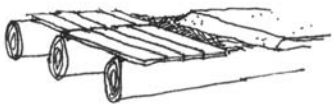
Rejas (wooden grills)



Wooden frame with a *lienzo* or *manta* (cotton cloth covering)

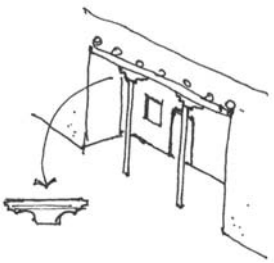


Pintle casement window



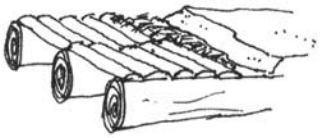
Tablas (adzed boards) decking was used for the *sala* (room of most importance)

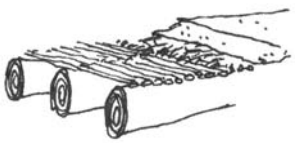
Zapatas were used to support portal beam



Colonial style *portals* were narrow porches, supported at intervals, and extended along one side of the building or around the entire plaza or interior courtyard.

Rajas or *cedros* (split wood decking)

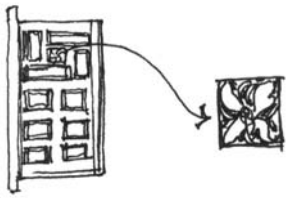




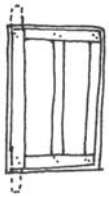
Latillas or *sabinos* (small round pole decking)

Solid doors were later replaced with divided panels with spindles for ventilation. This type was mainly used in wall cupboards.

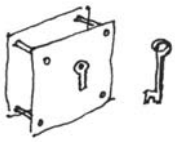
Portón (two large gates with smaller cut out door) leading to the *placita* in a *hacienda*



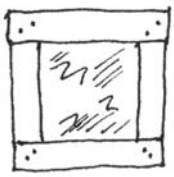
Door designs incorporated 17th century Baroque joinery from Spain and show the influence of the Moors.



Zambullo (pintle door) with adzed panels



Metal locks are occasionally seen.



Heavy wood frame around a selinite slab

1776
Domínguez of Mexico City reports on the church buildings in New Mexico. He records 8,000 Pueblo Indians and 10,261 Spaniards living in communities where friars are active.

1786
De Anza's treaty ends Comanche attacks on the Spanish and Pueblos, greatly increases the security of villages established beyond the Rio Grandé valley.

1816
War of Mexican Independence erupts.

1821
Treaty of Córdova recognizes Mexico's Independence from Spain, and the Santa Fe Trail opens commerce with the United States.

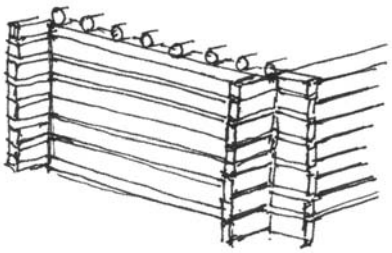
1816-46
Mexican Period

Architecture of the American Period

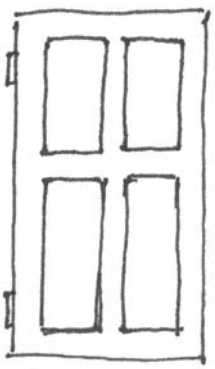
Early Territorial Period (1848-1865)

The Territorial Style was introduced in New Mexico with the American acquisition of the region in 1848. Architecturally, the Territorial Style was a western frontier interpretation of the popular Greek Revival used in the Eastern United States. Interestingly, the Territorial Style did not come into vogue in New Mexico until after the Civil War, at which point the Greek Revival in the East had already diminished in popularity. Because other materials were scarce, adobe was widely used for construction during this period.

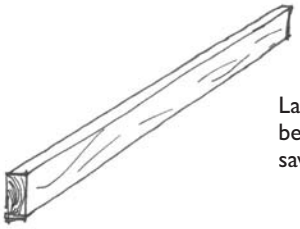
TYPICAL EARLY TERRITORIAL ARCHITECTURAL FEATURES



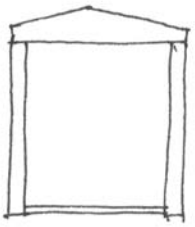
Log structures were constructed in higher elevations and were used for grist mills, barns and storage by the Spanish. This practice continued through the American period



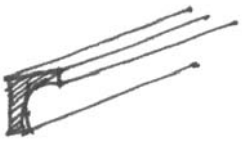
Taller doors appeared with metal hinges



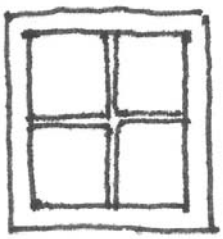
Larger spans of lumber became possible because of sawmills



Simple pedimented lintels were employed over doors and windows with wood trim



Wood moldings painted white imitated the eastern Greek Revival.



Windows were constructed with manufactured glazing (glass)

Heavy posts, chamfered and squared at the corners, were used for portals.

1836
Church hierarchy recognizes Mexico's Independence.

1840
A lack of friars and priests in the region contributes to the development of a distinctive form of New Mexican folk Catholicism.

1846
Kearney invades New Mexico with the Army of the American West.

1848-65
Early Territorial Period

1848
The U.S. Army sets up a sawmill in Santa Fe.

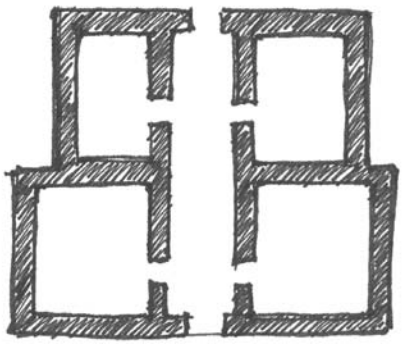
1850
Archbishop Lamy is appointed the first bishop of the New Mexico Territory. An estimated 36,000 Anglo Americans are living in New Mexico.

Middle Territorial Period (1865-1880)

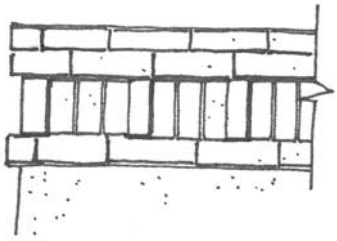
The typical floor plan for houses of this period changed from the linear Spanish footprint to a symmetrical layout organized around a central hall, and with more complex spatial orientation. Centralized and composed façades were introduced and many older houses were renovated to conform to new design ideals.

Fired bricks were not manufactured in New Mexico until the 1860s. Up until then bricks had been transported from the Midwest via the Santa Fe Trail. Bricks were important for design detail and were used to imitate the crown of a cornice and to protect the tops of adobe parapets from erosion. Bricks were laid to project from the plane of the wall in an alternating pattern that simulated the dentil ornamentation associated with the Greek Revival.

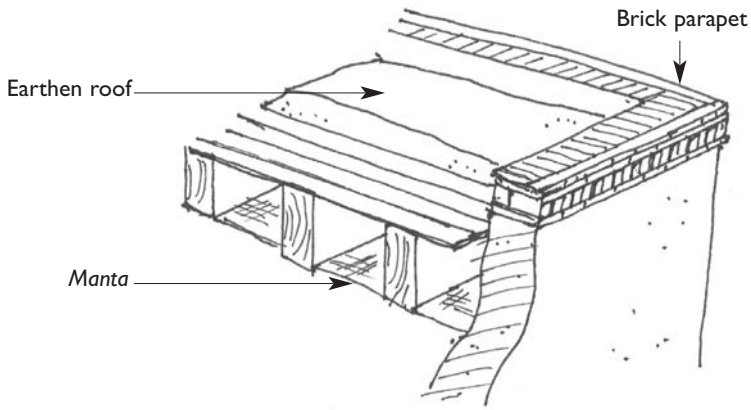
The material of choice for walls, floors and roofs continued to be earth. The use of earth on roofs, however, resulted in dust and dirt sifting through the decking. To eliminate this problem, a *manta* (cloth) painted with a mixture of flour and water was sometimes attached to the underside of the wood roof beams. The manta shrank tight to resemble a flat plaster ceiling.



Central hall floor plan



Brick parapet (detail)



1851
Sawmills are established in several areas in the territory. Lamy arrives in New Mexico. Fort Union is constructed with Greek Revival (Territorial Style) details.

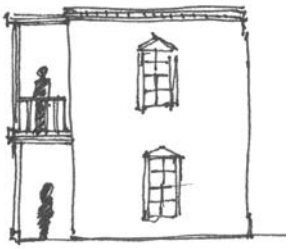
1852
Sisters of Loretto establish Loretto Academy in Santa Fe.

1853
The Gadsden Purchase results in the acquisition from Mexico of a vast tract of desert land in southern New Mexico.

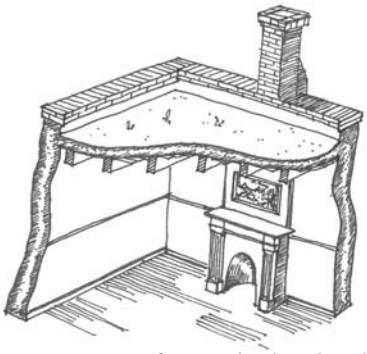
1860
The population of New Mexico increases to 93,516.

1861
Outbreak of the U.S. Civil War.

TYPICAL MIDDLE TERRITORIAL ARCHITECTURAL FEATURES



The roofs and decks for the two-story portals were often supported by chamfered posts



Fireplaces were more frequently placed in the center of a wall rather than in the corner

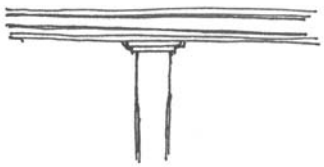
Double hung windows became more common

Interior shutters and exterior blinds were frequently used

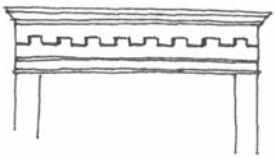
Pediments were constructed of heavier moldings over windows and doors

Doors were made more elaborate with sidelights and transoms

Paneled doors came from the Midwest and East, where they were commercially manufactured

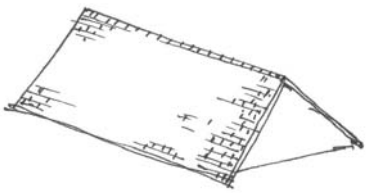


Heavier horizontal moldings

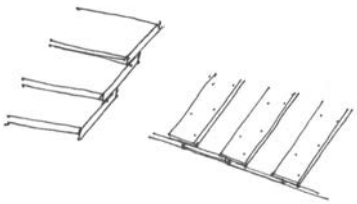


Wood dentil ornamentation was frequently added to wooden entablatures

Pitched shingle and ternplate (an alloy of lead and tin) roofs were used on more important buildings



In northern New Mexico, board and board-and-batten roofs were commonly used



1863
The Navajos are defeated and forced onto a reservation near Fort Sumner.

1865
Civil War ends. Sisters of Charity establish a hospital and orphanage in Santa Fe. The remodeling of churches with "Folk Gothic" forms and details begins in earnest.

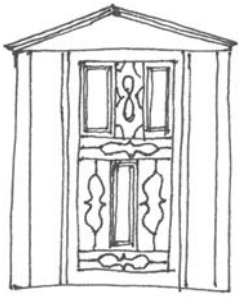
1869
Lamy begins construction of the Cathedral of St. Francis in Santa Fe around the Spanish Colonial parroquia*, which he systematically dismantles. French and Italian stone masons arrive in New Mexico.*

1879
The AT&SF Railway reaches Las Vegas, NM. Wholesale importation of materials, styles, and building experts from the East and Midwest begins.

1880-1912
Late Territorial Period

The Railroad Era and Late Territorial Period (1880-1920)

The arrival of the railroad in New Mexico resulted in the rapid introduction of a range of new and often mass-produced building materials. Towns with access to the railroad were the most impacted by this development. Pressed metal, cast-iron products, corrugated tin, factory-made wood products, brick in a variety of colors and sizes, cement, and eventually fixtures of all types began to appear.



During this period a popular regional building style emerged in isolated rural areas of New Mexico. It was based on the combination of classical details combined with folk art elements, and resulted in an wide variety of decorative patterns and designs.

The following architectural styles eventually combined to form the New Mexican Vernacular style.

Gothic Revival (1860-1910)

The influence of French immigrants became prominent after Jean Baptiste Lamy was given responsibility for ecclesiastical reform of the Catholic Church in the territory. Ecclesiastic art and architecture reflected Gothic Revival and Romanesque Revival styles then popular in Europe, England and the United States.

Gothic wood elements were typically added to elaborate, or even disguise the simple original form of adobe walls and towers. These elements included pointed arches, pinnacles and turrets, as well as the addition of rose windows and verandas. In the 1860s and 1870s, Lamy, now the archbishop, imported builders from France and Italy to construct large stone masonry churches.

St. Augustine's Church at Isleta Pueblo, pictured above, was built in 1629. The building was "Gothicized" about 1880.

Italianate (1840s-1880s)

Window arches and elaborate ornamental brackets of wood or metal are the most prominent features of the Italianate style. Ceilings were built higher to emphasize vertical proportions. Over-scaled brackets supported broad overhanging cornices above windows. By the late 1880s, the Italianate style was eclipsed by the Richardsonian Romanesque style and the late-19th century Romanesque Revival.

Second Empire (1852-1880)

High mansard roofs with dormer windows characterized the Second Empire style, which took its name from the reign of Napoleon III in France. Buildings erected in this style were imposing and bold, and were often adorned with chimneys that boasted classical detailing.

Queen Anne (1886-1900)

In general, this style was more picturesque and usually organized around an asymmetrical floor plan. Materials were freely used in a variety of combinations to produce decorative wall sur-

1906
Edgar Lee Hewett drafts the Antiquities Act. Subsequent passage of the act by Congress authorizes the President of the United States to declare monuments on federal lands.

1915
The New Mexico Building at San Diego's Panama-California Exposition popularizes Spanish-Pueblo Revival architecture and the use of non-traditional building materials. L. Bradford Prince publishes Spanish Mission Churches of New Mexico.

1920
John Gaw Meem arrives in New Mexico.

1931
The Athens Charter establishes the precept that each country is responsible for the application of preservation principles according to their specific culture and traditions.

faces. Roofs were steeply pitched and bay windows were common.

Classical Revival (1890s-1940s)

This style was used frequently for public (and particularly federally-funded buildings) during the first half of the 20th century. The predominant characteristics of the style were porticos with pediments, and windows and doorways surmounted by prominent lintels that were designed based on ancient Roman systems of proportion.

Mission Revival (1900s-1930s)

This style, a subset of the Spanish Colonial Revival that enjoyed popularity during the first third of the 20th century, was frequently employed in New Mexico for railway stations. The style features arches, low-pitched tiled roofs, curvilinear gables, and stuccoed walls that are recognized by their lack of ornamentation.

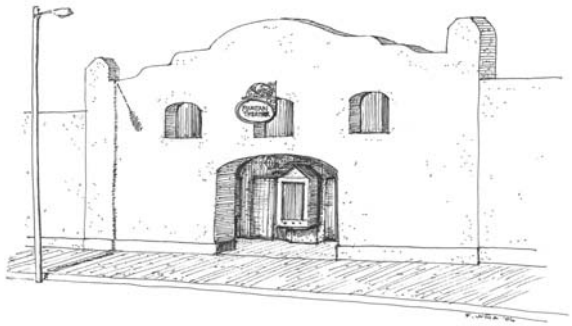
Spanish-Pueblo Revival (1908-1945)

The pueblo style persisted in New Mexico as the most common building style throughout the 19th and early 20th centuries. Some historically significant buildings, most prominently Santa Fe's venerable Palace of the Governors, that had acquired Victorian details were altered to reflect what was thought to be their original early Spanish Colonial or Pueblo style.

The Pueblo-Spanish Revival quickly caught on as a regional trend. This style is characterized by large adobe, tile or concrete brick walls, projecting *vigas*, rounded parapets, *canales*, and exposed wood lintels.

New Mexico Vernacular (1830-1930)

This architectural form is a melting pot of the styles and types employed in New Mexico. The structures are most often built of local materials and frequently reflect Territorial, Queen Anne, Gothic Revival and others stylistic influences.



The Fountain Theater, in Mesilla, N.M. blends elements of Mission Revial and Spanish-Pueblo Revival styles. The theater was constructed by 1905.

Rancho de Chimayo in Chimayo, N.M., probably constructed between 1893-1906, is an excellent example of the New Mexico Vernacular style.

1932
The Society for the Preservation and Restoration of New Mexico Churches is incorporated.

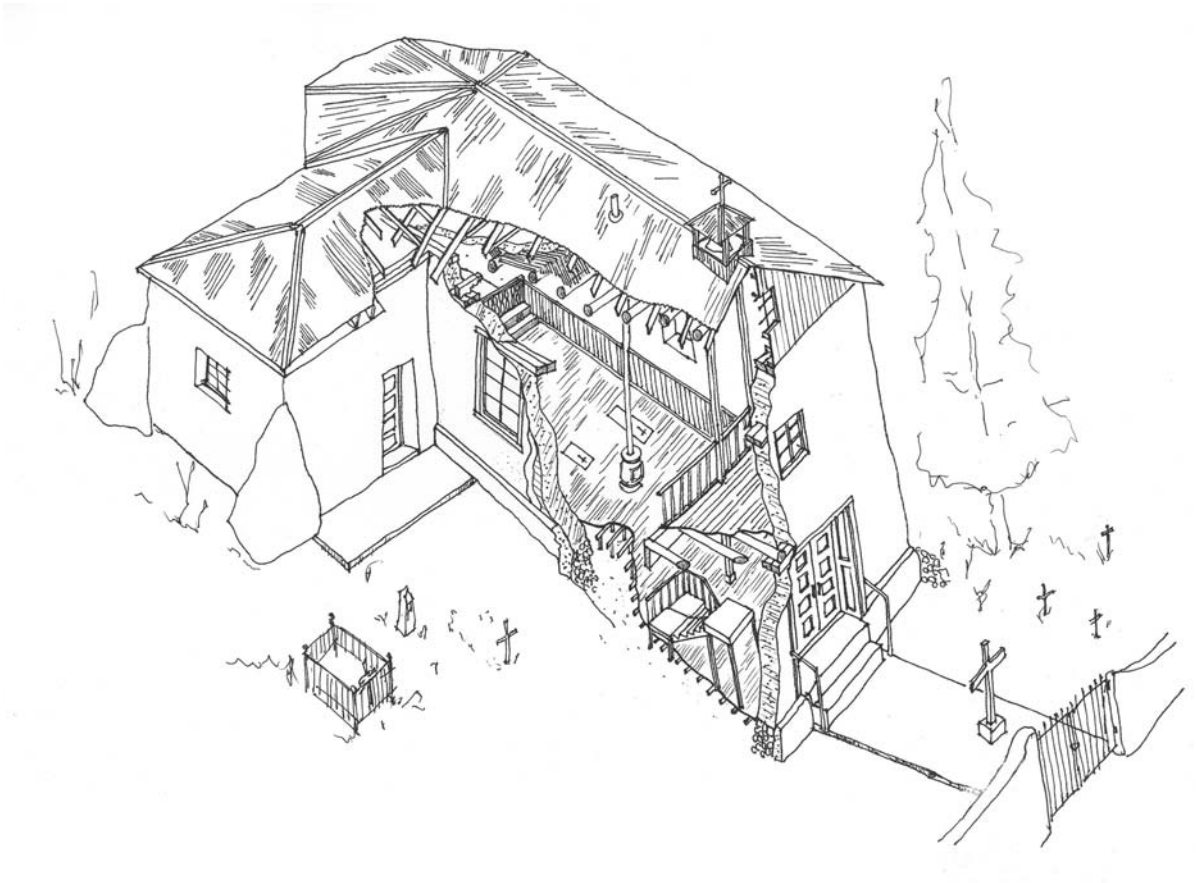
1964
Venice Charter elevates the significance of the setting, whether urban or rural, of historic monuments, including that of "modest works of the past which have acquired cultural significance with the passing of time".

1966
United States passes the National Historic Preservation Act (NHPA)

1976
ICOMOS creates the International Committee for Vernacular Architecture

1986
The predecessor organization of Cornerstones Community Partnerships is launched as "Churches-Symbols of Community" in cooperation with the New Mexico Community Foundation.

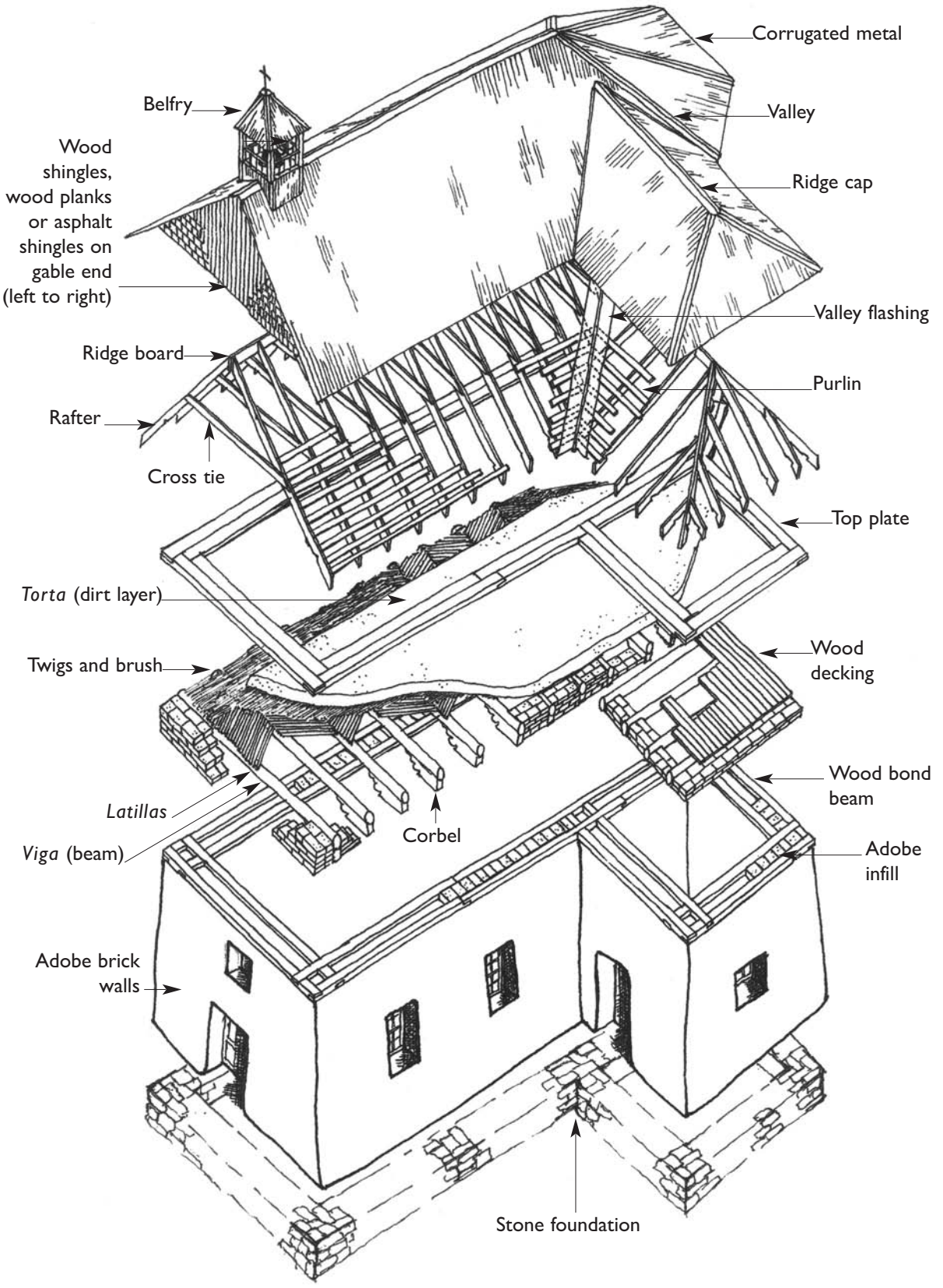
ARCHITECTURAL TERMINOLOGY



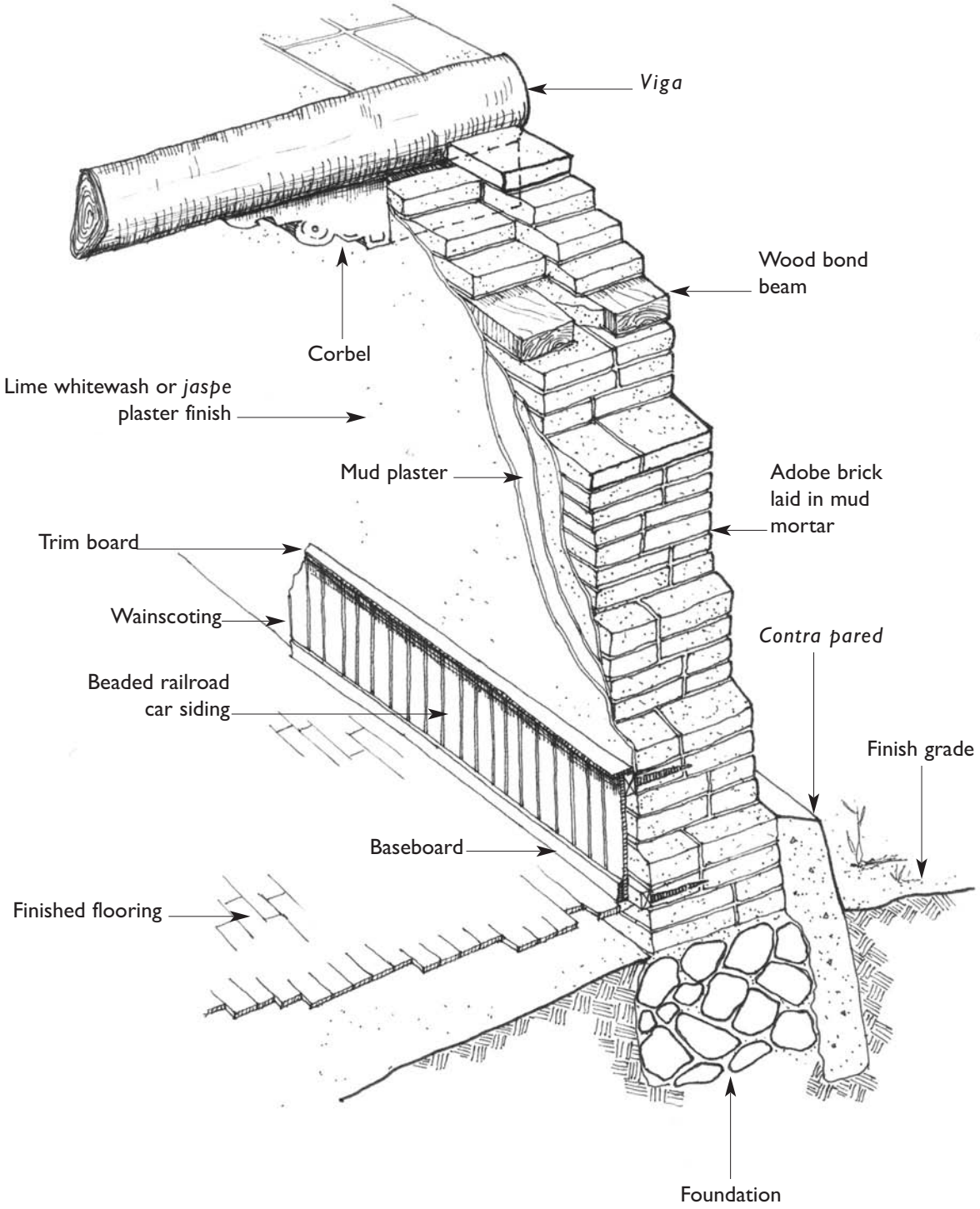
This section is intended to give the reader a better knowledge of the common architectural terms used for many buildings found in New Mexico and the Southwest. Examples of architectural features from the preceding section of this handbook are identified here in detail. Most of these features are depicted in photographs and drawings found in many parts of this handbook. It also answers questions about certain architectural elements referred to in subsequent sections. Buildings described by the term vernacular may display details from a variety of architectural styles. These details are often combined randomly and indiscriminately, expressing various tastes, time periods, and the materials that were available when a building was constructed.

The distinctive architectural details that appear in many of the vernacular buildings in the Southwest are vital reflections of the history of the structures and their locations. Architectural details should be safeguarded during repairs and construction and must be preserved and repaired whenever possible, rather than replaced.

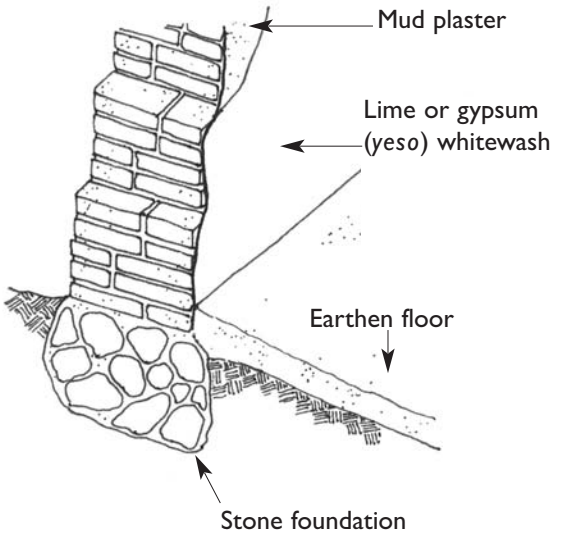
GENERAL BUILDING TERMS



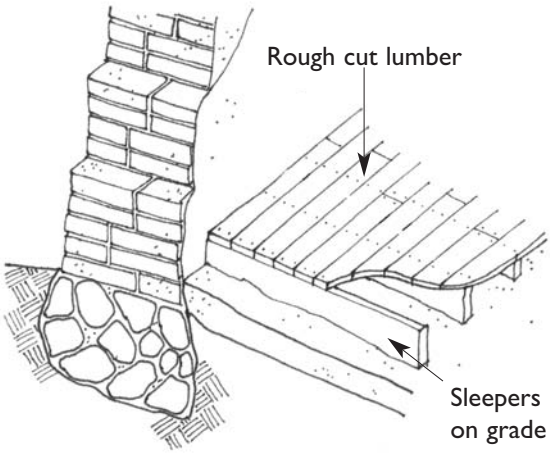
TYPICAL WALL CONSTRUCTION



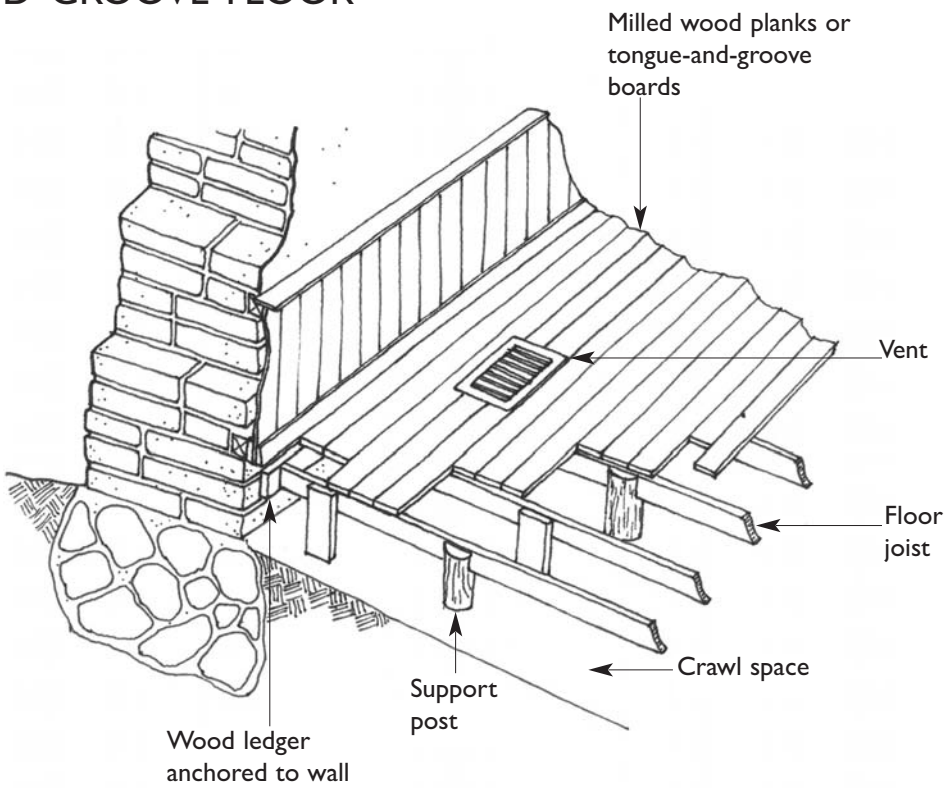
DIRT FLOOR



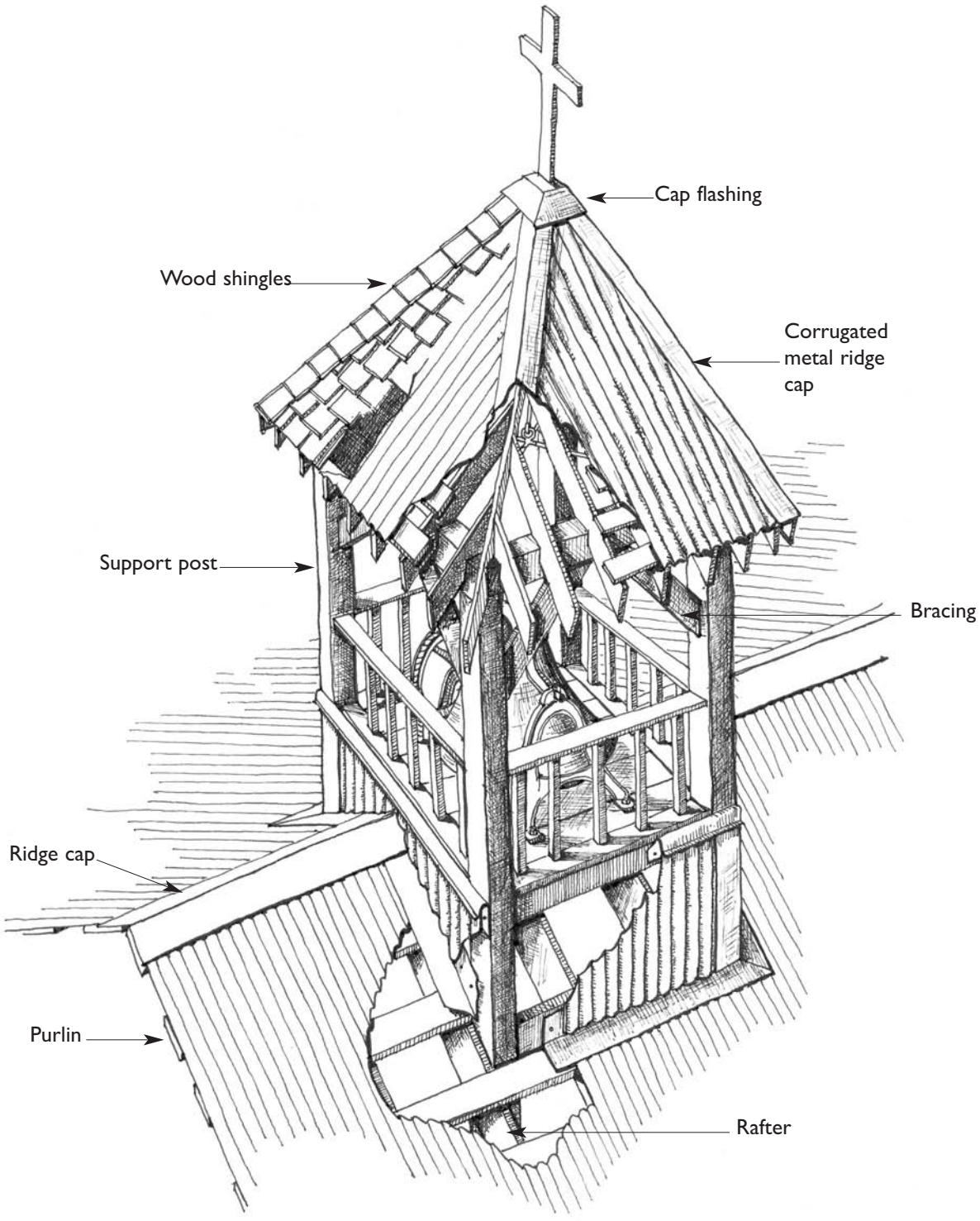
ROUGH CUT WOOD FLOOR



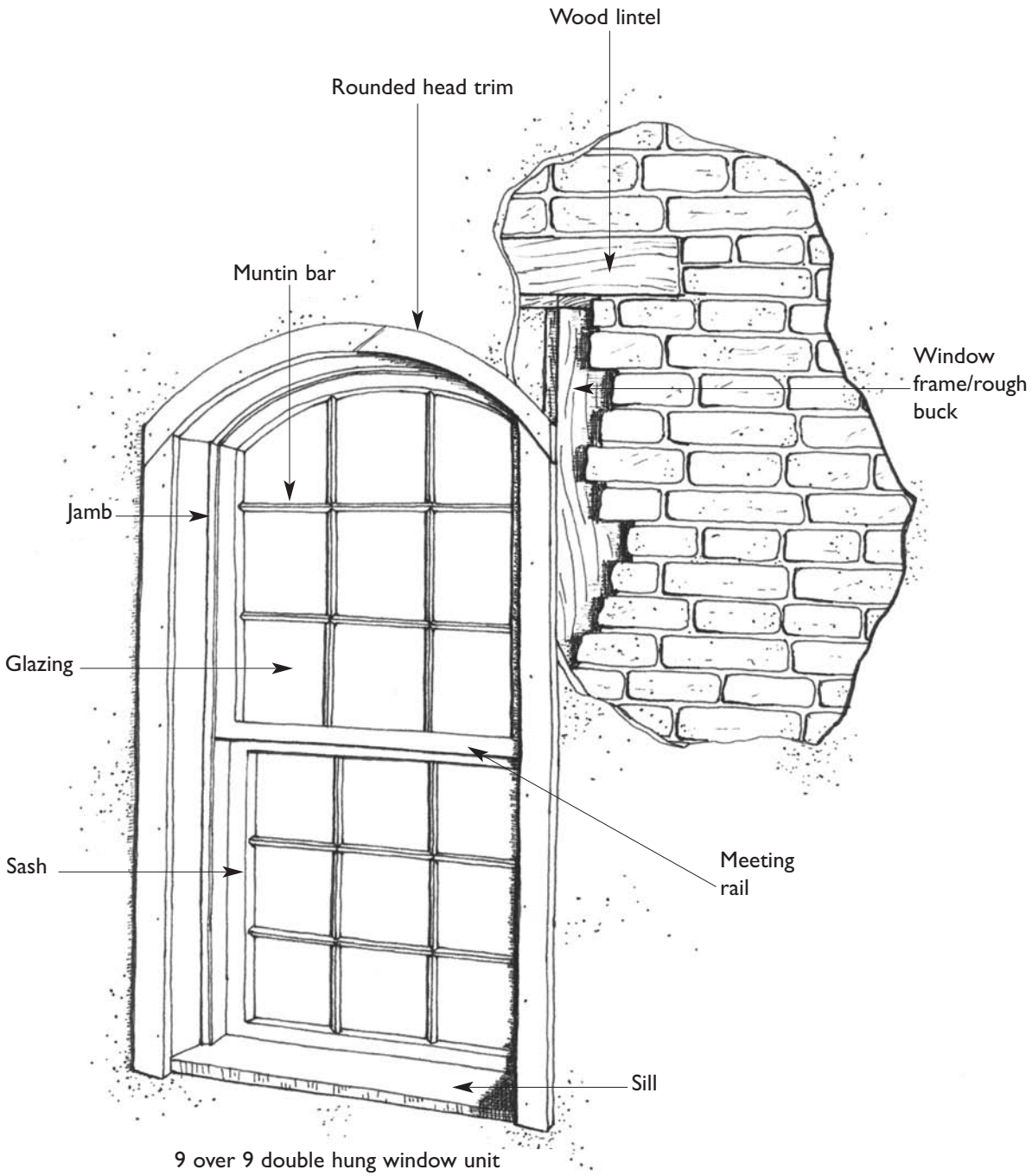
TYPICAL WOOD PLANK OR TONGUE-AND-GROOVE FLOOR



BELFRY CONSTRUCTION

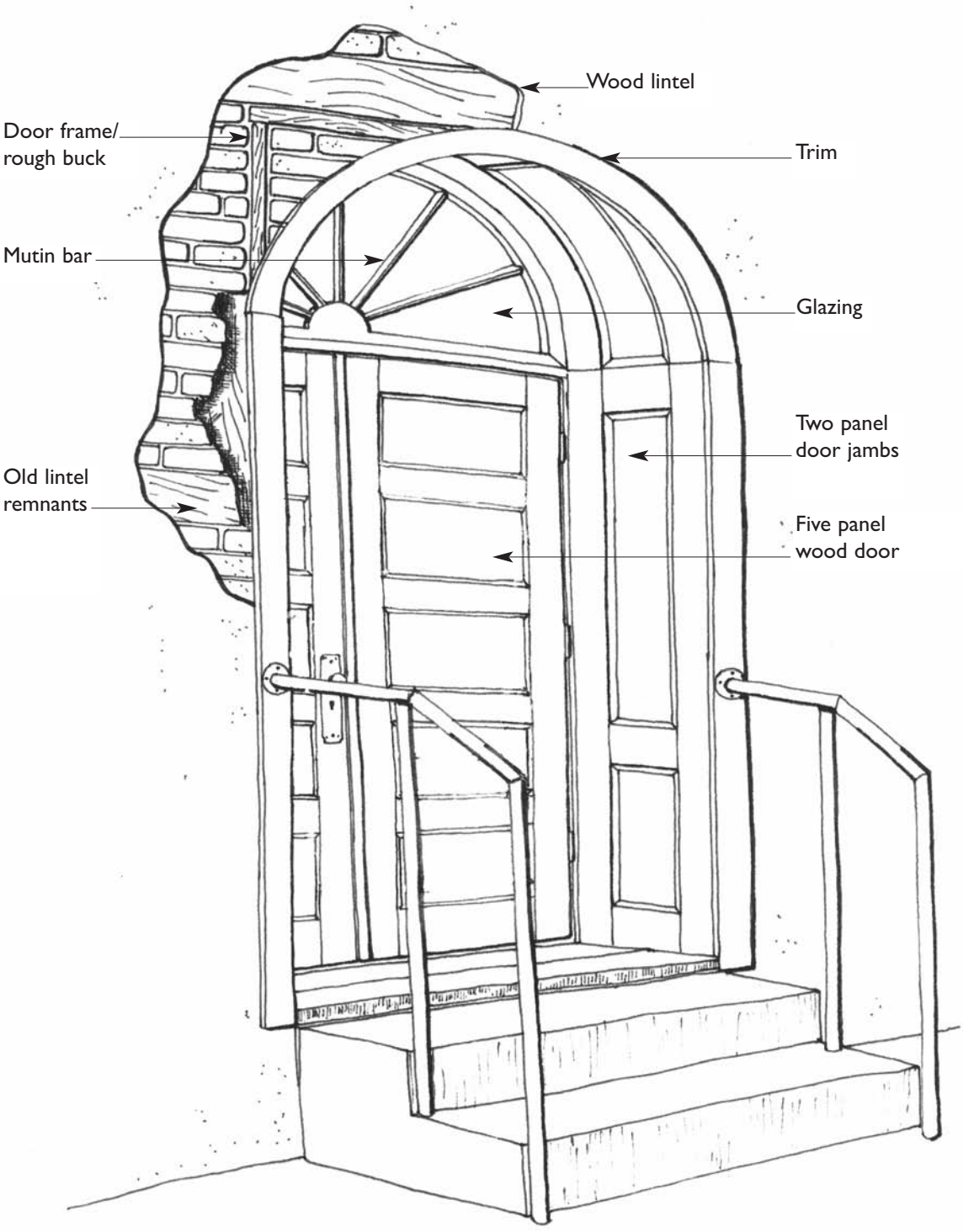


WINDOW TERMINOLOGY

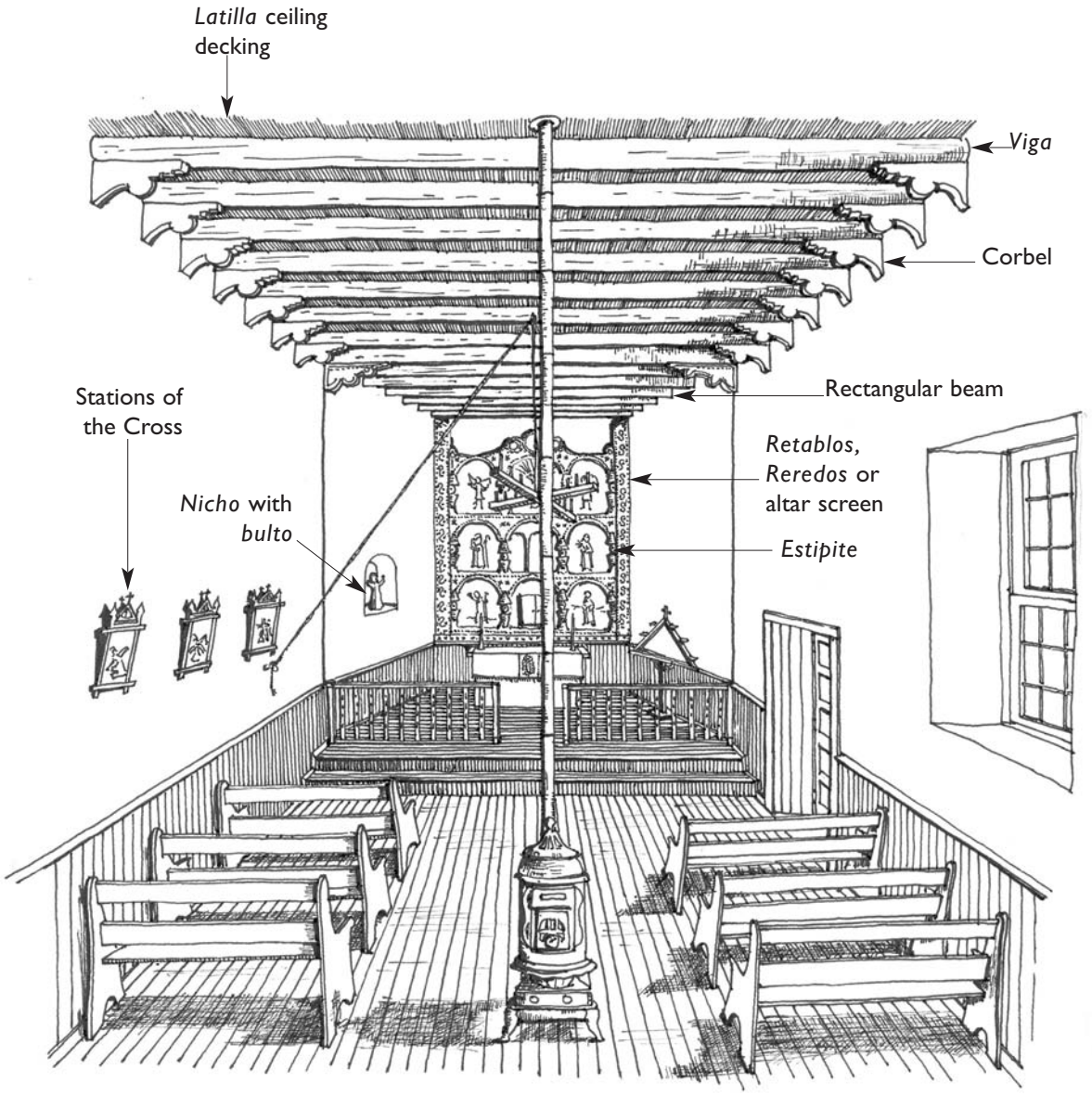


9 over 9 double hung window unit

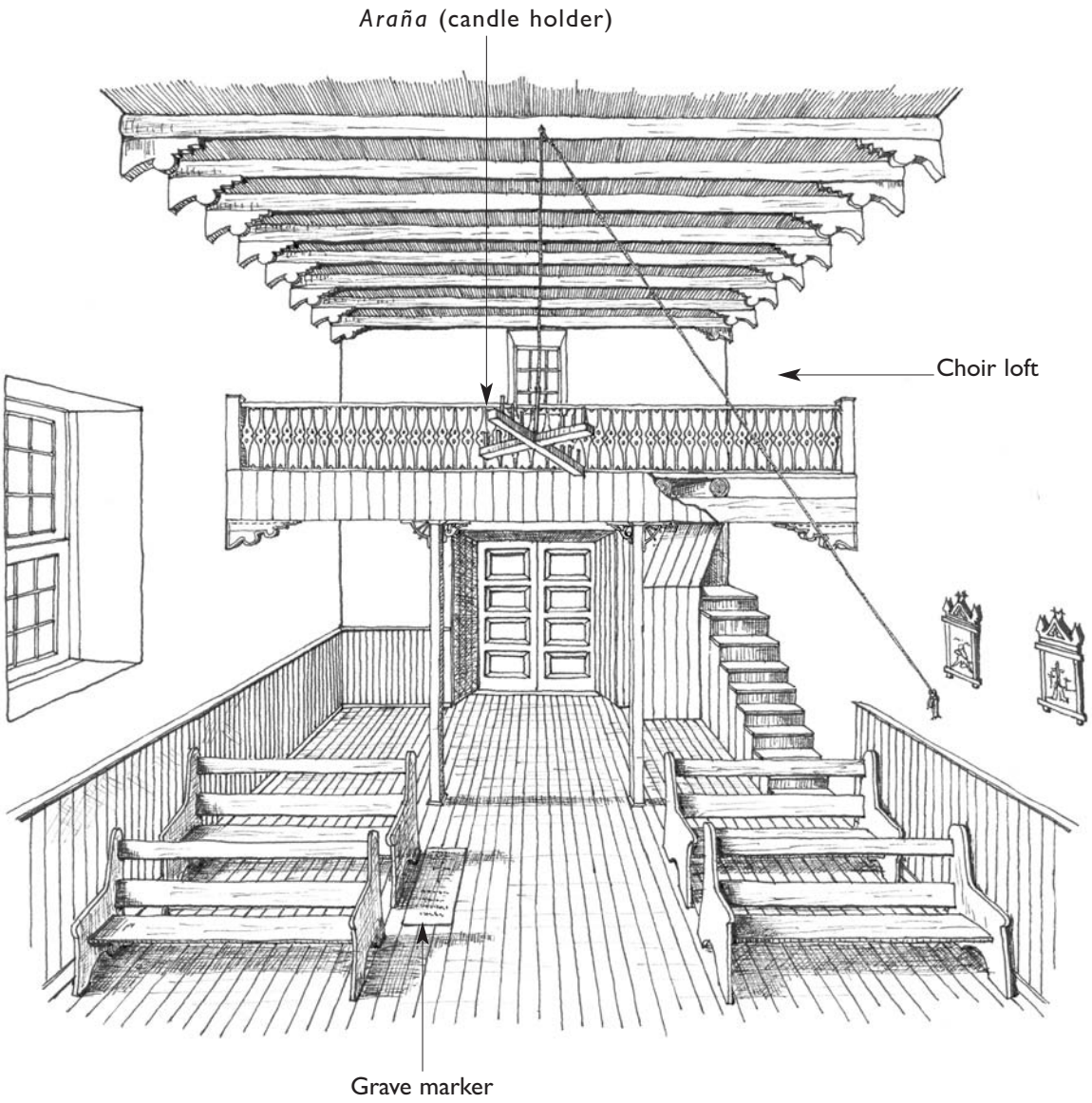
DOOR TERMINOLOGY



ARCHITECTURAL FEATURES: INTERIOR NAVE AND SANCTUARY

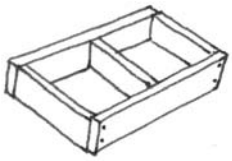


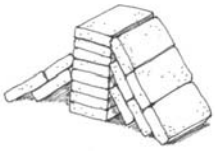
ARCHITECTURAL FEATURES: INTERIOR NAVE AND CHOIR LOFT



TOOLS, EQUIPMENT, MATERIALS AND SUPPLIES

Each section of this handbook has an introductory page illustrating the tools, equipment, materials and supplies needed for the procedures described in that section. The following legend identifies the symbols that are used for them throughout the handbook.


Adobe brick form


Adobe bricks

Air compressor

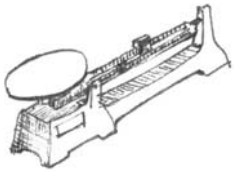
Alum
(aluminum sulfate)

Anchor Bolt

Auger bit

Awl (punch)

Axe


Balance scales

Bones

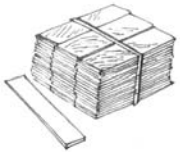
Betonomite®

Brick layer's (mason's)
trowel

Broom

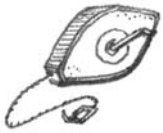
Buckets
(metal and/or plastic)

Caulking gun


Cedar shingles

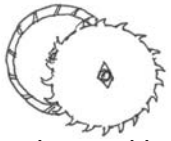
Cement

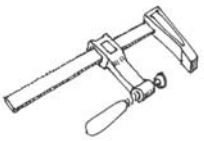
Chainsaw


Chalk line

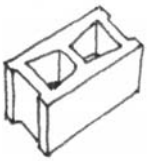
Chisel

Circular saw


Circular saw blade,
diamond blade

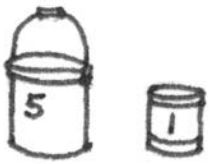


Clamp

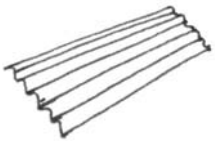


CMU's

Conduit pipe

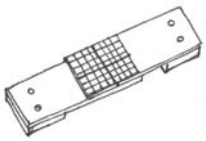


Containers



Corrugated metal

Crack monitor



Crack monitor - Avongard-type

Drill

Drums, 55 gallon

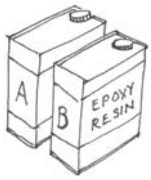
Drywall compound mixer

Duct tape

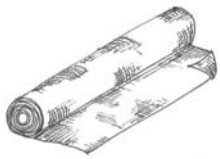
Duplex scaffolding nail

Dust mask

Electrical tape



Epoxy resin

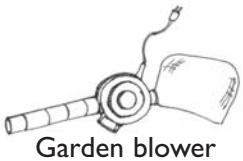


Filter fabric

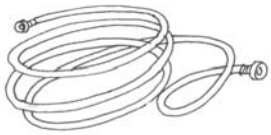
Flashing

Flashlight

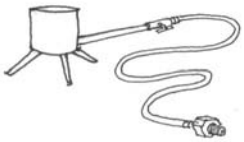
Funnel



Garden blower with vacuum



Garden hose



Gas burner

Gas container

Gas tank

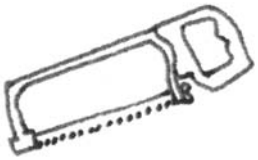
Glass fiber rods (threaded and unthreaded) and nuts

Glass jar

Gloves

Goggles

Gravel



Hacksaw

Halogen light

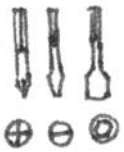
Hammer

Handsaw

Hard hat

Hearing protectors and ear plugs

Hepa filter mask



Hex bits

Hoe

Hollow core drill bit

Hydraulic jack

Ice and water shield

Jigsaw

Knee pads

Knife

Ladder

Lawn mower

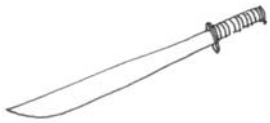
Level

Lime

Lime putty

Lumber

Lye soap



Machete

Margin trowel

Masonry drill bit

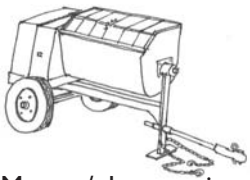
Maul

Measuring tape

Mineral oxide pigment

Mixer

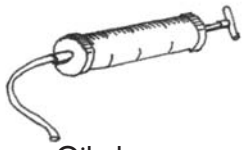
Mop

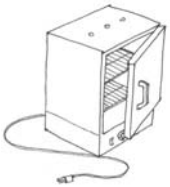

Mortar/plaster mixer

Nail puller (cat's paw)

Nails

Nuts and bolts


Oil plunger

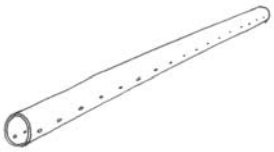

Oven

Paint brush

Paint roller

Paper cups

Pencil


Perforated pipe

Pick

Plaster (dash) brush

Plaster of Paris

Plasterer's hawk

Plasterer's trowel

Plastic (15 mil)

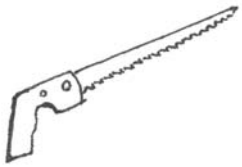
Pliers

Plumb bob

Plumber's bit

Plumber's strap

Plywood


Pointed hand saw

Polypropylene strap

Prickly pear cactus (nopal)

Pulley

Putty knife

PVC cement

PVC fittings

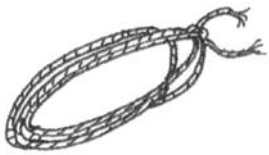
PVC pipe

Rebar

Ridge cap

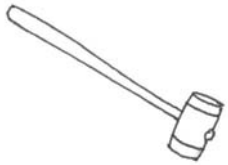
Rock hammer

Roofing felt



Rope

Rotary hammer drill



Rubber mallet

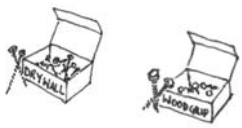
Sand

Sawhorse

Scaffolding

Screen

Screw drivers



Screws (drywall and wood grip)

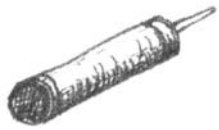
Self tapping screws

Sheep skin

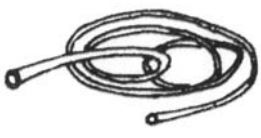
Sheet metal shears

Shoring jack

Shovel



Silicon sealant

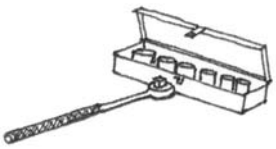


Siphon hose

Sledge hammer

Soap dish

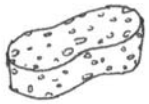
Socket paring chisel



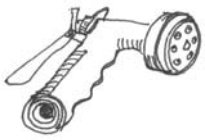
Socket wrenches

Soil

Spade bit

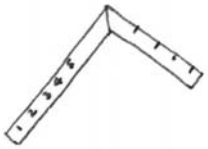


Sponge

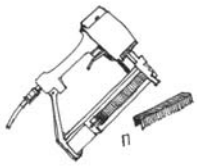


Spray attachment

Sprayer



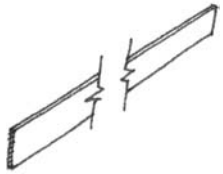
Square



Staple gun

Staples

Steel drill bit



Steel strapping

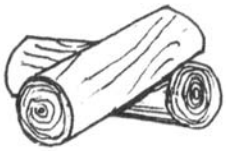
Stone

Straw

String

Surveyor's level

Utility knife



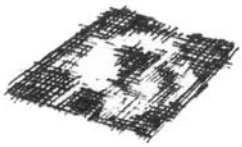
Vigas

Washers
(metal and plastic)

Water (potable)

Wheel barrow

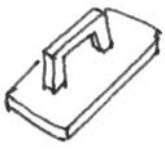
Whisk broom



Window screen

Wire cutters

Wood dowel



Wood float

Wood glue

Wrecking bar

Zip-lock bags

ARCHAEOLOGICAL SITES AND BURIAL GROUNDS

It is important to be aware when working on historic buildings, and especially old churches, that the location of human burials may have been forgotten. Human remains can be found during even the most minor ground-disturbing activities. These graves might be hundreds of years old or might date to just a few decades ago. Regardless of their age, the remains of those who have gone before us deserve respect and appropriate treatment regardless of how long ago they might have been buried by their family and friends.

Laws have been enacted on both the State and Federal levels to help ensure the protection of human burial sites. For graves that were placed outside a formal cemetery (often an archaeological situation), this protection usually takes the form of a permit that would allow disturbance to happen under specific conditions. Graves placed in formal cemeteries are similarly protected by the need for a permit to disinter the remains. In effect, the laws make it a crime to intentionally disturb a gravesite or to remove archaeological resources or human remains without an official permit.

The Archaeological Resources Protection Act (ARPA) was enacted in 1979 to protect and preserve archaeological resources on Federal and Indian lands, including archaeological burials. Archaeological resources are considered the following: a) items of past human existence, b) from which scientific information may be obtained, c) over 100 years old. Additionally, the Native American Graves Protection and Repatriation Act (NAGPRA) protects remains of any age belonging to Native Americans. In order to excavate or remove archaeological resources of any type located on Federal or Indian lands, a permit is required from the Federal land manager.

In New Mexico, if human remains are exposed during construction or repairs on State or private land they are subject to the unmarked burial provisions of New Mexico's Cultural Properties Act (18-6-11.2 NMSA 1978) and the implementing regulation (4.10.11 NMAC,

Issuance of Permits to Excavate Unmarked Human Burials in the State of New Mexico). The law requires that the New Mexico Office of the Medical Investigator (OMI) be notified immediately when bones are discovered and that no further disturbance take place until the remains have been examined. If the OMI finds that the discovery is not of mediocolegal significance (essentially, does not constitute a crime scene), then the discovery is referred to the Historic Preservation Division, Department of Cultural Affairs, for archaeological follow-up. Removing human remains or anything interred with a burial without a burial permit issued by the New Mexico Cultural Properties Review Committee is a felony punishable by fines and imprisonment.

If, during construction, you find bones that might be human remains, leave them in place and immediately halt any work that might continue to disturb them. Take adequate steps to protect them from the elements, then call the local police department *and* the Historic Preservation Division of the New Mexico Department of Cultural Affairs *immediately*. Always leave human remains (or any bones you suspect might be human) in place until OMI personnel or professional archaeologists have been allowed to remove them.

For more information or to report the discovery of artifacts or human remains in New Mexico contact:

New Mexico State Police,
(505) 827-9066

New Mexico State Historic
Preservation Division,
(505) 827-6320

Archdiocese of Santa Fe,
Office of Historic Patrimony,
(505) 983-3811

If your work is taking place outside New Mexico, contact the State Historic Preservation Office (SHPO) in your locality for specific information regarding laws, policy and procedures:

Arizona, (602) 542-4174

California, (916) 653-6624

Colorado, (303) 866-3355

Nevada, (775) 684-3440

Texas, (512) 463-8222

Utah, (801) 533-3503

Contacts for SHPO offices in other states can be obtained from the National Council of State Historic Preservation Offices (NCSHPO), **www.ncshpo.org.**

SAFETY ON THE JOB

Safety on the job is the responsibility of everyone. The following recommended safety measures should be used as a guide for safety measures to be employed on construction sites. Common sense, however, should always prevail.

Face shields, safety goggles and filtering breathing masks should be worn wherever flying particles, corrosive vapors and/or liquids are present.

Eye protection should be worn whenever there is a possibility of debris entering the eyes, especially when working with or around dry cement or lime, and when drilling, grinding, welding or cutting.

Hard hats should be worn when working on any construction site.

Ear protection should be worn when working on or around heavy equipment or shop tools.

Back braces and/or belts should be worn when lifting, bending, pushing, pulling or carrying heavy or bulky materials. If necessary, ask for help from other workers.

Safety shoes with steel toes should be worn at all times.

Guidelines for health and safety on any job site are outlined in *Occupational Safety and Health Standards for the Construction Industry*, a booklet published through the Texas Engineering Extension Service for the (US) Occupational Health and Safety Administration. The guidelines, also available on CD-Rom, are broken down into the following subparts. They should be reviewed and made available as safety training for everyone at the project site:

Electrical, Subpart K
Fall Protection, Subpart M
Health Hazards, Subpart D (see note below)
Personal Protection and Prevention, Subpart E
Fire Protection and Prevention, Subpart F
Materials Handling, Storage, Use and Disposal, Subpart H
Tools - Hand and Power, Subpart I
Scaffolds, Subpart L
Excavations, Subpart P
Stairways and Ladders, Subpart X
Confined Space Entry, Appendix C

NOTE: Not specifically addressed by OSHA are two hazards that may be significantly present on preservation sites in the Southwest due to the nature of restorations and repairs to historic buildings. These are Hantavirus and silicon dust. Safety guidelines for these hazards can be obtained through the New Mexico Infoline at (800) 879-3421.

Worker training in safety is extremely important. The most frequently cited (by OSHA inspectors) problem on job sites is the lack of a safety training program. A serious accident on a project site can be disasterous not only because of the injuries caused to workers, but also for the negative impact it may have on the continuation outlook for the project itself. Ten-hour and 30-hour Construction Safety OSHA Outreach Training is available through Cornerstones Community Partnerships, which has a certified OSHA Outreach Trainer on staff.

The United States Occupational Health and Safety Administration can be contacted at (800) 723-3811 or at **www.teex.com/osha.**

PART TWO

ALL ABOUT ADOBE

INTERPRETING SOURCES, PROCESSES AND EFFECTS OF DETERIORATION

Before beginning the process of repairing an historic building or site, it is important to identify the sources of deterioration and create an outline for future conservation, preservation, and restoration work. When assessing an historic building it is critical to examine the landscape or urban environment in which the structure was originally built. The cultural and architectural landscape surrounding a structure may give clues as to how the restoration may proceed most appropriately.

This section illustrates some of the ways in which various elements damage adobe structures. In almost every example, the problem was identified and repaired using the methods and materials described in this handbook.

Adobe structures, when properly maintained, can last for hundreds of years. Water is the most common source of deterioration in earthen buildings because it can invade an adobe wall or other parts of a building. Adobe is clay and sand, mixed with straw and water, and formed into sun-dried bricks. If sufficient moisture is added, adobe bricks revert to mud.

In many cases where the base of an adobe wall is in contact with damp earth, moisture can travel up into the wall. Moisture can enter an adobe building through roof leaks, failed flashing at roof penetrations (chimneys, vents, sky lights), poorly sealed doors and windows, and large cracks in the plaster. Components made of concrete, such as sidewalks, buttresses or concrete aprons, trap moisture and increase damage to the base. In all these cases, capillary action will suck moisture upward like a sponge. In other cases, when the protective surface coating – originally mud or lime plaster – deteriorates, rain water and snow erode the exposed adobe bricks.

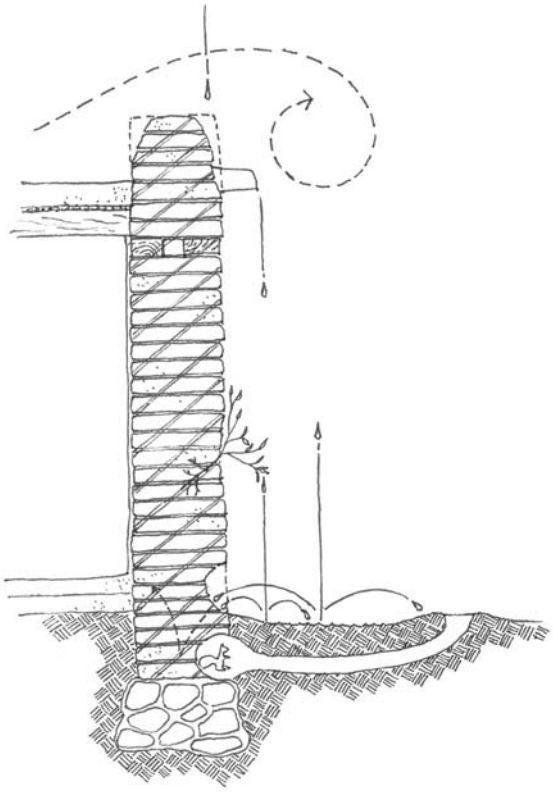
In the early part of the 20th century, cement plaster began to replace mud and lime plaster on many churches and other adobe buildings. Cement inhibits the evaporation of water and therefore traps moisture within the structure.

If water penetrates into the wall behind the plaster by capillary action or through cracks or a broken flashing, it cannot escape and the adobe bricks become saturated. The basic problem with using cement on earthen buildings is its incompatibility: cement is hard, while earth is soft. Each behaves in an entirely different mannner during environmental cycles. Another measure intended to repair damage to damp walls is the addition of a protective concrete collar around the base of the wall, called a *contra pared*. This too tends to trap moisture in the wall and becomes another 'remedy' that causes more damage than it prevents. Cement plaster is a problem not only because it retains moisture, but also because it hides wall damage. An important advantage of earthen or lime plasters is that they reveal damage immediately.

COMMON SOURCES AND CAUSES OF DETERIORATION

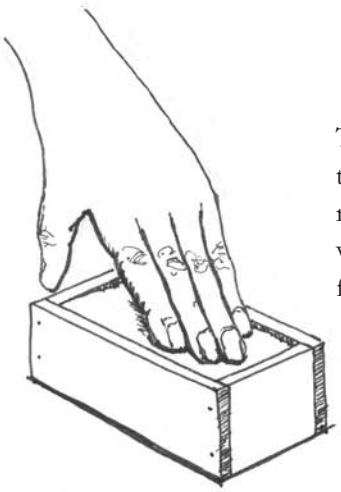
Identifying the source of deterioration is the first step toward repair. The following list outlines both natural and man-made sources.

- Fire – arson or natural
- Erosion – wind, rain, snow, sleet, or hail may cause erosion of plaster, adobe, and wood
- Rot – wood deterioration
- Vegetation – plants near the base of adobe walls moisten earthen plaster, cause basal erosion and structural failure
- Pests
- Rodents
- Broken downspouts
- Leaking plumbing
- Negative site drainage
- Bad interventions – additions of cement plasters, concrete *contra paredes*, sidewalks, and buttresses
- Short eaves
- Rise in water table
- Vandalism
- Seismic activity
- Faulty roofs
- Missing or damaged fenestration (doors, windows)



PERFORMING A CAPILLARITY TEST

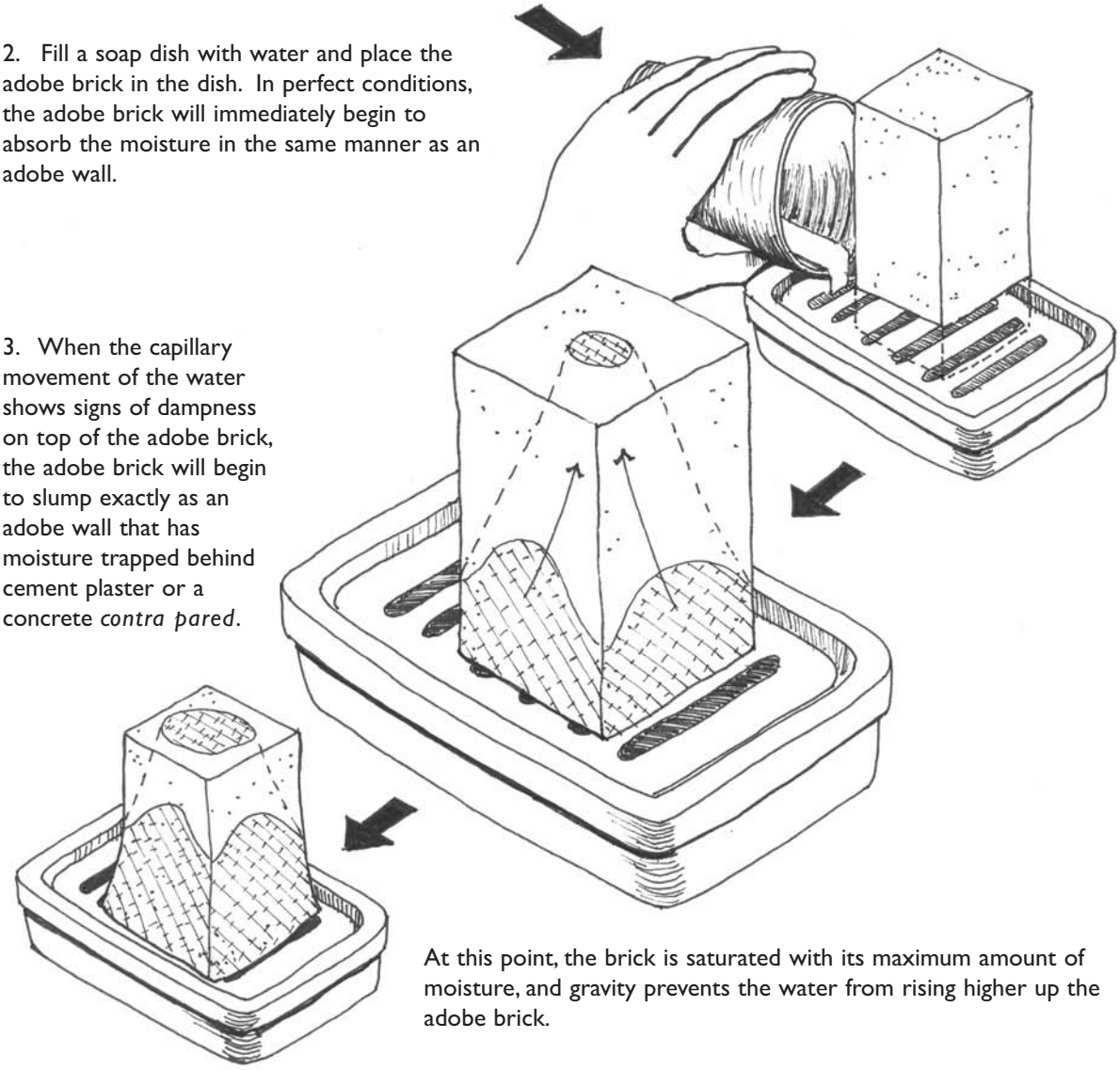
This test illustrates the movement of water from the base of an adobe brick up to its center as a result of capillary action. Cement additions prevent moisture from otherwise escaping to the surface through a breathable mud or lime plaster.



1. Make a small adobe brick following the instructions given in the succeeding sections of this manual.

2. Fill a soap dish with water and place the adobe brick in the dish. In perfect conditions, the adobe brick will immediately begin to absorb the moisture in the same manner as an adobe wall.

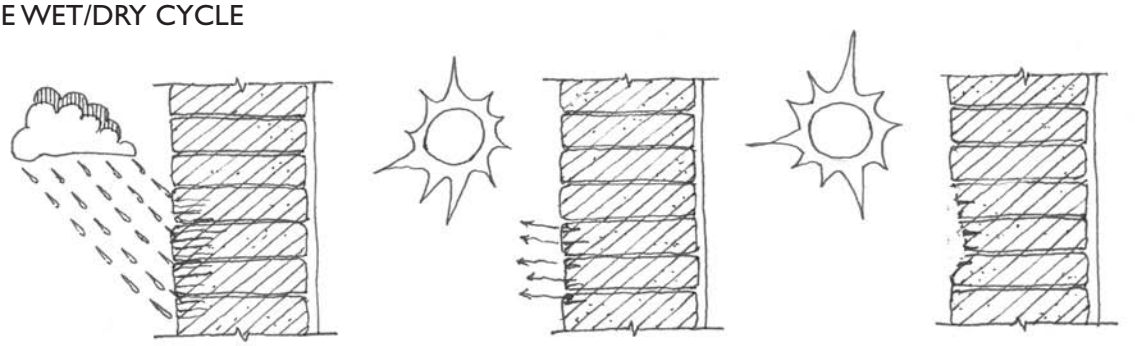
3. When the capillary movement of the water shows signs of dampness on top of the adobe brick, the adobe brick will begin to slump exactly as an adobe wall that has moisture trapped behind cement plaster or a concrete *contra pared*.



At this point, the brick is saturated with its maximum amount of moisture, and gravity prevents the water from rising higher up the adobe brick.

COMMON PROCESSES OF DETERIORATION

THE WET/DRY CYCLE

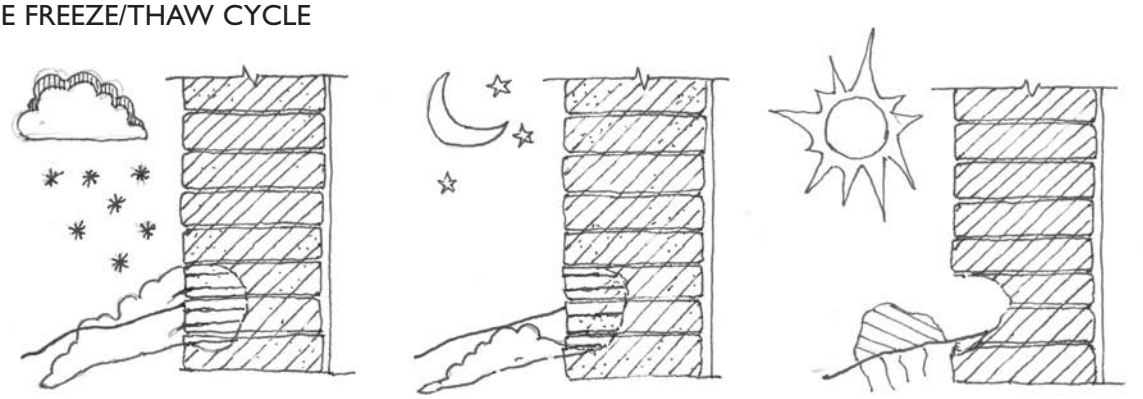


Water saturates wall.

Dissolved soluble salts migrate to wall surface as wall dries and water evaporates.

Salts crystallize on the wall surface and accelerate erosion.

THE FREEZE/THAW CYCLE

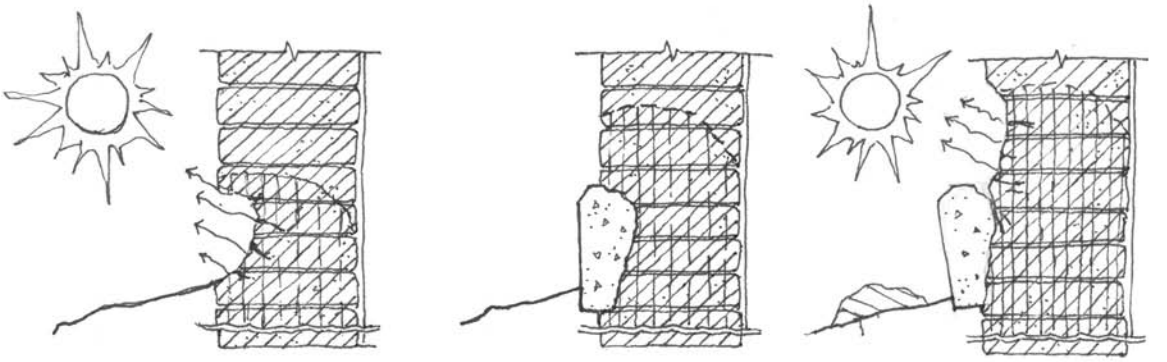


Water saturates wall.

Freezing temperature results in water crystal expansion.

Wall thaws with loss of integrity.

CAPILLARY RISE

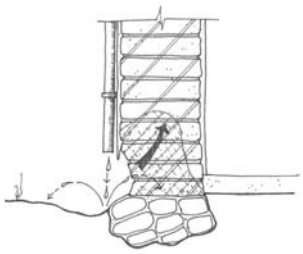


Rising damp results in basal erosion.

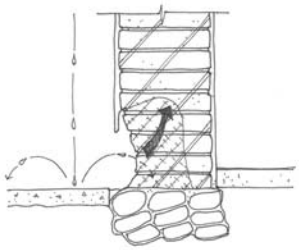
If basal erosion is repaired with portland cement, damp rises even higher.

New erosion occurs above portland cement repair.

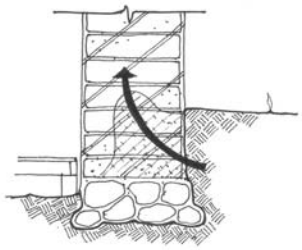
FACTORS THAT CONTRIBUTE TO CAPILLARY RISE



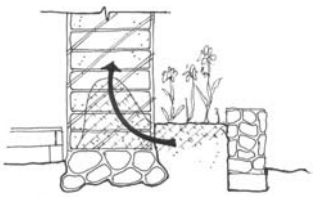
Damaged and improperly maintained downspouts cause deterioration at the base of a wall and increase capillary rise ...



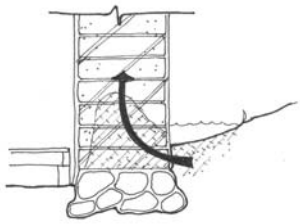
... as do leaking gutters or *canales*. Hard surfaces like concrete sidewalks next to a wall increase the force and velocity of the "splash back" against the wall and speed up the deterioration process.



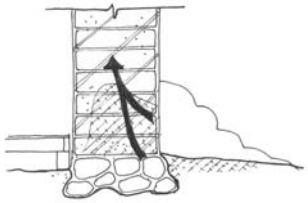
When the exterior grade is too high, capillary rise moves higher up the interior of the wall ...



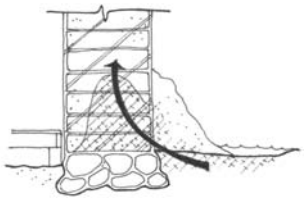
... the same thing can happen when a planter is constructed next to a wall. If the plants require frequent watering, the problem becomes even worse.



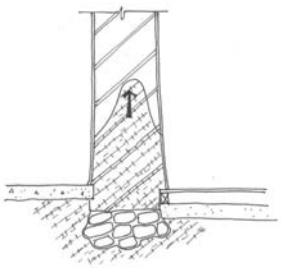
An exterior grade that slopes toward the building causes water to pool against it and increases the amount of capillary rise ...



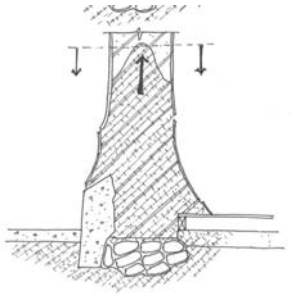
... snow that is allowed to drift around the base of the building has the same effect.



In fact any type of debris that is allowed to pile up against an adobe wall traps moisure in it and contributes to capillary rise.



An impervious surface, such a concrete sidewalk or slab floor, or even plastic landscaping cloth placed too close to the building, inhibits natural evaporation in the ground around the foundation, concentrates water at the base of the building and contributes to capillary rise.



Water trapped in a wall causes the loss of structual integrity. Evenually gravity will cause the wall to "slump" and finally collapse.

After identifying the sources of deterioration, it is important to prevent further deterioration from taking place. Repairs include stopping roof and other leaks, providing good site drainage, installing subsurface drainage systems, and replacing cement plaster with permeable coatings such as mud and/or lime plasters. These coatings allow moisture to escape from adobe walls before they become saturated and lose their ability to bear weight. The following sections of this manual will show you how to identify and correct specific moisture problems.

A SPECIAL NOTE ON SEISMIC ZONES

If you are restoring a building within a seismic (earthquake) zone, it is important to observe how the original builders created stability for the building. In many cases, it is the use of incompatible materials and the addition of recent modifications that make adobe buildings more susceptible to damage during an earthquake.

There are many ways to improve a building's stability in the face of potential seismic activity. Encouraging horizontal continuity in the building through the use of wooden bond beams, nylon straps, and wood plates is one way to decrease the chance of a critical separation. The use of concrete ties or concrete bond beams creates a far too rigid environment, increasing the potential for damage. Window and door openings should remain in the center of walls, and no new openings should be made near wall or roof joints. In addition, window and door lintels should be significantly longer than those used outside earthquake zones.

Single story structures are inherently more horizontally stable and are less likely to separate during an earthquake. If the building must have more than one story, the second level should be made of *bajareque*, or waddle and daub, which is inherently more flexible because of its vertical and horizontal woven structure.

There is a wealth of information on earthen structures in earthquake zones. For more detail, refer to the Getty Conservation Institute's Getty Seismic Adobe Project (GSAP) at:

www.getty.edu/conservation/science/seismic/index.html

EMERGENCY STABILIZATION AND SHORING

Immediate action is called for when a wall or a portion of a wall is near collapse, or when necessary repairs will put the wall in danger of collapse. A collapsing wall is usually caused by deterioration at its base due to trapped moisture within, or when the wall is not appropriately attached to the rest of the walls in the building. Signs of this condition include bulging at the base and the appearance of horizontal or diagonal cracks at the corners. For other possible sources of deterioration and erosion, such as coving at the base see the preceding chapter, *Interpreting Sources, Processes, and Effects of Deterioration*.

Walls that are out of plumb may indicate they are saturated at the base or that lateral loads are pushing on the wall. On the other hand, some massive adobe walls have been out of plumb from the time of their original construction. Because an adobe wall is out of plumb does not necessarily mean it is ready to collapse. Too often it is assumed that a wall out of plumb is in danger of falling over, and attempts to correct the out-of-plumb condition cause further damage. Such attempts include building buttresses against walls that trap moisture and installing cables or tie rods at the top of walls that damage the walls by introducing tension. Buttresses often pull a wall out of plumb because they are built as later additions with incompatible materials. Buttresses or cables and tie rods should never be introduced without first gathering evidence that the walls are indeed moving or in danger of slumping.

When a wall is beginning to slump downward or outward, the immediate need is to prevent the roof from collapsing as well. Methods of emergency shoring for roof *vigas* and a system for more long-term shoring are illustrated below. Long-term shoring can remain in place until the adobe wall is rebuilt or repaired.

Sandbags may also be used to stabilize the corner and base of a wall until permanent repairs can be made or better shoring is installed. This procedure is detailed on the following page.

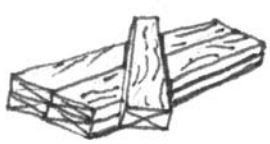
After emergency shoring is installed, the cause of deterioration and failure should be identified. Installing emergency shoring should provide the necessary time for stabilization and restoration of the structure.

NOTE: It is always recommended to consult a qualified structural engineer before installing long-term shoring. Very high-tech shoring units are also available if desired.

TOOLS AND MATERIALS REQUIRED

Shoring jack

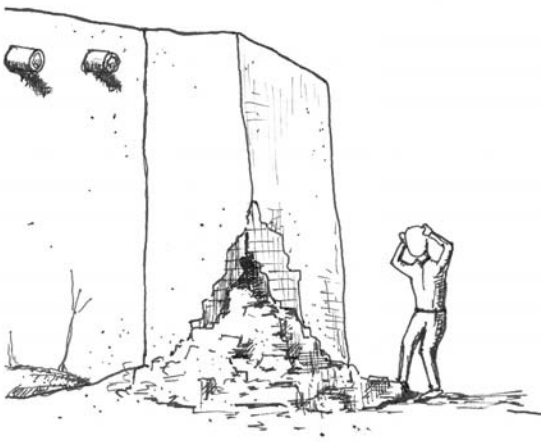
Plywood



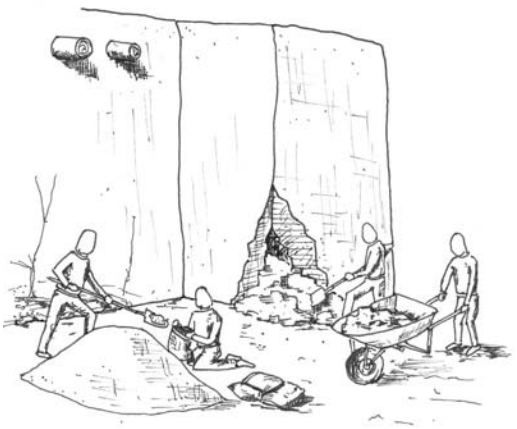
Lumber

Duplex scaffolding nail

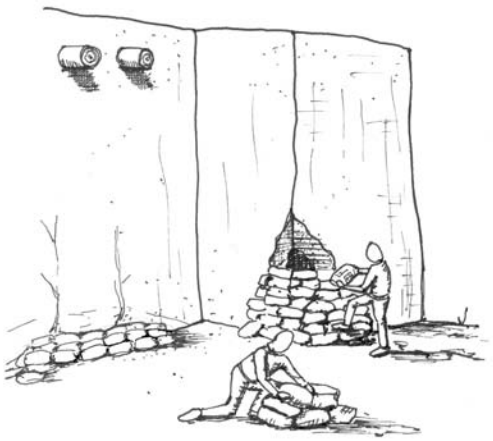
EMERGENCY SANDBAG STABILIZATION



1. Corner collapse. First review the preceeding chapter on the *Sources, Processes and Effects of Deterioration* to make sure you understand the forces that caused the collapse.

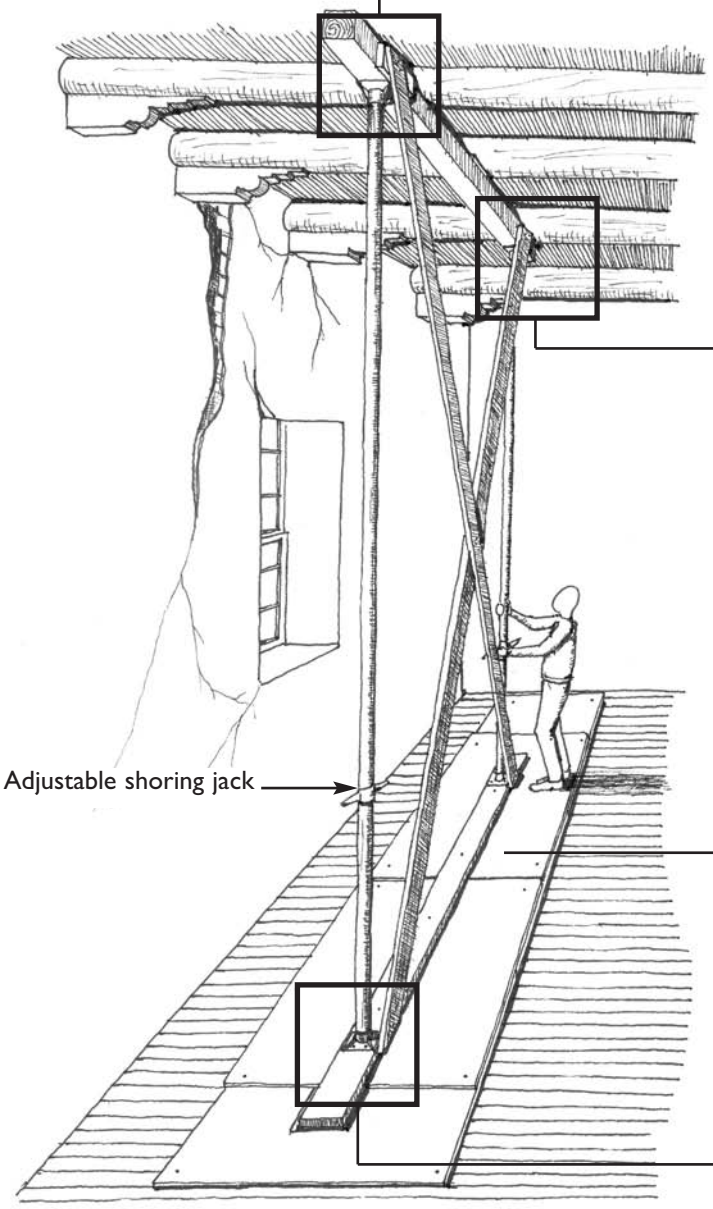


2. Prevent further damage by removing the rubble that retains moisture. Fill burlap or grain bags with sand or fine gravel and tie securely.

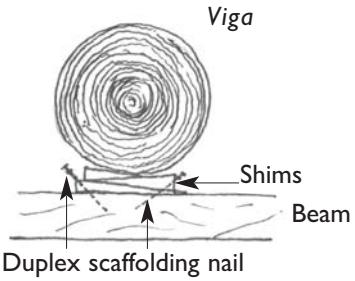


3. Pack the collapsed wall sections with sandbags to provide temporary support to the upper wall. To provide additional support, stack the sandbags outside the void into a buttress. Make sure the opening is not too large to work around it, since further collapse may occur and a different system should then be utilized. See the section on diagonal bracing on the following page for additonal detail.

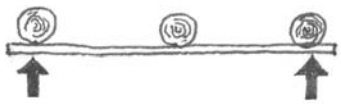
EMERGENCY SHORING



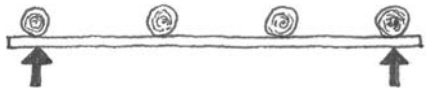
Section



Horizontal Beam Sizing

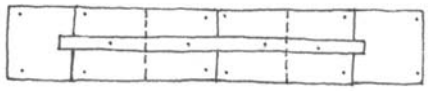


4x4" shoring beam spans to a maximum of 3 *vigas*



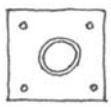
4x6" shoring beam spans to a maximum of 4 *vigas*

Base



Use 5/8 or 3/4-inch thick plywood for the diaphragm. Screw or nail a 2x8" to the diaphragm to serve as the bottom plate

Fastening

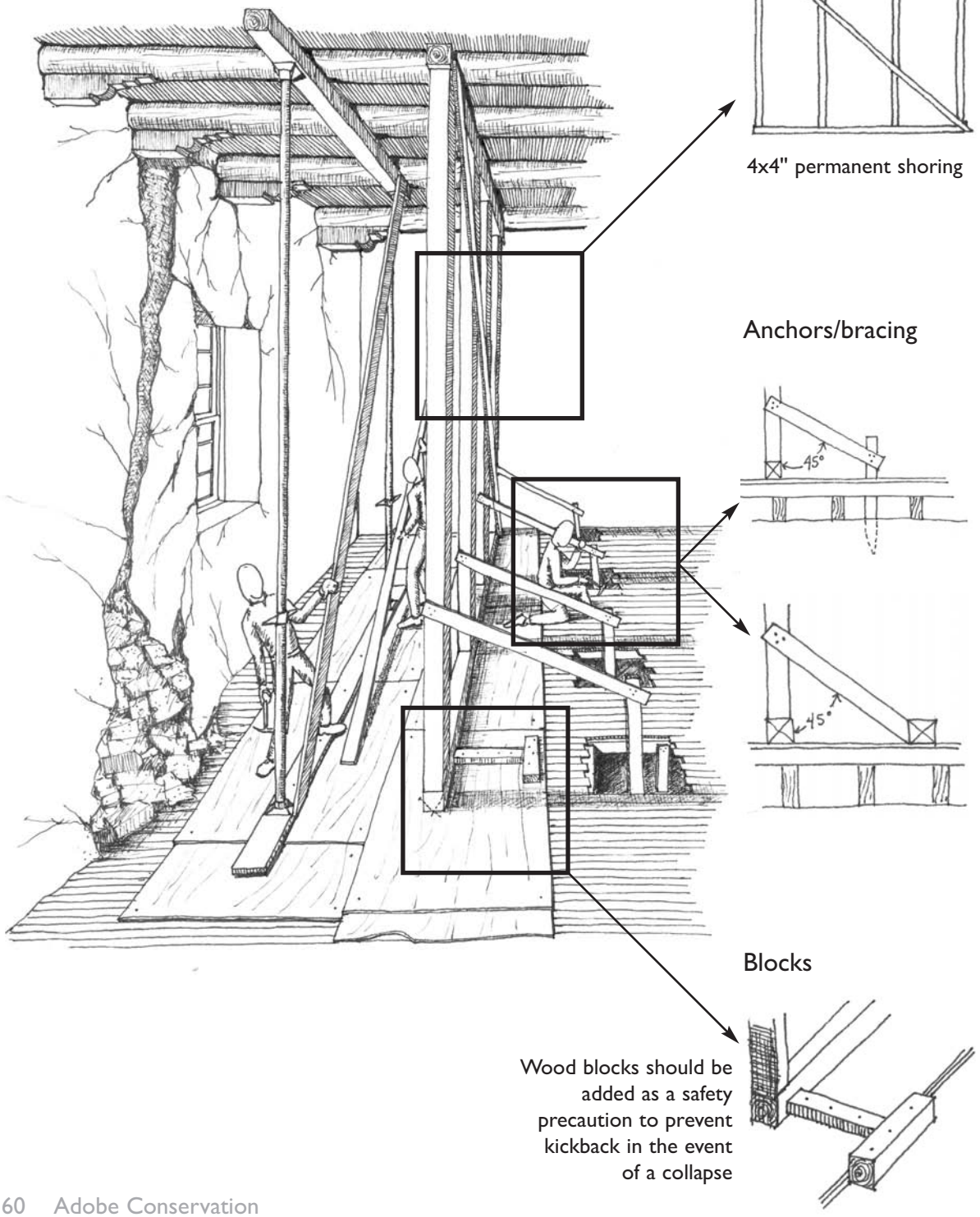


Shoring jack base

Duplex scaffolding nail

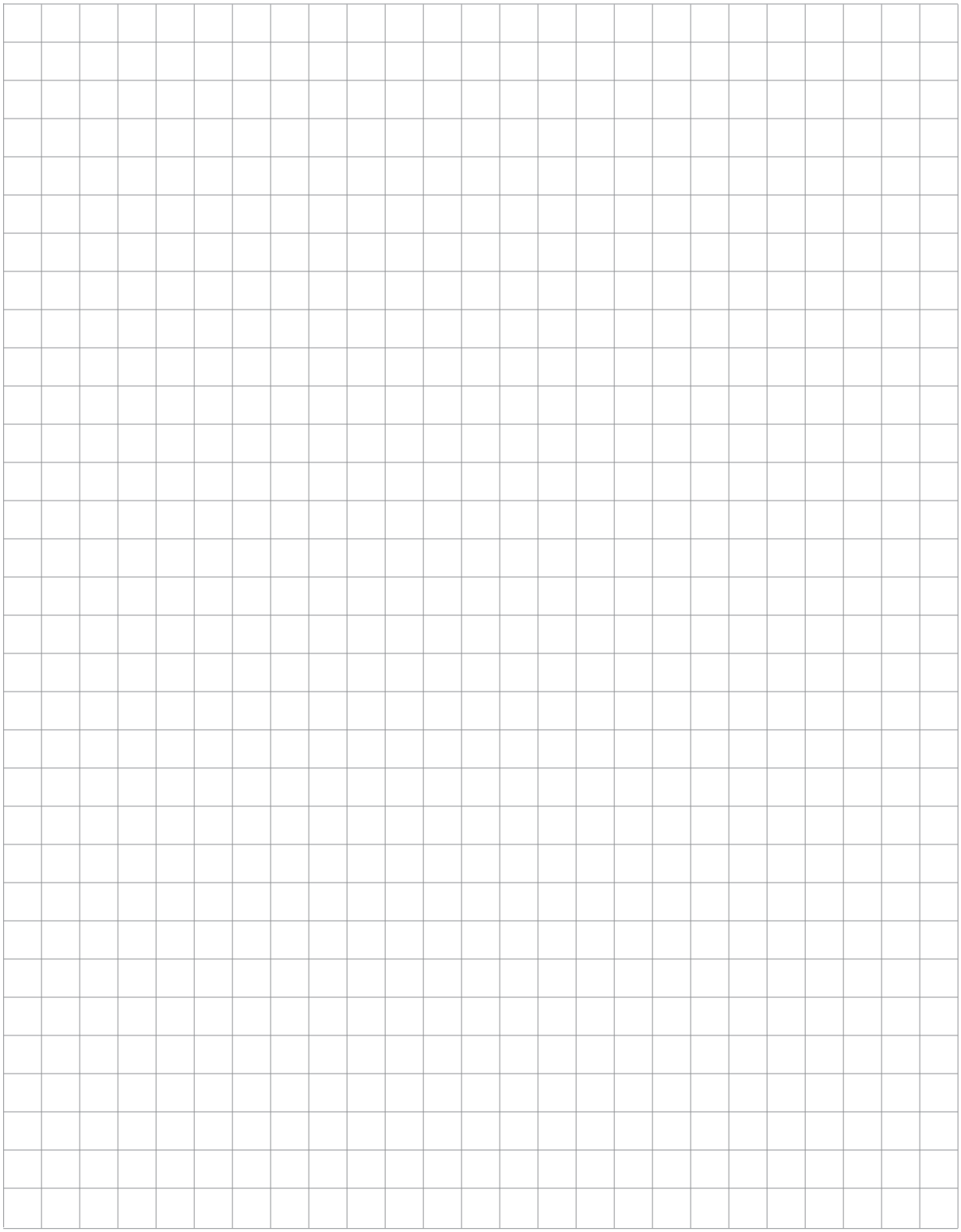
Use duplex scaffolding nails to hold the top and base of the shoring jack in place

PERMANENT SHORING



FIELD NOTES

FIELD NOTES



MOISTURE TESTING IN ADOBE WALLS

Moisture is the number one cause of structural failure in adobe walls. In massive adobe walls it is important to know the moisture content of the interior of the wall. Moisture content in walls can be monitored to determine their present condition and how to approach repairs.

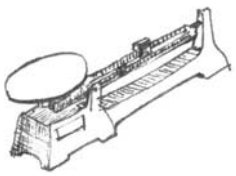
The presence, if not the amount, of moisture is simple to detect by touch and sight. Signs of moisture include: deterioration or staining of plasters and paints; structural cracks that have been caused by settling; rotten wood members; or the smell of dampness/mildew. These conditions should be documented with photographs and the sources of moisture analyzed. Why is the moisture there? Where is it coming from? How can it be diverted from the building in a way that is historically and structurally appropriate? (See Part One, *Interpreting Sources, Processes and Effects of Deterioration,* and Part Three, *Installing Subsurface Drainage Systems*.)

Once the severity of the moisture content has been established and the source of deterioration has been identified, corrective measures should be taken. If the percentage of moisture is 12% or greater, the adobe wall has approached its structural limits and immediate action is necessary. Cracks and slumping of adobe walls should be taken seriously!

Moisture at the base of a wall will tend to rise by capillarity and can rise only so high since gravity will stop its upward movement. At this point the massive upper wall loads are no longer being supported by the wet lower portion of the wall. Cracks, slumping, settling, and the eventual collapse of the wall can be expected.

This section describes the procedure for determining the moisture content of an adobe wall. Test samples should be taken at different points close to the base of the wall, and especially in areas where there is reason to suspect excessive moisture.

TOOLS AND MATERIALS REQUIRED

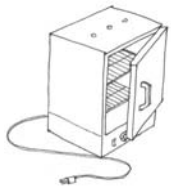


Balance scales

Hollow core drill bit

Hollow core drill bit

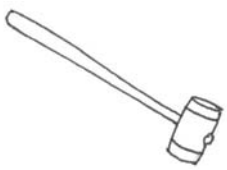
Masonry drill bit



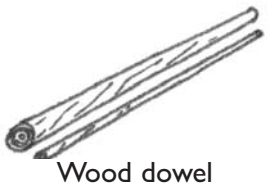
Oven

Rock hammer

Rotary hammer drill



Rubber mallet

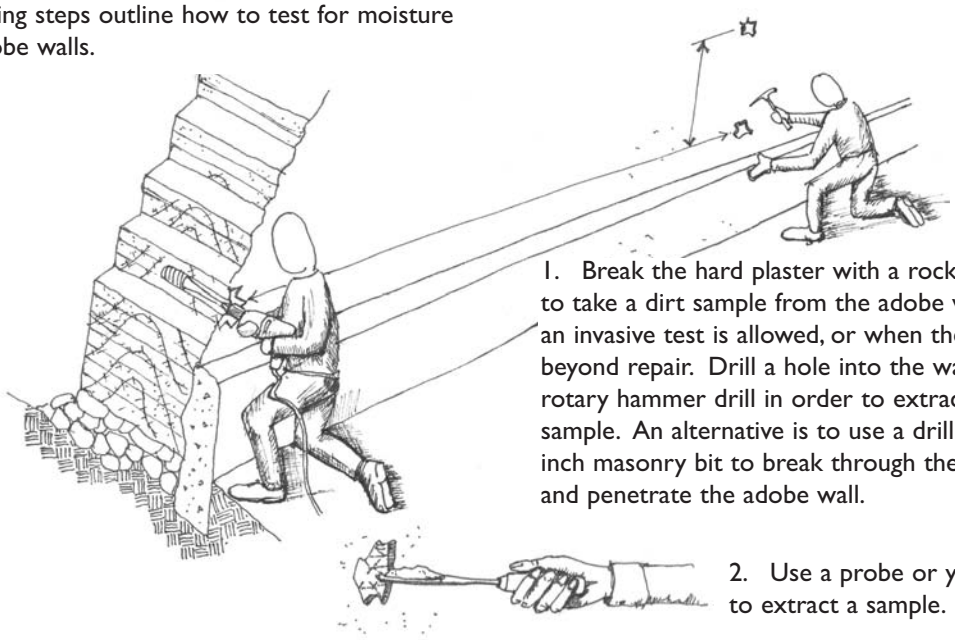


Wood dowel

Zip-lock bags

MOISTURE TESTING IN ADOBE WALLS

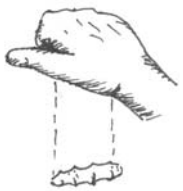
The following steps outline how to test for moisture level in adobe walls.

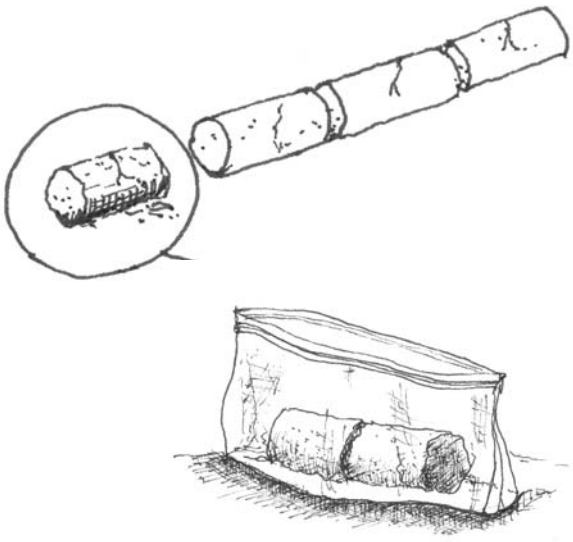


1. Break the hard plaster with a rock hammer to take a dirt sample from the adobe wall when an invasive test is allowed, or when the plaster is beyond repair. Drill a hole into the wall using a rotary hammer drill in order to extract a core sample. An alternative is to use a drill and a 3/4-inch masonry bit to break through the plaster and penetrate the adobe wall.

2. Use a probe or your hand to extract a sample.

3. Take the sample in your hand and squeeze. If the sample breaks apart and is powdery, the moisture content is low. If the sample compacts, leaving finger marks as you open your hand, the wall contains moisture and should be tested according to the following steps.





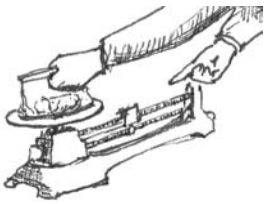
4. With a core bit or a conduit take core samples extracted close to the mid-span of the wall. To extract a sample, use a 1/2 inch conduit pipe, a long 3/4 inch masonry bit, a long wood dowel that fits the opening of the conduit pipe, and a rubber mallet.

5. Wrap duct tape several times around one end of the conduit pipe, leaving the end open. Also wrap duct tape around one end of the wooden dowel.

6. Using a drill with a masonry bit, drill through the plaster and into the wall to a depth of several inches.

7. Insert the end of the conduit pipe without tape into the hole. Gently tap the taped end with a rubber mallet to drive the pipe into the hole. Pull the conduit out and measure the depth of the sample. Insert the wooden dowel into the end of the conduit with the tape on it and tap it to push the core sample out and into a ziploc bag.

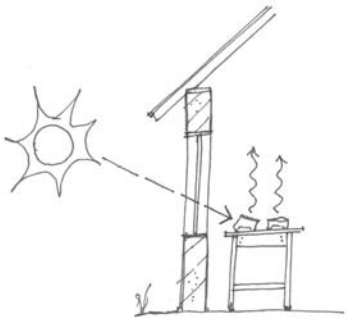
8. Seal the bag and immediately weigh the sample at the site. This will provide you with the wet weight of the sample. Label the bag with the location of the extraction, the depth of the core sample and the wet weight. For better measurements use an electric scale.



9. Carefully place all contents of the baggie in a ceramic dish, then dry the baggie, which will be used later in the test, by turning it inside out to allow any condensed moisture to evaporate.

10. Put the ceramic dish containing the sample in an oven set at 200 degrees for roughly 20-30 minutes. Always check sample every few minutes.

11. If an oven is not available, you can dry adobe samples in direct sunlight. To prevent weather conditions from ruining the samples, dry the sample inside a building for a minimum of two days. Make sure the baggie is turned inside out to allow moisture to evaporate. In high humidity, the sample must be dried in an oven or in a pan over an open flame.



12. Allow the dried sample to cool, then put it back into the dry baggie. Weigh it and record the weight again. This will give you the dry weight of the sample.

To obtain the percentage of moisture in the sample, divide the difference between the wet weight and the dry weight by the wet weight.

Wet Weight	38.76 grams
Minus Dry Weight	34.44 grams
Equals Difference	04.32 grams of moisture

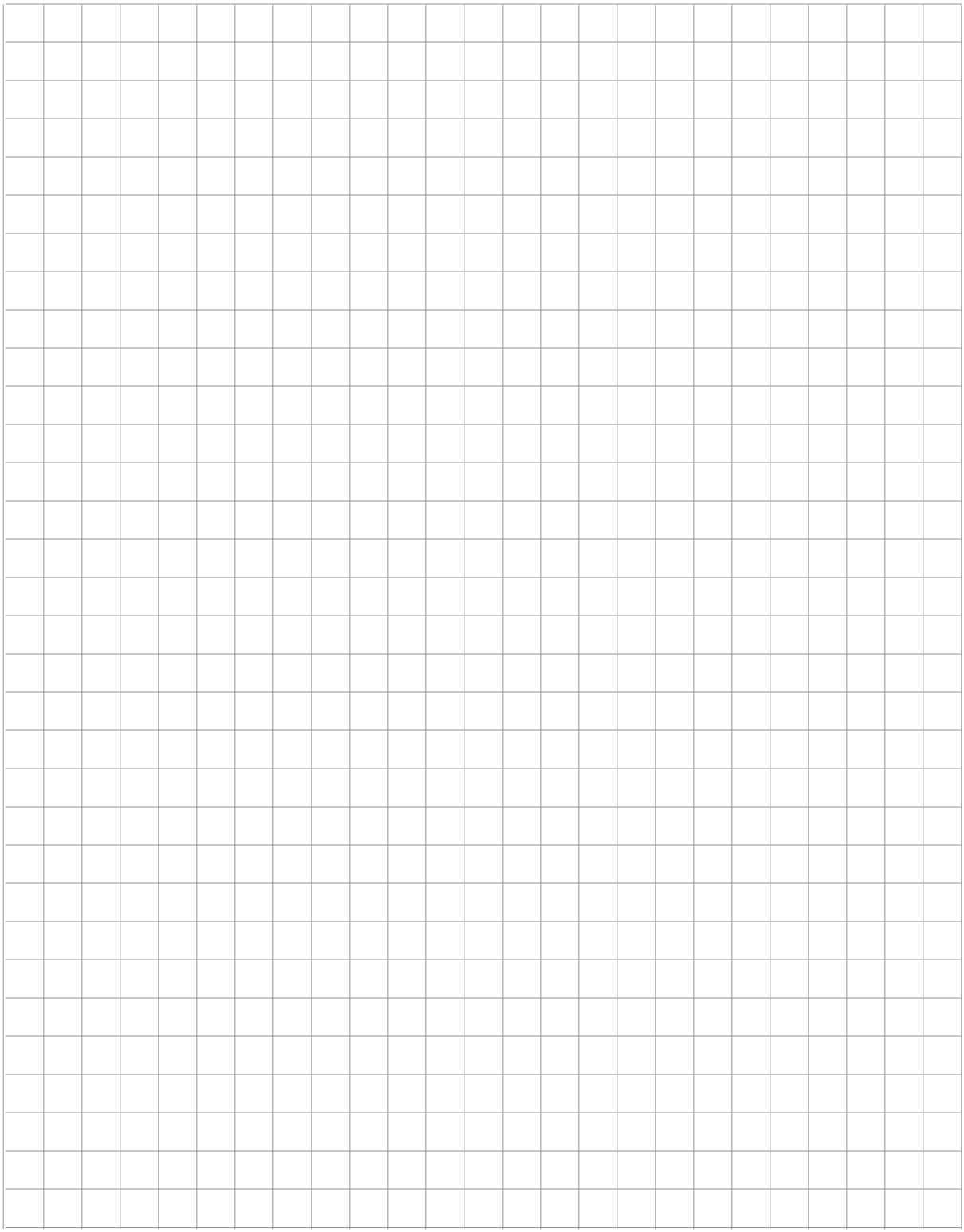
Difference	04.32 grams of moisture
Divided by	38.76 grams wet weight
Equals	0.11145 grams of moisture

0.11145 x 100 = 11.15% of moisture

Scale of moisture values:

9%	Consider putting safety procedures in place.
12%	Adobe wall approaching structural limit.
14%	Structure has probably begun slumping.

FIELD NOTES



MONITORING CRACKS IN ADOBE WALLS

Structural cracks may be caused by seismic activity, moisture invasion, wall movement from a collapsing roof structure, lateral loads from pitched roofs, openings, removal of an earthen roof, or by poorly constructed walls. It is important to determine the structural integrity of the wall. This section shows how to determine whether the condition that caused the crack is a continuing problem or whether it is a stable condition for which a patch will suffice.

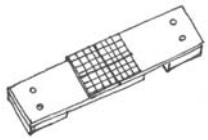
There are simple ways to determine if a crack is moving or enlarging. Draw a pencil line over the crack or at the end of the crack line, or use a plaster of Paris patch over the crack. Then, observe the changes to the pencil line or the plaster of Paris over time. The best method, however, is to install a crack monitor as shown on the following pages.

The monitor will determine cracking at a deeper level than the surface cracks and will often reveal structural problems within an adobe wall. A strain gauge/crack monitor will measure the width of the crack down to thousandths of an inch. This method is efficient for measuring both structural and non-structural plaster cracks.

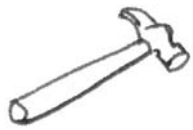
Adobe has a natural expansion/contraction cycle that is daily and seasonal. Hard plasters such as cement hide many problems that mud plaster does not. The crack monitoring procedure described here can be used for both adobe walls covered by hard plasters and for walls covered with traditional earth or lime plasters.

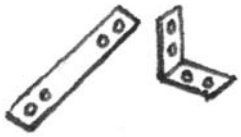
TOOLS AND MATERIALS REQUIRED

Crack monitor/ strain gauge


Crack monitor - Avongard-type

Chisel


Hammer


Metal straps

Nuts and bolts

Plaster of Paris

Putty knife

Screw drivers

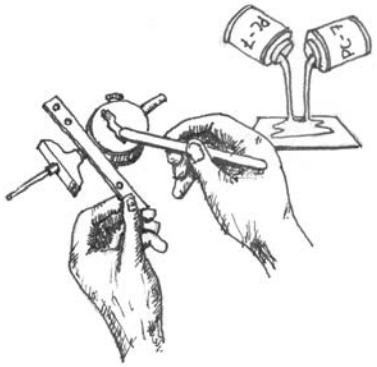
Screws (drywall and wood grip)

Washers

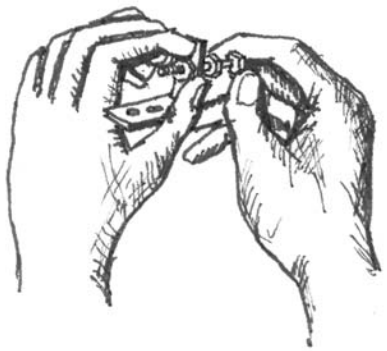
Additional materials:
Epoxy cement
Drill with phillips bit driver

MOUNTING A CRACK MONITOR

1. Open holes through plaster into the adobe wall so that the monitor can be applied on the structural wall and not on the plaster surface. This is especially important if a cement plaster covers the wall.

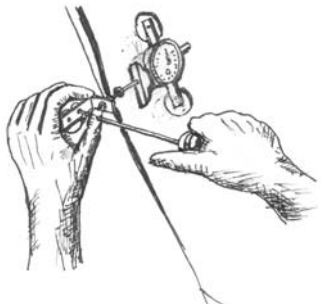


2. Using epoxy or metal bonding cement, bond a metal strip to the back of the monitor and allow it to dry.

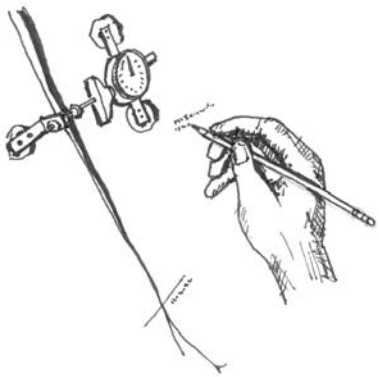


3. Place a hex bolt in a 90°-angle steel flat bar and secure with a nut on each side.

4. To prevent the monitor from resting on the wall plaster, screw the monitor into wall using six-inch drywall screws with washers to raise the level of the monitor above the surface of any existing plaster. Use drill and drive when possible.



5. Using the same process used to install the monitor to the wall, attach the angle bar to the wall using six-inch drywall screws. Insert the plunger 3/4 of an inch into the monitor by adjusting the bolt. Then adjust the hex bolt on the angle piece so that the head of the hex bolt and the end of the plunger meet.

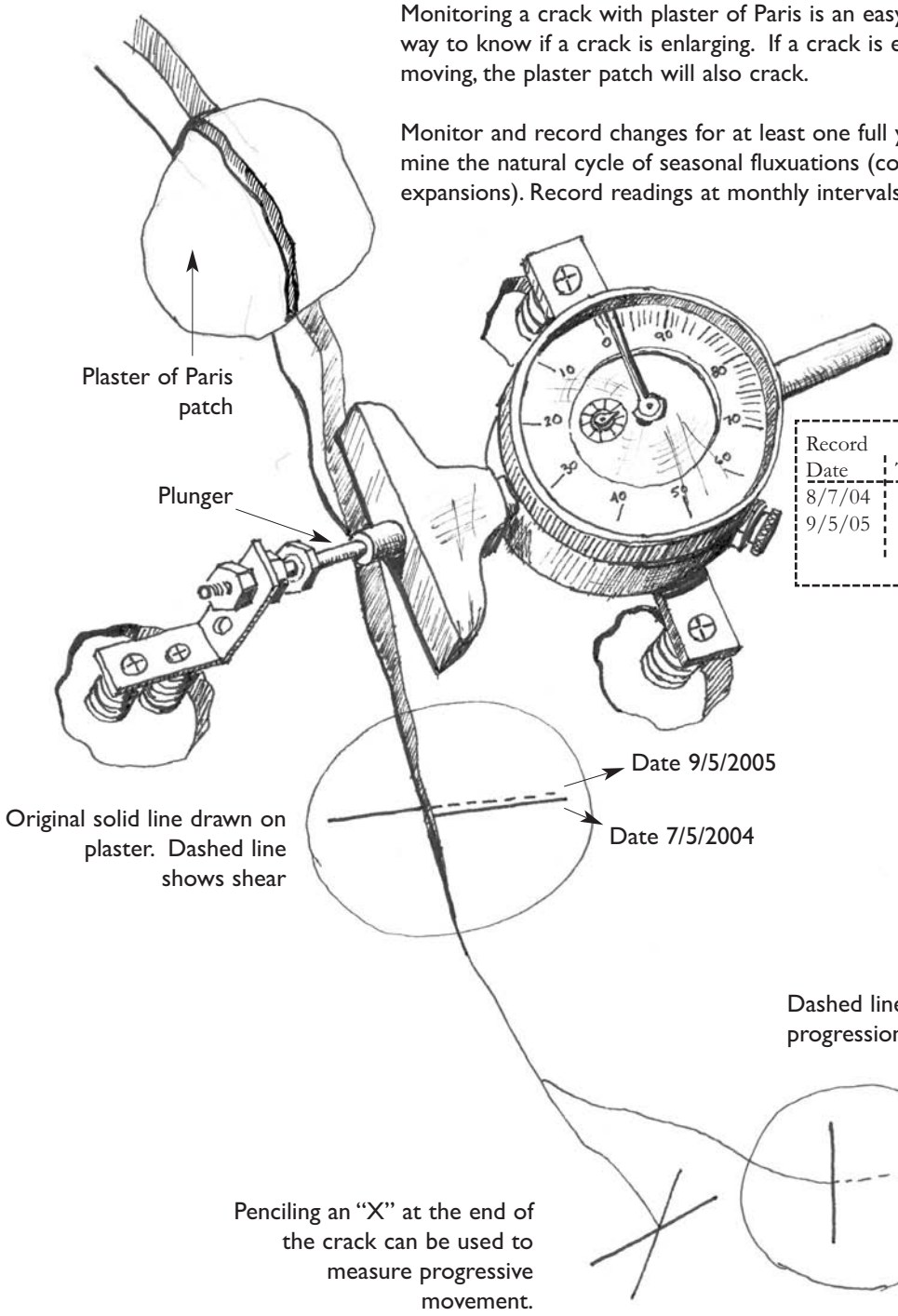


6. Record the readings for the monitor and cracks. This system will work for cracks that are opening and closing, but not for cracks that might shift. See data collection step on the following page.

ALIGNMENT
RECORDING LINES

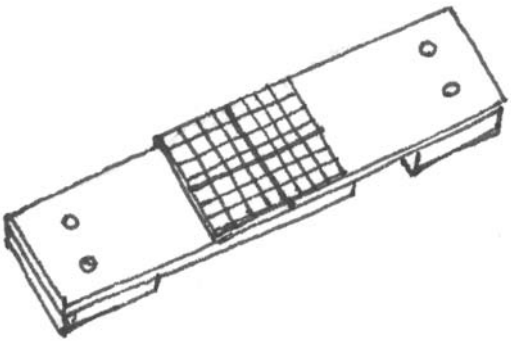
Monitoring a crack with plaster of Paris is an easy and inexpensive way to know if a crack is enlarging. If a crack is enlarging or moving, the plaster patch will also crack.

Monitor and record changes for at least one full year to determine the natural cycle of seasonal fluxuations (contractions and expansions). Record readings at monthly intervals.

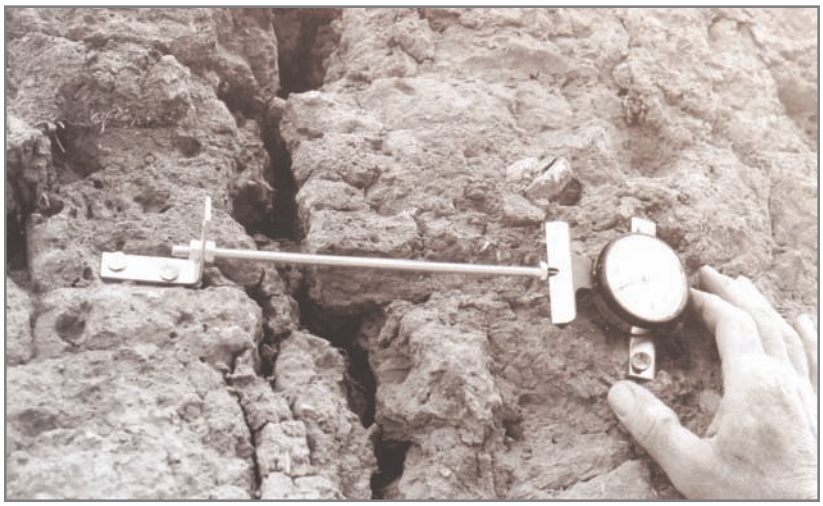


AVONGARD-TYPE CRACK MONITORS

Using an Avongard-type crack monitor is an option that may be easier to use. These monitors can be glued to hard surfaces or can be mounted with screws in the same manner described for a strain gauge/crack monitor in the previous section in order to determine if movement is occurring in the wall and not just in the plaster. If cementitious plaster exists, remove a small square or rectangular section of the plaster first so that the monitor can be applied directly to the surface of the wall.



An Avongard-type monitor consists of a two-part grid system. One piece is solid white with a black grid system and the other is clear or translucent with a red cross. Used together they delineate how and where a crack is moving. Bond both pieces together with clean tape so that when installed they both start at point zero. Once applied, carefully break the tape and record the first reading. A sheet to determine movement of the monitor is included with each monitor when purchased from the manufacturer, Avongard Products USA, Ltd., (310) 587-2533; **www.avongard.com**



This photo demonstrates how a crack monitor can be installed on rough and uneven walll surfaces.

ADOBE MATERIAL SELECTION, MIXING AND TESTING

The next sections are intended to familiarize the reader with the clays, silts, and sands found in traditional adobe mixtures. Soils may vary from location to location, therefore clay, silt, and sand proportions should always be analyzed. The following sections will also provide a good understanding of soil properties and how they should be handled and mixed. These simple tests are inexpensive and fun to do.

Historically, there have been many different methods of earthen building. Adobe is the most widespread today, but it is important to be familiar with the variety of methods that are practiced as they are still found in many historic structures. Each method involves a slightly different process of material selection.

TOOLS AND MATERIALS REQUIRED

Paper cup

Pencil

Glass jar

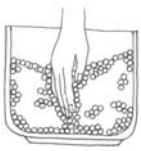
Water (potable)

Soil

Soil is composed of a combination of gravel, silt, sand and clay. Earth ideal for construction typically comes from the subsoil layer. Topsoil contains too much organic matter that continues to decompose and change over time. Topsoil can be identified by its dark color and musty smell. Topsoil should be removed over the subsoil layer and replaced after work has been completed in order to restore fertility to the ground (Norton: 3). To find the appropriate soil for earthen blocks and plasters, soil samples should be taken from different levels in the ground. Soil suitable for making adobe bricks is generally easy to mix and mold. When it is shaped into bricks, it will not warp or crack excessively while drying. The resulting bricks will be strong enough to withstand handling and have a high resistance to natural weathering (Hubbell: 26)

Remember, mixing adobe mud is an art. Fortunately, there are people in almost every New Mexican community who have the ability to 'feel' when the mixture of clay, sand, straw and water is correct. The tests and methods illustrated here can serve as reinforcement.

Sharp, angular sand is best for use in mud and lime plasters and for adobes. Grain size should be varied, especially for making adobes, mud mortar and mud plaster base coats. Try pushing your hand into a container of marbles of the same size; you will meet with little resistence. Do the same with a container filled with marbles of varying sizes and resistence is increased. When grain size in mud is too similar, its adhesion properties are diminished. The grain size of sand for use in mud plaster should have an even gradation from very fine to 1/4 inch . Pass all materials through a 3/8-inch screen when making mud plaster. Adobes may contain larger sized particles.



EARTHEN BUILDING METHODS

Adobe

Sun-baked earth bricks are made with a thick, malleable mud to which straw is often added. Straw, pine needles, and similar additions help the clay and sand particles dry evenly and bind together. Traditionally, adobes were shaped by hand or in wood or metal molds. The example shown below, from the late 19th century in Mexico City, features very large individual adobe bricks.

Cob

Cob construction, common in certain parts of England, involves stacking rounded balls of mud and lightly compressing them with hands and feet to form walls. The mud is reinforced by fibers, usually straw, grass, or twigs.

Bajareque / Jacál / Quincha

Bajareque, also known as wattle and daub, consists of a combination of high clay content mud with vegetable fibers or manure smoothed onto a lattice of cross-tied upright posts. In New Mexico this method is referred to as *jacál,* a term that originally pertained to small sheds built alongside houses.

Paredes de Cajón

This uncommon but interesting technique has only been encountered by Cornerstones' staff in the building shown here; the Oratorio de Jesus Nazareno in La Jara, New Mexico. The technique, however, may be found more frequently in Mexico where it is also known as *encofrado*. It is essentially the rammd earth *(pisé de terre)* technique described below. In this case, however, walls are erected out of stones and mud that are shoveled together into wood forms, as shown below). The material is not rammed, as is the case with *pisé de terre*. This technique has structural deficiencies, particularly at corners, which may account for its rarity.

Puddled/Coursed Mud

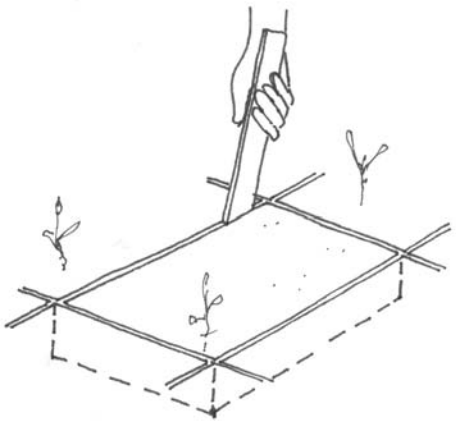
Puddled or coursed mud constructions are among the oldest earthen building methods. These two methods are very similar and often confused. Puddled mud involves a wetter consistency of mud and the use of hand-molded forms to shape a wall. Coursed mud construction involves piling handfuls of moist mud onto a wall and allowing each "course" to dry before adding the next layer.

Rammed Earth/*Pisé de Terre/Tapial*

Rammed earth architecture, most commonly referred to as *pisé de terre,* involves compacting earth in a constructed form. After compaction, the form is removed and raised to the next section of the wall being built. Popularized in the early 19th century in America by the publication of architectural "how to" books such as *Johnson's Rural Economy,* the technique was even briefly popular in the humid southern United States, where a similar technique known as tabby that used oyster shells as the key ingredient, was also practiced. Both *pisé de terre* and tabby fell out of favor in the South prior to the Civil War, by which time they were also rarely practiced elsewhere in the United States. In Latin America the rammed earth technique is known as *tapial*.

Terrón

Terrón is a Spanish term used in Mexico for sod construction. This building process creates bricks from earthen blocks that are cut from grass-covered ground found along the banks or flood plain



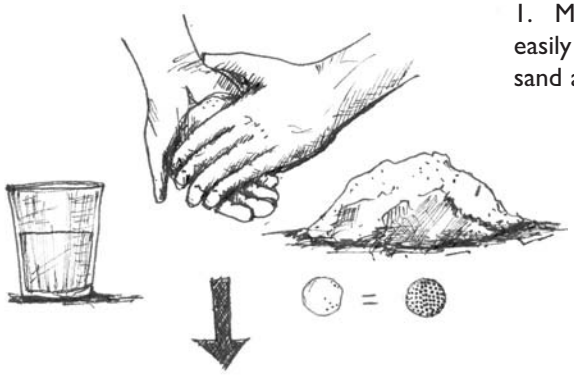
of rivers (see illustation above). The surface layer of grass and its root system help hold the brick together during the cutting and drying process. Once the *terrón* bricks dry, they are used in a manner that is identical to traditonal adobe construction. For that reason, it can be difficult to distinguish a *terrón* brick from an adobe, unless you look carefully for the remaining surface layer of grass stubble and roots that can usually be found on one surface of the brick. The photo

shown here was taken at an early 20th century barn in Bernalillo, New Mexico, which is being rehabilitated as a wine museum by the Town of Bernalillo.

Wood Frame with Mud Infill

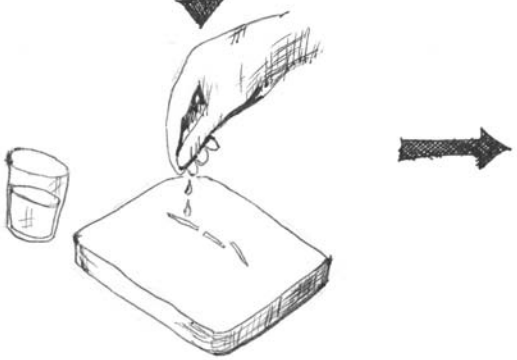
In this technique a wood frame construction infilled with mud provides the structural stability for the building. The mud acts primarily as insulation, and in this respect is very similar to the cob tradition practiced in parts of England. In New Mexico, the technique was more common to well-timbered regions, like the Mora Valley. The example shown below is from the town of Mora, New Mexico.

ADHESION/COHESION TESTING

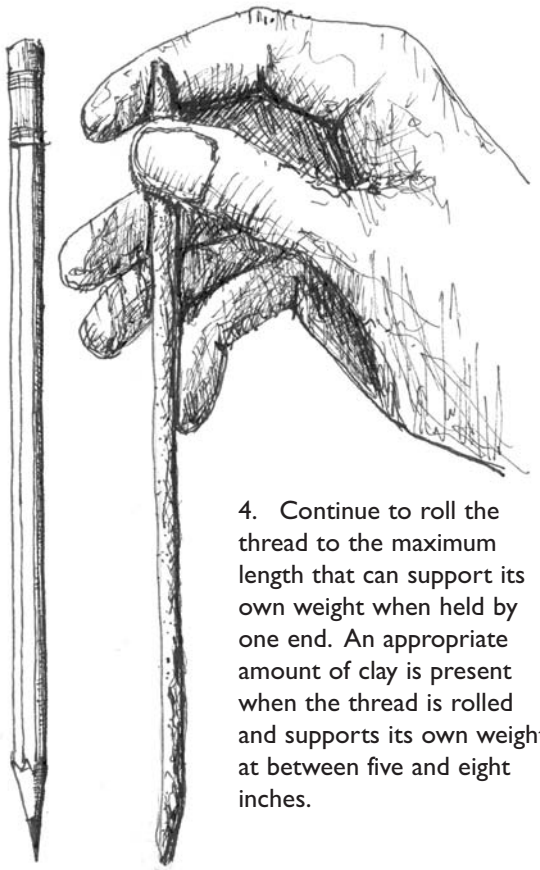


1. Mix soil with just enough water so that a lump can be easily molded in your hands. It should not be sticky. Large sand and gravel particles should be removed.

2. Roll the soil into a thread. Use the palm of your hand or fingers to exert just enough pressure to make the soil thread get continually smaller.



3. If the thread breaks before you roll it out to a 1/4-inch diameter, (the size of a pencil), it is too dry and you need to add more water.



4. Continue to roll the thread to the maximum length that can support its own weight when held by one end. An appropriate amount of clay is present when the thread is rolled and supports its own weight at between five and eight inches.

NOTE:
If the thread is sticky even with a minimal amount of water, it probably has too much clay content.

If the thread cannot be rolled to a diameter of 1/4 inch when more water is added, it has little or no clay.

If the 1/4-inch thread can be rolled to a length exceeding eight inches that still supports its own weight, it probably has too much clay.

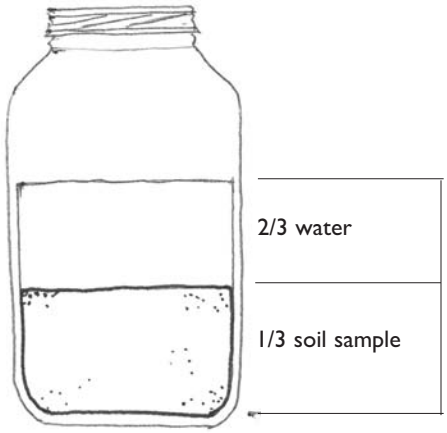
This test is dependent on the sand size as well. If the sand is predominantly coarse, then a thicker and shorter thread will result with the same amount of clay.

SHAKE JAR TESTING

"Shake Jar" testing is used to test the composition of soils or to determine the percentage by volume of silts, clays and sands in the soil.

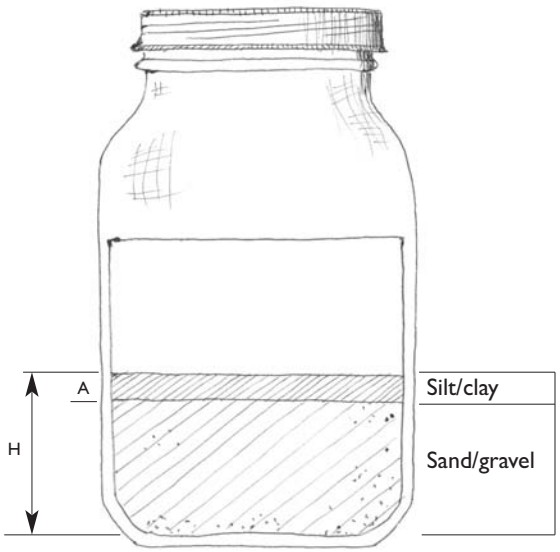
1. Fill the bottom third of a clear glass jar with the soil to be tested. Remove any particles that are larger than 1/4-inch in diameter. Then fill the jar two-thirds with water.

2. Shake jar thoroughly.



3. Allow contents to settle for one hour.

4. Shake again. Allow contents to settle for at least eight hours.



5. Observe the soil suspension in the glass jar. The largest particles or sands will settle to the bottom of the jar and the smallest particles, the clays and silts, will rest on top. A fairly distinct line between the particles will exist. Below the line, the individual sand particles can be seen with the naked eye. Above the line the clay and silt appear as a solid line.

When possible, clay should be calculated separately from silt.

The percentage of silt and clay can be calculated by measuring (A) and (H) and using the following equation: (A) ÷ (H) x 100% = (%)

20% clay to 80% silt and sand is recommended for a successful adobe mud. In some cases, however, more or less than 20% clay content has made a workable mud for adobe. Appropriate clay content will vary due to location and building method.

PLASTICITY TESTING

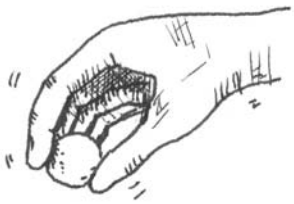
Testing for plasticity helps attain successful adhesion and cohesion properties for adobes and for mud plaster

FINGER SQUEEZE TEST

1. Work a sample of soil into a lump.

2. Roll the lump until the thread formed crumbles at 1/4-inch diameter or the size of a pencil. The thread will crumble because it dries as you keep rolling it.

3. When the thread crumbles and breaks, mold the sample into a ball.



4. Apply pressure by squeezing the ball between your thumb and finger.

5. If the ball cracks and easily crumbles, it probably contains too much sand.

6. If the molded ball can be deformed only with a lot of effort and does not crack or crumble, the soil has enough clay to be malleable and plastic.

NOTE:
Some silts can give the impression of plasticity due to their fine texture.

MAKING ADOBE BRICKS

This section describes how to make the basic building unit for traditional construction in the Southwest – sun-dried earthen bricks called adobes.

According to many historians, the Spanish first brought form-molded adobe technology to the New World. Although hand-shaped or puddled mud techniques were more common among the Puebloans during the building of such monumental constructions as Casa Grande in Arizona, recent archaeological discoveries reveal that form-molded methods were indeed practiced in the pre-colonial New World. In his *Historia General de las Cosas de la Nueva España*, written in the 16th century, a Franciscan priest named Sahagún states, "*El adobe ya era conocido por los naturales*" – adobe was already know by the natives (Kubler: 174). Recent archaeological excavation at a site on the New Mexico/Arizona border has uncovered evidence of form-molded adobe dating to around 1250 A.D. At Fourmile Pueblo Ruin in Arizona, archaeologists discovered uniform and angular adobes with no trace of human fingerprints, suggesting the use of forms, possibly dug in the ground, for making adobes,

More than 22,000 new adobes were made by hand during preservation of the mission church of Nuestra Señora de la Limpia Concepción in Socorro, Texas (Jim Gautier, 2002)

Linguistically, the word adobe can be traced back to its historic roots in the Middle East, where 9,000 year-old adobe structures still exist. The ancient Egyptian hieroglyph *tob* (or *dbt*) probably gave rise to the Arabic word *ottob*

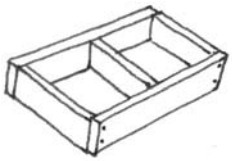
TOOLS AND MATERIALS REQUIRED

Straw

Soil

Sand

Water (potable)



Adobe brick form

Wheel barrow

Shovel

Brick layer's (mason's) trowel

(or *Al-Tub*) which traversed the Mediterranean and across northern Africa to Spain where it became adobe. The word adobe has several meanings. It can refer to the sun-dried mud bricks used for construction, as well as the mud used to make the bricks. Adobe is now also a common term for any structure made from mud-bricks in the United States.

Indigenous populations in Mexico and Peru also developed adobe technologies that paralleled the earthen building activity in Asia, Europe, and Africa. Early communities in the New World used adobe to build their homes and religious structures long before the arrival of the Spanish. The linguistic evolution from indigenous languages to Spanish again reflects the richness of the adobe heritage. The indigenous Mexican language, Nahuatl, has a word *zoquetl*, which means mud. The indigenous pueblo of Zoquitlán is thus, "the place where mud abounds". The Spanish word for mud, *zoquete,* which is used in Mexico and New Mexico, descends directly from the Nahuatl word, *zoquetl*. Interestingly, the Spanish word may be phonetically linked to the Arabic word *suquit*, which means "an object without value" (Guerrero B: 48).

As a tradition in the Southwest, the adobe building process had designated roles for the sexes to perform, with both roles being equally important. Men gathered the timbers for *vigas,* while the women made and applied the mud plaster. Early pueblo builders did not have lime for their plaster, but instead used a mixture of ashes, charcoal and mud. This ancient method of making mud plaster involved setting sagebrush and reeds on fire and then combining the burned remains with mud.

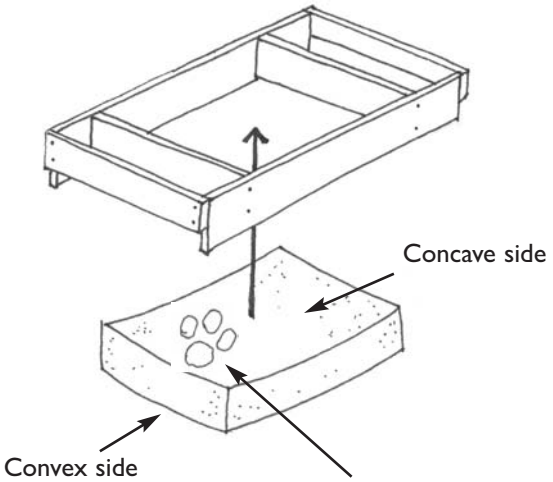
During the Pueblo period it was more common for builders to shape mud bricks by hand or by coursing rather than to use forms to mold them. In colonial times, however, the use of simple wooden molds called *adoberas* became very common. Such forms were prevalent in Spain and the Spanish brought this new technology with them to Mexico and the Southwest. Typical colonial adobe bricks measured 5 x 10 x 18 inches and weighed about 55 pounds. Standard adobe bricks in the United States today weigh much less and measure 4 x 10 x 14 inches. However, it is important to note that adobe bricks have varied in size over the years.

For best results in preservation projects, always use adobes the same size as those originally used in the building being repaired. The mix of clay and sand will also vary by locality based on the soil type. Local building tradition will indicate where the best soils and sands can be found and the correct proportions to use (see *Adobe Material Selection and Testing* above for guidelines that support this local knowledge).

NOTE: The use of non-natural additives to stabilize adobes should be avoided. Such additives are usually cement, polymers, or petroleum products. Not only are mud bricks "stabilized" in this fashion incompatible with historic adobes, they also resist the adhesion of permeable plasters (mud or lime) that work best with historic adobe structures.

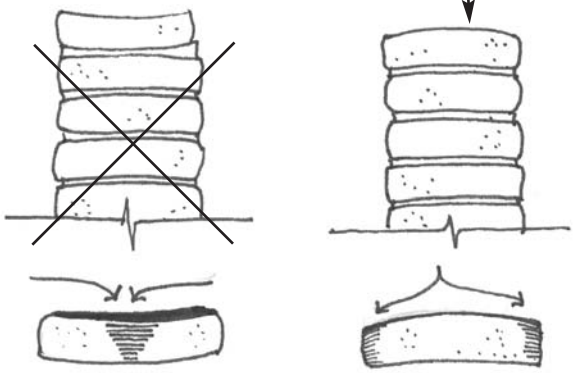
FORMING AND LAYING ADOBE BRICKS

Adobe made in a form



Footprints indicate the top or concave side of the adobe when it is cast. This side becomes the bottom when the adobe is laid.

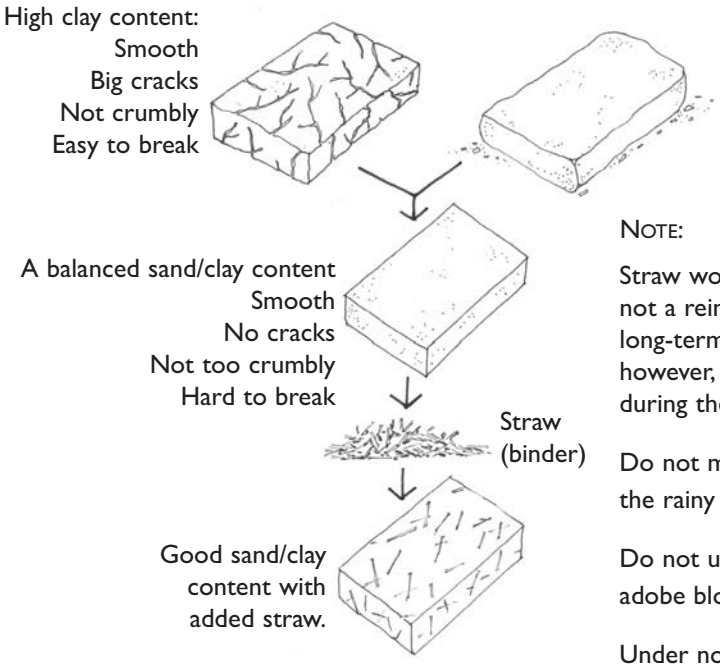
Always lay an adobe with the concave side down. This way it sits firmly in the mud mortar.



If adobes are layed with the concave side up, moisture may accumulate in the central mass.

This way water is directed downward to the inside and outside surface where it can evaporate.

Dry Adobes



Note:

Straw works as a binder to prevent cracking, but is not a reinforcement. Adobes do not have any added long-term strength because of the addition of straw; however, straw helps adobes shrink more uniformly during the drying process.

Do not make adobe bricks in the winter or during the rainy season.

Do not use mechanically pressed or amended adobe blocks when restoring an adobe structure.

Under normal conditions a curing time of 3 to 4 weeks is necessary.

MAKING ADOBE STEP BY STEP

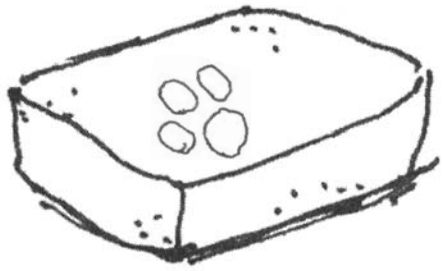
1. Mud can be mixed in a concrete motor-driven mixer or in a pit. If mixed in a motor mixer, add water before adding soil. If mixed in a pit, soak soil overnight before mixing with straw. Mix soil into a stiff/wet mud by stomping with feet if possible. If soil contains large gravel and debris less than one and a half inches in diameter, it should not be screened. If large pieces are not commonly found in soil, do not screen but remove by hand. If screening is desired, screen soil through a large grid screen. Be aware that screening may change clay to sand/gravel proportions.

2. Add straw to mud and mix. To estimate whether the mix contains the appropriate amount of water, make a three-inch deep groove in the mix. The sides of the groove should bulge, but not flow together.

3. The form should be perfectly smooth and clean. Soak the wooden form with water. Level the forms on the site and place mud in the damp form.

4. Force mud into the corners of the mold by hand. Fill voids and strike the surplus mud from the top using your hands or a dampened piece of wood as a screed bar.

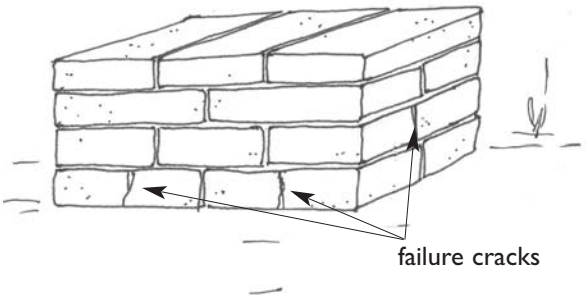
5. Slowly lift the form straight up from the adobes. If surface cracks appear on the adobe, immediately sprinkle water on the top and smooth. Do not let the empty form to sit too long with mud on it. Wash the adobe form before reuse.

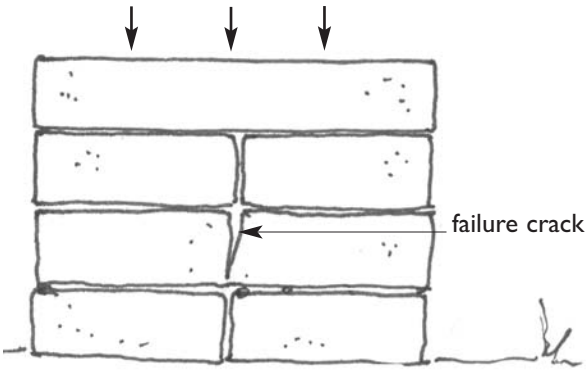


6. The top of the brick sags as it dries. This concave side becomes the bottom when it is laid. If a puppy walks across your bricks while they are drying, lay the side with the paw prints facedown!

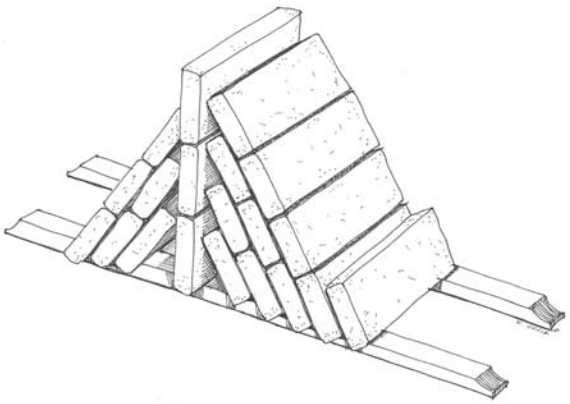
7. Leave the adobes undisturbed for three or four days. Stand them on their long edge once they are dry enough to handle without breaking.

8. Allow the adobes to dry on their edges for at least ten days to two weeks depending on the weather. Arrange in a zigzag pattern to prevent the "domino" effect if one should happen to fall over. Scrape any loose material from the bottom of the adobes. Once dry, a brick-layer's trowel may be used to clean the surface, corners and edges of the adobes.





9 and 10. These diagrams show the incorrect way of stacking adobes. Adobes are not always uniform in thickness. Incorrect stacking applies loads at points where the adobes have peaks and valleys.



11. This diagram shows the correct way of stacking adobes. Leaning adobes against each other diagonally applies less weight to the bricks while drying.

12. Stack the adobes loosely and protect the top of the pile with a tarp, roofing metal, or plywood weighted with stones, dirt or concrete blocks. Do not seal the entire pile. The adobes must breathe.

FIELD NOTES

PART THREE

HOW TO PROCEED

INSTALLING A SUBSURFACE DRAINAGE SYSTEM

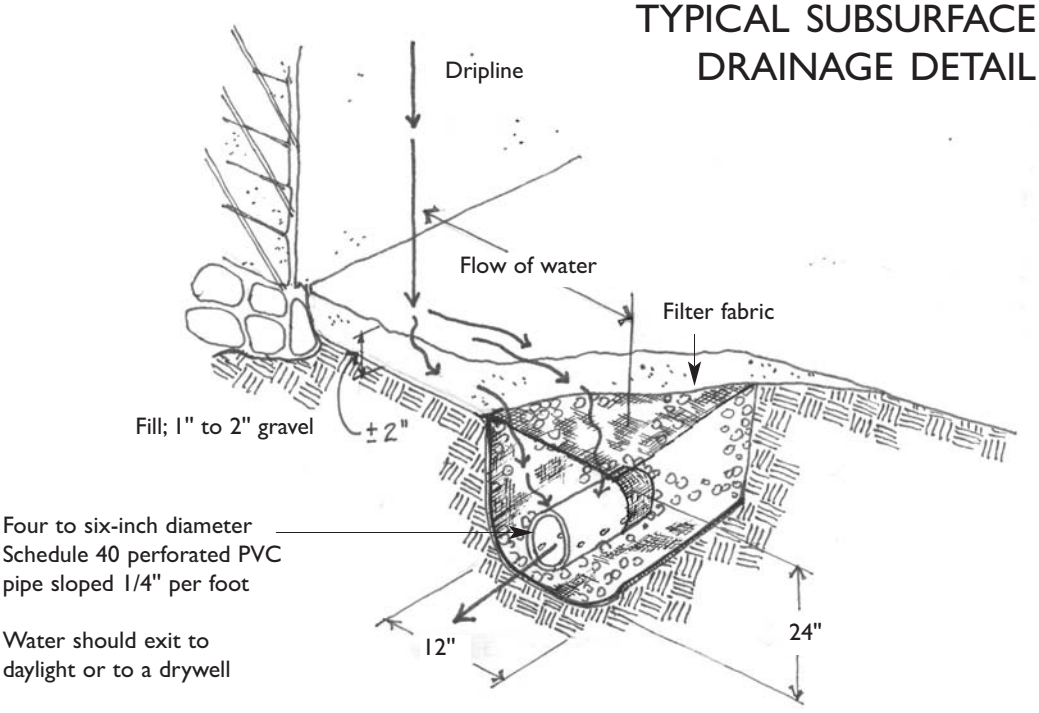
Many historic earthen structures in the Southwest are built without footings or are built on footings of river cobbles or ledge stone set in mud mortar. Whenever an earthen wall is in contact with wet ground, wicking or capillary action draws moisture into the wall. Long-term moisture entrapment causes adobes to lose their structural integrity. The wall will slump and may eventually collapse.

Broken gutters and downspouts, broken and leaky plumbing, a high water table, invasive vegetation, improper drainage and man-made ponds will also lead to deterioration in earthen walls. Other possible causes of drainage problems are the addition of concrete sidewalks and roads or pavement near the structure. These new infrastructures change the way the land naturally drains and thus cause erosion at the base of earthen walls.

This section describes how the installation of a subsurface drainage system reroutes runoff away from a building and prevents water from penetrating its walls.

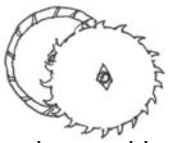
NOTE: Before digging, make sure the area is not an archaeological site or grave site (see Part One, *Archaeological Sites and Burial Grounds*).

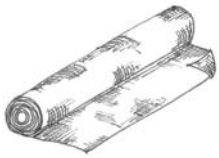
TYPICAL SUBSURFACE DRAINAGE DETAIL

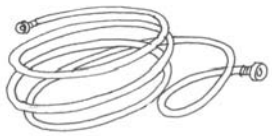


TOOLS AND MATERIALS REQUIRED

Circular saw


Circular saw blade, diamond blade


Filter fabric


Garden hose

Gas container

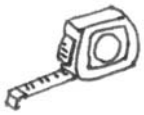
Gloves

Goggles

Gravel

Handsaw

Level


Measuring tape

Pick

PVC cement

PVC pipe

PVC fittings

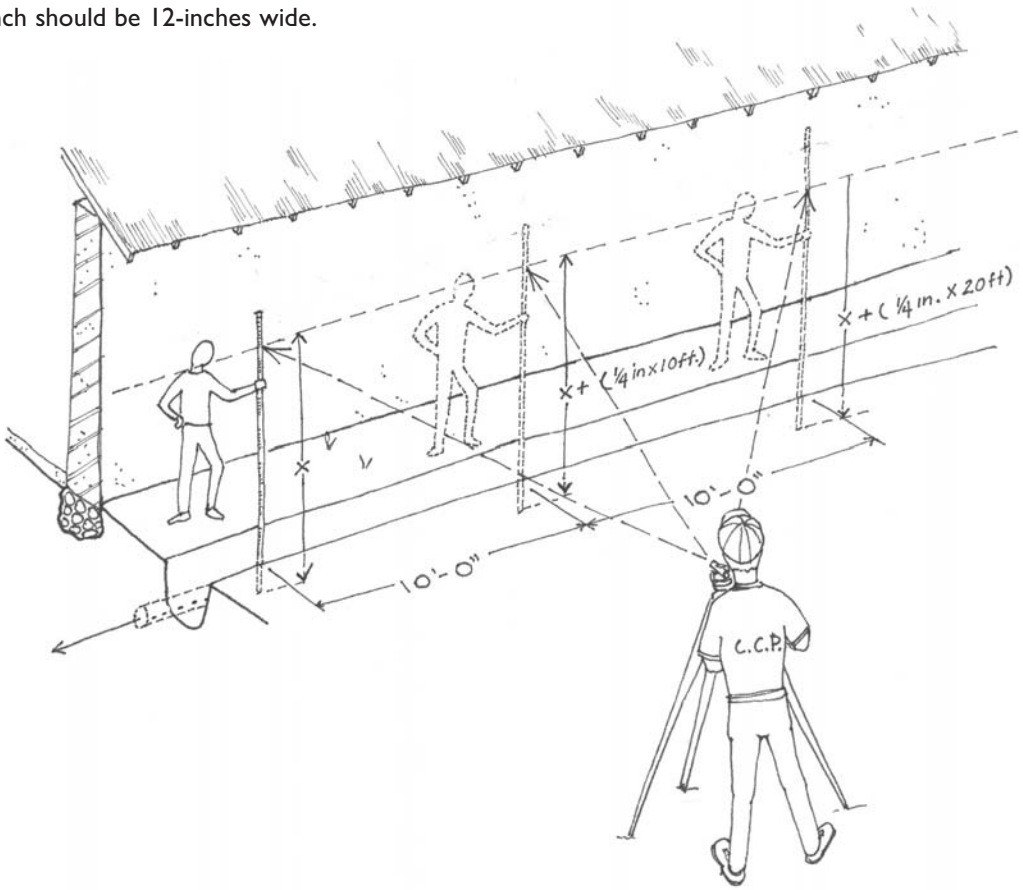
Shovel

Surveyor's level

The following steps outline how to install a subsurface drainage system.

1. Dig a trench four feet away from the base of wall around the entire building.

2. Trench should be 12-inches wide.

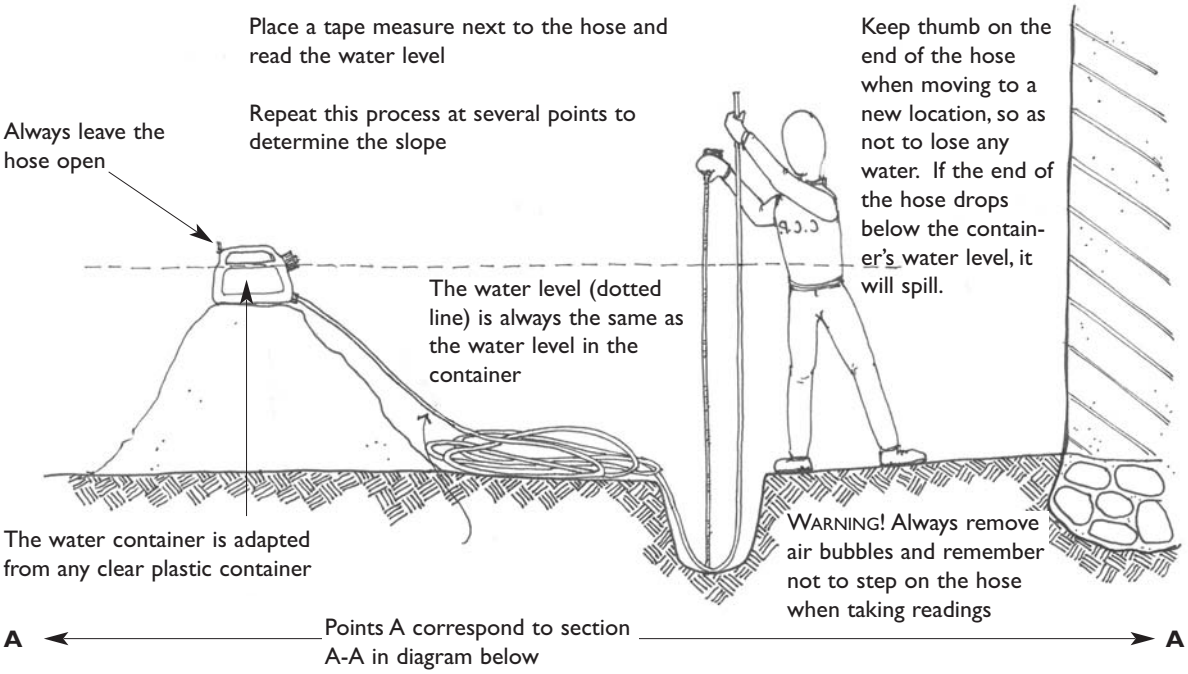


3. Shoot grade to achieve 1/4 inch per foot slope for positive drainage.

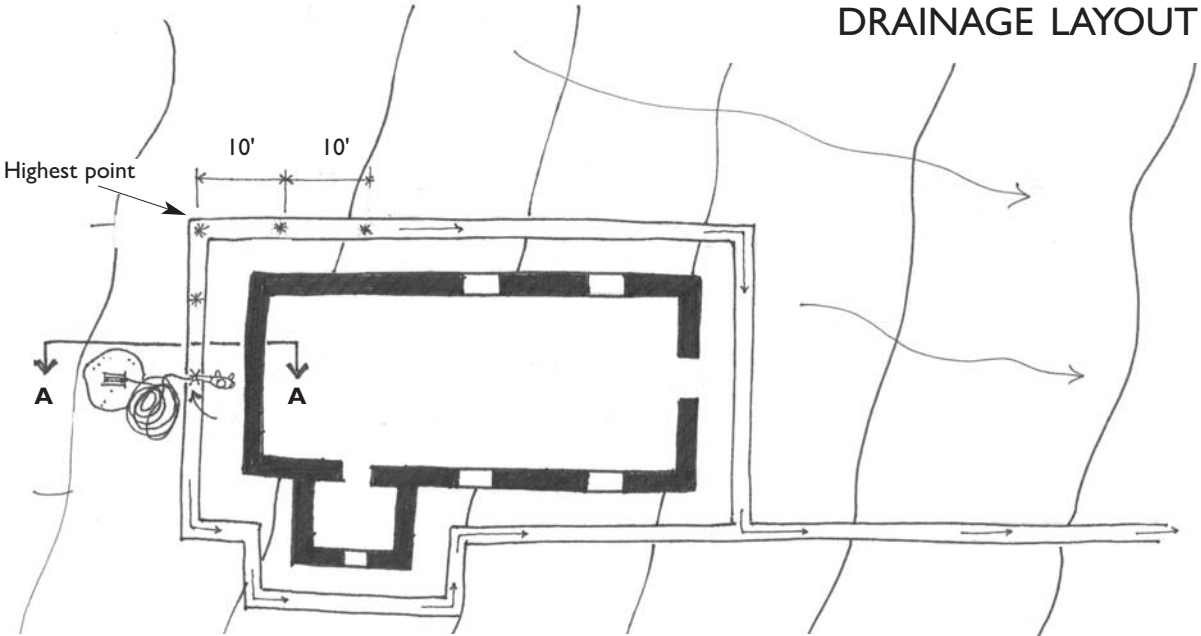
SIGHTING MEASUREMENTS

USING A "BLIND" OR WATER LEVEL

Using water as a level is an ancient technique. This method is a less expensive alternative to using a builder's level.



A TYPICAL SUBSURFACE SITE DRAINAGE LAYOUT



If using a water level, take the first reading at the high point. If a 1/4 inch per foot slope is desired, the readings should increase by two and a half inches for every ten foot increment. Begin at the high point and move in both directions down the slope and around the structure.

For example: (Intervals) X (Slope per Foot) = (Slope per Interval)
(10 ft.) X (1/4 in.) = (2 1/2 in. / 10 ft.)

5. Clear the dirt and rubble away from the trench and create the correct slope.

6. Line the trench with geo-textile or filter fabric.

A TYPICAL SUBSURFACE DRAINAGE DETAIL

A level can be used to check the slope of the perforated pipe.

If a 1/4 inch per foot drop is desired, use a two foot level.

You will have a half inch between the end of the level and the lower end of the pipe.

7. Layer the bottom of the trench with a few inches of gravel to obtain correct slope.

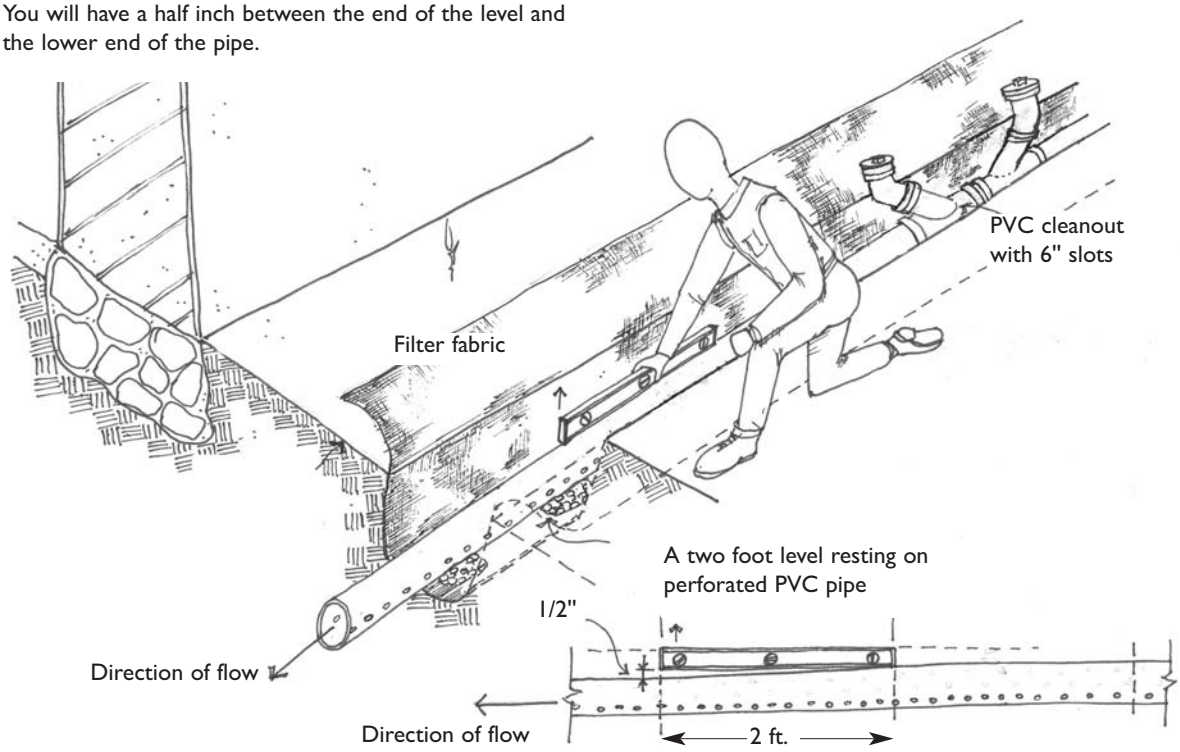
8. Lay Schedule 40 perforated PVC pipe in the trench, using a filter fabric sock outside the pipe if a double filter is desired. Install cleanouts. The last ten feet of the pipe should not be perforated. Use standard 40 PVC pipe and take it to daylight.

9. Check your level again and apply a second layer of gravel over the PVC pipe to top your trench with gravel.

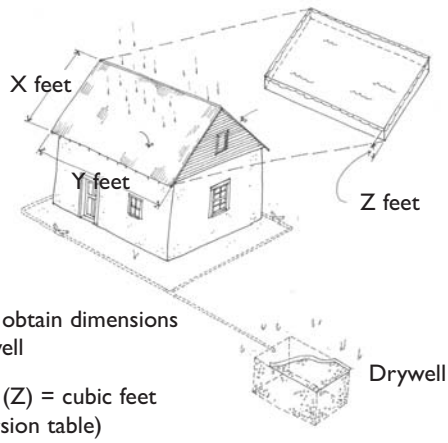
10. Fold the excess filter fabric over the gravel-filled trench. Make sure you get a good overlap.

11. Once the filter fabric has been installed, fill the trench with gravel.

12. The end of the pipe should be taken to daylight. If that is not possible, take it to a drywell. If the pipe runs to daylight, screen it off with galvanized screen to prevent animals from nesting in the pipe.



DESIGNING A DRYWELL FOR THIRTEEN INCHES AVERAGE ANNUAL PRECIPITATION

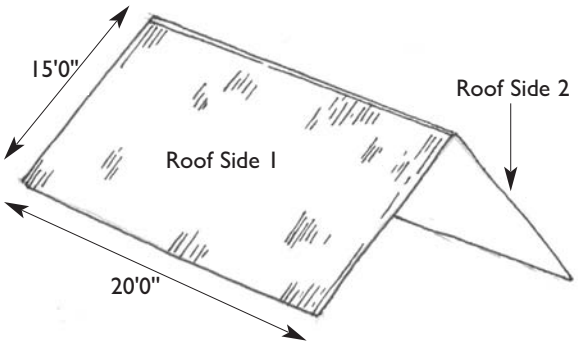


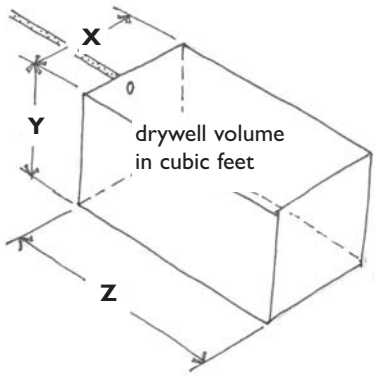
Formula to obtain dimensions of the drywell

(X) x (Y) x (Z) = cubic feet
(see conversion table)

Conversion Table

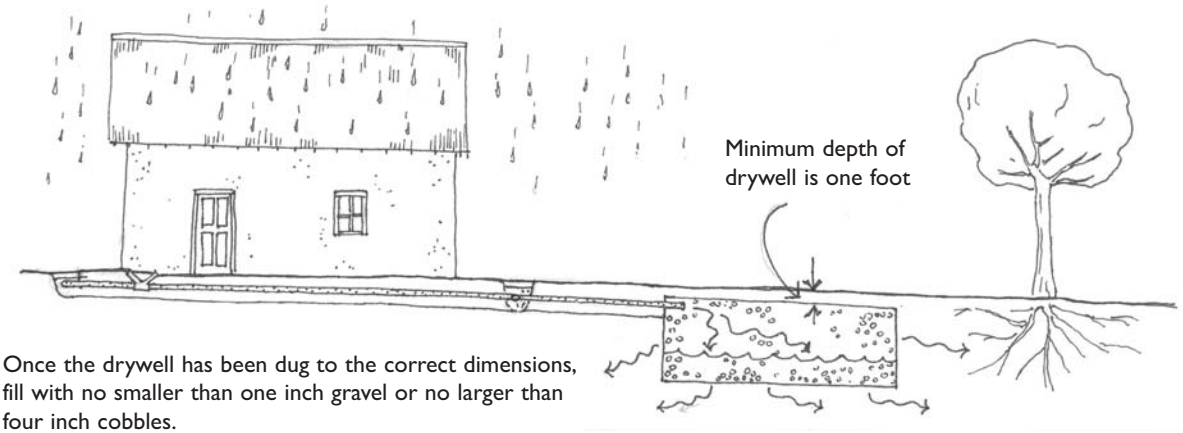
4 inches	=	.33 feet
5 inches	=	.41 feet
6 inches	=	.50 feet
7 inches	=	.58 feet
8 inches	=	.66 feet
9 inches	=	.75 feet
10 inches	=	.83 feet
11 inches	=	.91 feet
12 inches	=	1.00 feet
13 inches	=	1.08 feet
14 inches	=	1.16 feet
15 inches	=	1.25 feet
16 inches	=	1.33 feet
17 inches	=	1.41 feet
18 inches	=	1.50 feet





To determine sample drywell size:
(15'0") x (20'0") x 2 sides of roof = 600 sq. ft.
(600 sq. ft.) x (13" precipitation) = 648 cu. ft.
(600 sq. ft.) x (1.08 ft.) = 648 cu. ft.

Example:
(X ft.) x (Y ft.) x (Z ft.) = cu. ft.
(6 ft.) x (9 ft.) x (12 ft.) = 648 cu. ft.



Once the drywell has been dug to the correct dimensions, fill with no smaller than one inch gravel or no larger than four inch cobbles.

NOTE: Drywell cannot be too near trees.
A cistern may also be created to collect the water.

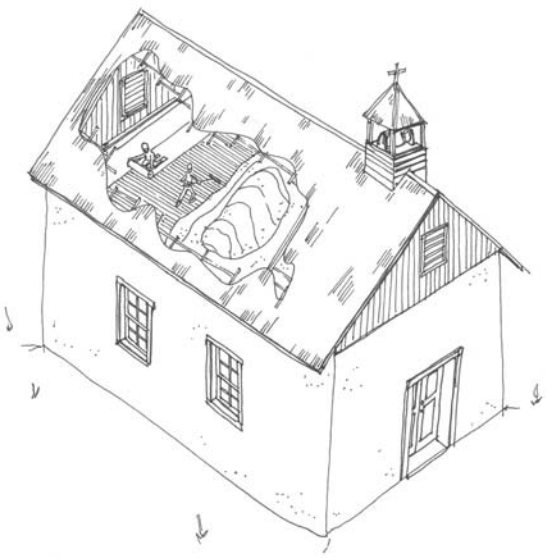
CLEANING THE ATTIC

When metal roofing and wood shingles became available, new pitched roofs were often installed over the original flat earthen roofs on many buildings. Most new churches and buildings built after the railroad arrived in the 1880s had such pitched roofs. Even after installing a pitched roof, many builders kept or added to an existing earthen roof for insulation purposes. The earliest pitched roofs in northern New Mexico were covered with sawn boards running with pitch and narrow battens covering the joints. This type of roof is called "board-and-batten."

Typically, New Mexican roofs were constructed in a series of layers. *Vigas* or beams provided structural support for the second layer, referred to as *latillas* (peeled branches) or *rajas* (hand-split poles). In later years when lumber was made readily available, rough sawn lumber replaced the *latillas* and *rajas*. Brush such as yucca, or other local plants including cattails or *carrizo/tule*, prevented the final earth layer from sifting down through the boards. The dirt layer was applied in thin layers and compacted over the brush.

Many historic structures have drop ceilings that were added during remodeling. Materials such as linen *mantas* or pressed metal and, in recent times, paneling and acoustical tiles are often found. *Mantas* were typically painted with lime that would shrink and tighten the cloth, giving it the appearance of a plaster ceiling.

The *torta,* or dirt layer, provides stability to the walls, helping keep them in place by distributing the load down to the walls. The *vigas* act as tie rods helping keep the adobe walls together. If the *torta* is removed, the bonding of the *vigas* to the walls may be compromised causing an unstable condition.



Church attics are favorite nesting places for pigeons and bats that enter through the bell tower or unscreened ventilation openings. The resulting accumulation of droppings, guano, and litter not only adds weight to the ceiling structure but is also a source of corrosion, moisture retention and bacterial infection. To rid the attic of bats or pigeons before beginning the cleaning process, follow their daily flight pattern and use a ventilated screen to cover their entry point. Choose a screening method that has the least adverse visual impact. Remember to be attentive to nesting season so as not to trap nestlings or pups. Bat Conservation International in Texas has more information at (512) 327-9721.

WARNING: Always use protective eyewear and a high-quality facemask to protect against dust and the bacteria in animal droppings.

TOOLS AND MATERIALS REQUIRED

Broom

Dust mask

Flashlight

Gloves

Goggles

Halogen light

Measuring tape

Plastic (6 and 5 mil)

Roofing felt

Shovel

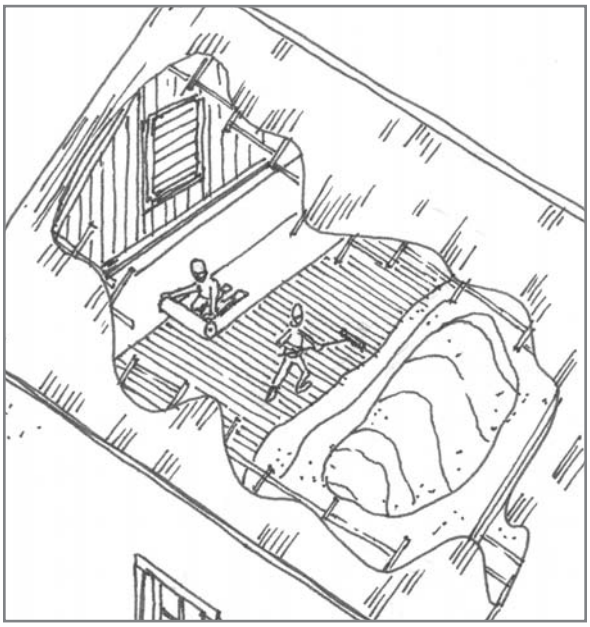
Utility knife

Wheel barrow

The following section shows how to remove pigeon or bat droppings from the attic and how to install a protective membrane under the *torta* to prevent dust from sifting through the decking.

1. Carefully remove pigeon droppings to expose the *torta*. The pigeon droppings and debris can be taken out through the roof by removing a sheet of corrugated metal, or through the gable end if it can be opened. Always wear a mask when working around pigeon and bat droppings.

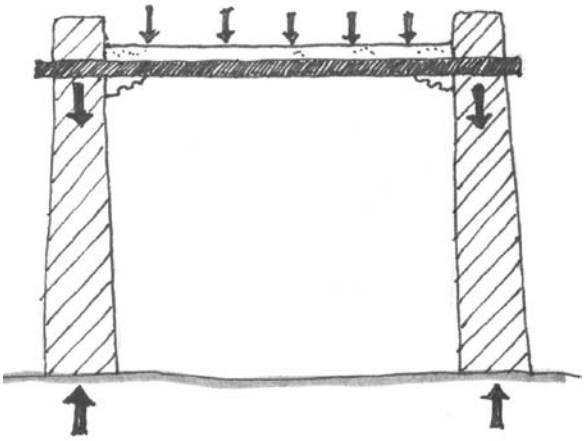
2. Dig a hole in the *torta* to expose the wooden deck. Measure the depth of the *torta*.



3. The *torta* should be removed from one end of the building and piled adjacent to the exposed area. Work in sections from one end of the attic to the other.

NOTE: Before removing the *torta*, document the layers and if possible the type of soil used for them. This information will reveal both how the roof was constructed historically and how it can be recreated.

4. Sweep and clean the exposed wooden deck. Cover the deck with 15 lb. geo-textile with an 8-inch to 12-inch overlap. Take the dirt piled on the opposite end and distribute over the geo-textile. This will decrease dust infiltration between deck boards over time (see Part Three, *Earthen Roofs* for more information). Keep in mind that you may encounter cultural materials (historic or prehistoric artifacts) as you work with the dirt. Although these artifacts will have lost their original setting or provenance, they may still provide important information about the building and the people who created it.



5. Whenever possible retain the *torta* layer. Its weight provides stability to the walls and prevents outward movement. It also provides insulation. The load should be kept similar to what it was before the *torta* was removed, as long as the *vigas* are not deflecting. Slowly layer the dirt, compacting it with small amounts of moisture, not wet mud. If too much water is added to the mud layers, the weight may becomes too much for the *vigas* to bear.

SAFETY ISSUES

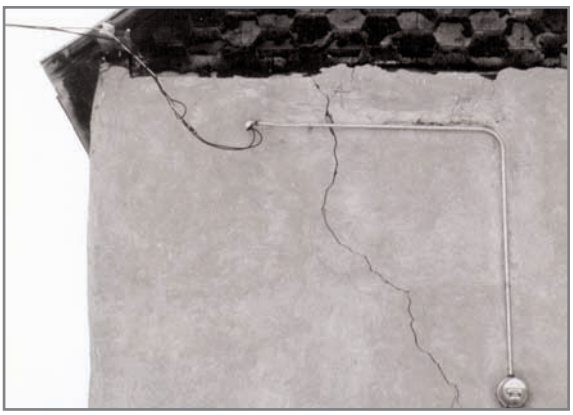
Bat and bird droppings, which by nature are both alkaline and acidic, can wreak havoc in an attic and will promote decay of wooden elements. When the droppings are disturbed, the dust that is created is extremely dangerous to inhale. Always wear a face mask, or if necessary, special respirators. Avoid creating more dust then is necessary by removing any doppings is a slow and carefull manner. (Bernard M. Felden, *Conservation of of Historic Buildings:* 151)

When the attic has been cleaned, take steps to prevent reinfestation by birds and bats by closing up or appropriately screening any openings, even those that seem very small.

FIELD NOTES

REMOVING CEMENT PLASTER

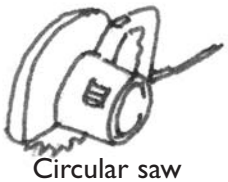
Early in the 20th century, plaster began to replace traditional mud and lime plaster to a large extent. Cement is less permeable than "softer" plaster materials and tends to trap moisture within adobe walls. As moisture rising from the ground and through the foundation is trapped, the moisture content increases and the wall loses strength. Eventually it will slump (see Part Two, *Moisture Testing in Adobe Walls* for more information).

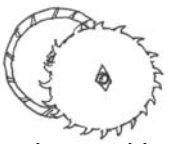


TOOLS AND MATERIALS REQUIRED

Axe

Chisel

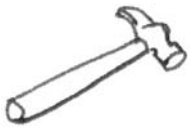

Circular saw


Circular saw blade, diamond blade

Dust mask

Gloves

Goggles


Hammer

Hard hat

Pick

Pliers

Scaffolding

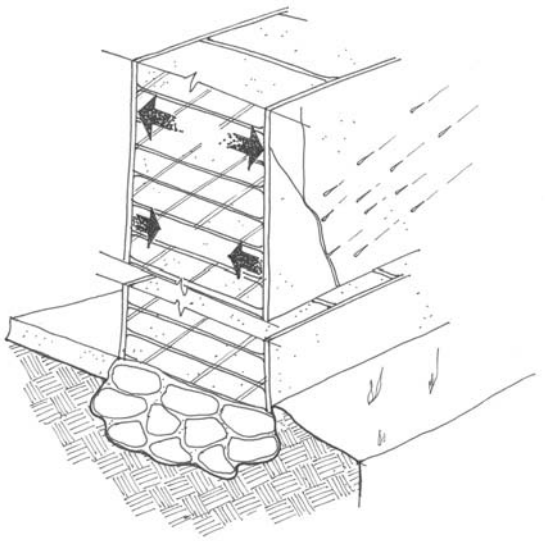
Sheet metal shears

Shovel

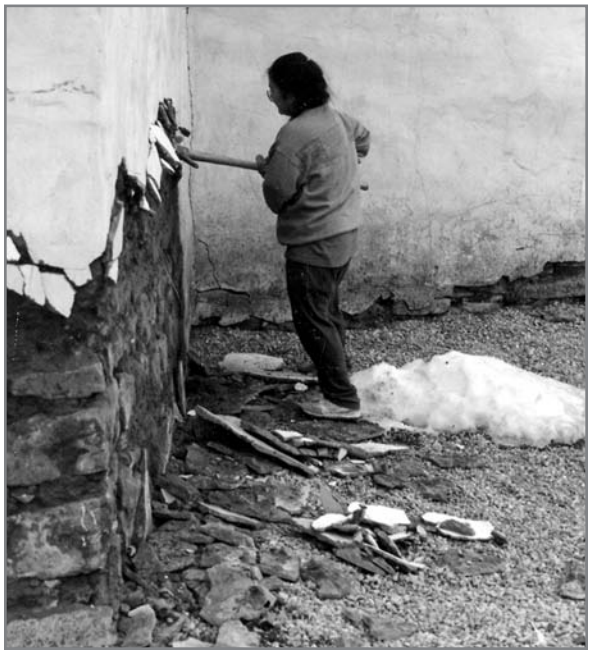
Wheel barrow

Wrecking bar

CEMENT PLASTERS



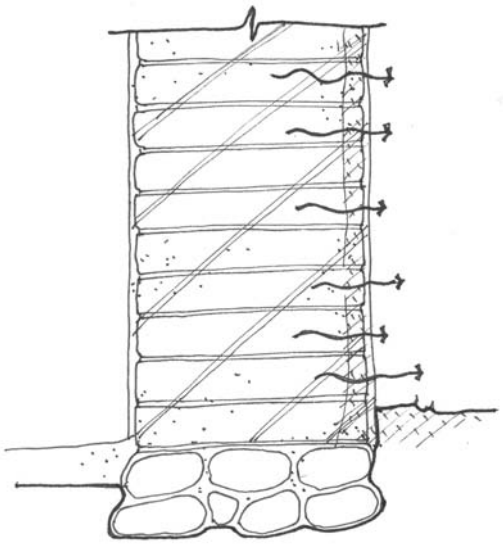
When a rigid cement plaster is applied to an adobe wall there is a high probability the plaster will crack from the thermal expansion of the wall mass. The incompatible plaster will create cracks where water can penetrate. Cement plaster moves at a different rate than does adobe when the temperature changes. This differential is a major cause of cracks in cement plaster.



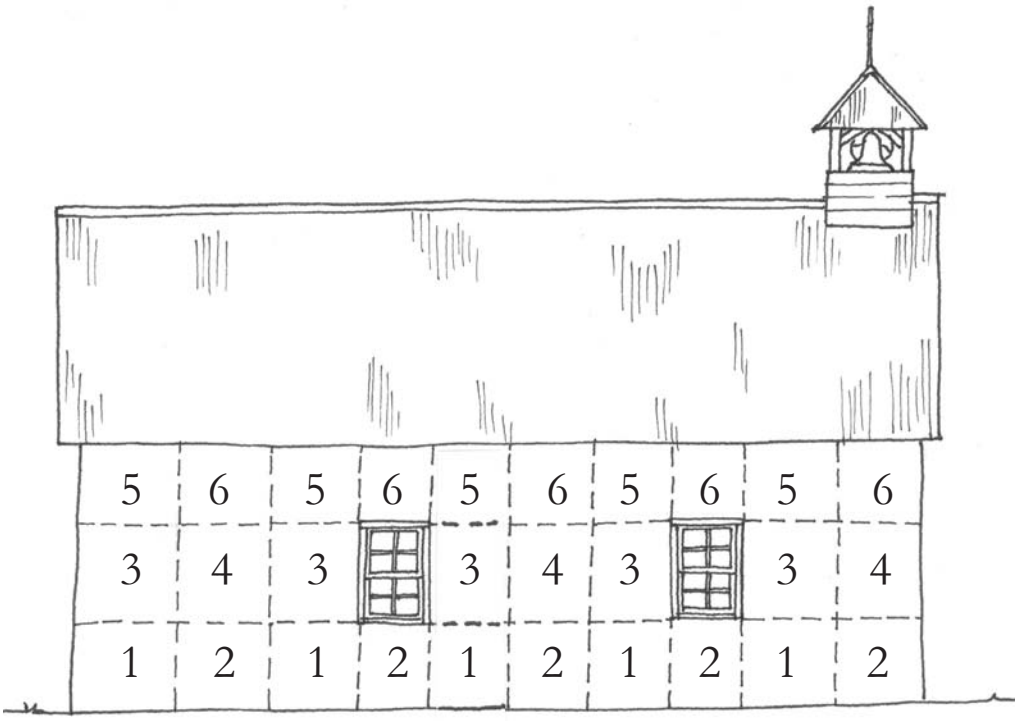
After the cement stucco has been cut into small (two- to three-foot) square sections, the plaster can usually be removed easily by using a wrecking bar to pull the plaster and wire lath away from the wall. If the adobe walls are wet, safety precautions should be taken.

NOTE: Use protective eyewear and a mask to protect against dust and flying particles.

MUD AND LIME PLASTERS



Mud and lime are more compatible with the thermal qualities of adobe. Mud and lime plasters, conversely, are permeable materials that allow the adobe walls to dry when wet.



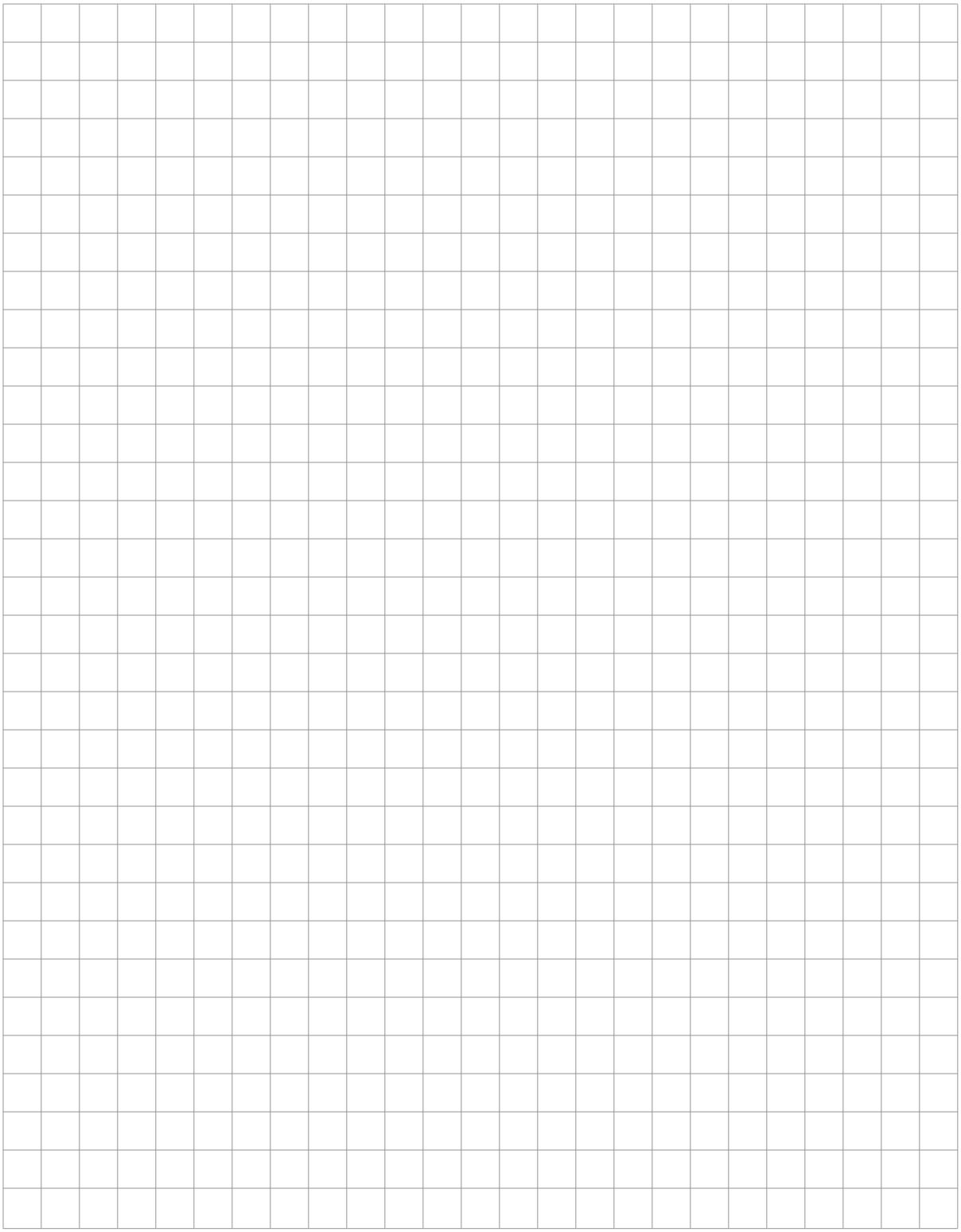
A small (3 feet by 3 feet maximum) cement plaster section at the base of the adobe wall should be cut and removed to determine the wall conditions. If the walls are either very wet or have lost more than 30% of their thickness at the base, safety shoring should be erected to carry the weight of the roof before removing any additional plaster from the walls (see Part Two, *Emergency Shoring* and *Repairing and Restoring Adobe Walls*). When shoring is in place, alternating sections of plaster can be removed. This will protect workers if there is a large delamination of material from above. These areas need time to dry before removing the remaining the plaster at this level. Reconstruct any deteriorated areas and replace adobes from the ground up. Place additional wall shoring along the vertical plane as needed.

Strong, hard plaster may need to be cut into manageable sections with a circular saw and diamond-toothed masonry blades. The first priority is to remove the cement without damaging the adobe building!

Sections of the wall plaster can be safely removed only after the basal repairs (including removal of the *contra pared*) are accomplished. When removing cement plaster from a wet wall, carefully remove it in two feet by two feet or three feet by three feet sections. The sections should be randomly spaced according to the diagram shown above. Work from bottom to top.

Allow each section to dry for one to two weeks if it is wet before continuing the process. If the walls are wet and all the plaster is removed, the walls may tend to shift while drying and the adobe wall might structurally fail.

FIELD NOTES



REMOVING A CONCRETE *CONTRA PARED*

A concrete *contra pared* (sometimes called a collar or apron) installed next to wet or eroded historic adobe walls may cause or exacerbate existing moisture problems. Most historic adobe structures were built over stone foundations laid in mud mortar or with no foundations at all. These walls may absorb the ground moisture through capillary action and the problems may only increase if a concrete *contra pared* is installed.

Concrete is a nearly impermeable material and does not allow adobe walls to dry when wet. Should the *contra pared* detach from the wall, the resulting gap or crack will allow water to penetrate and damage the adobes. Since concrete is a less permeable material, moisture in the base of the wall is retained. If not corrected, this may lead to loss of structural stability and collapse.

Signs of moisture activity in walls resulting from the application of cement plasters or concrete *contra paredes* are: water stains at the base of the walls, spalling paint, brittle plaster, the base of the wall slumping inward or outward over the *contra pared*, and cracks. A whitish residue on the surface of the walls (efflorescence) is an indictor of prolonged periods of dampness.

Other structural elements intended to bring stability to a wall are *contra fuertes* or buttresses. When these elements are constructed of concrete or stone laid in cement mortar, or when they are coated with cement plaster, they can harm adobe just like a *contra pared*.

There are two primary methods for removing a concrete *contra pared*. The method selected depends partly on its size and manner of construction (river rock, solid cement, rebar etc). The first involves underpinning the *contra pared* by hand and removing it in sections if it is small,

loose and weak. The second requires the use of a material called Betonomite®, a commercially available material comprised of a naturally-expansive clay called bentonite that contains special additives. The following section describes how to remove a *contra pared* with Betonomite®.

As water is added to it, Betonomite® swells and splits the concrete in the *contra pared* allowing it to be removed in sections. This same technique can be applied when removing concrete *contra fuertes* and slabs (see Part Three, *Installing Earthen Floors*).

When removing a concrete *contra pared* from an adobe structure, it is very important to use a technique that does not vibrate the adobe walls. Using a very large sledge, jackhammer or backhoe to remove concrete is likely to destroy or damage the adobe walls.

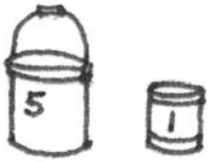
Keep in mind that careless or improper use of Betonomite® can cause serious damage to the stability of the wall against which the element is located. If you have concerns or doubts about the use of Betonomite®, please feel free to call Cornerstones at (505) 982-9521 for advice. One of our program managers with experience in its use will be happy to speak with you.

NOTE: Be aware that you may encounter rebar inside a contra pared. Use caution because drill bits may catch on the rebar whipping the drill out control, possibly causing serious injury.

TOOLS AND MATERIALS REQUIRED

Betonomite®

Chisel



Containers

Drywall compound mixer

Dust mask

Gloves

Goggles

Masonry drill bit

Maul

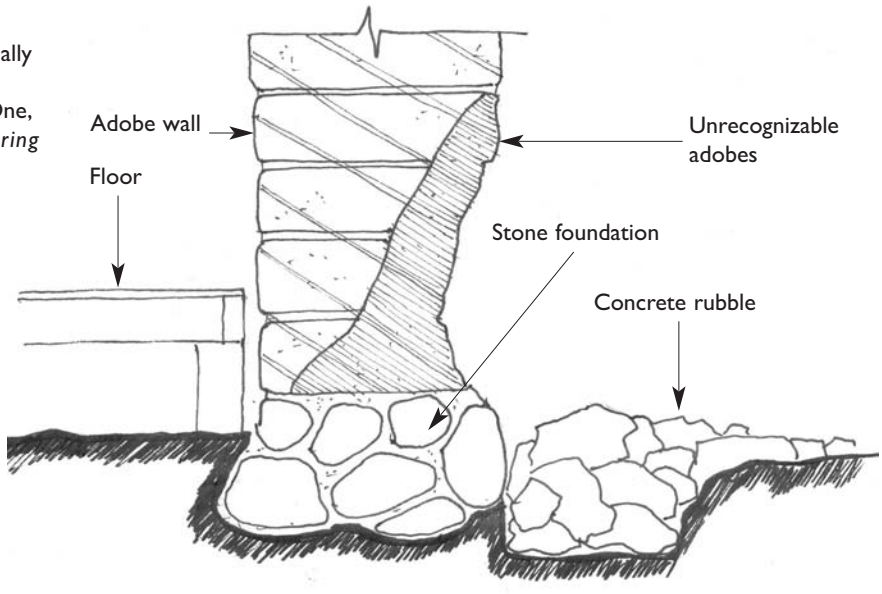
Rotary hammer drill

Sledge hammer

Water (potable)

WHAT TO EXPECT WHEN REMOVING A CONCRETE *CONTRA PARED*

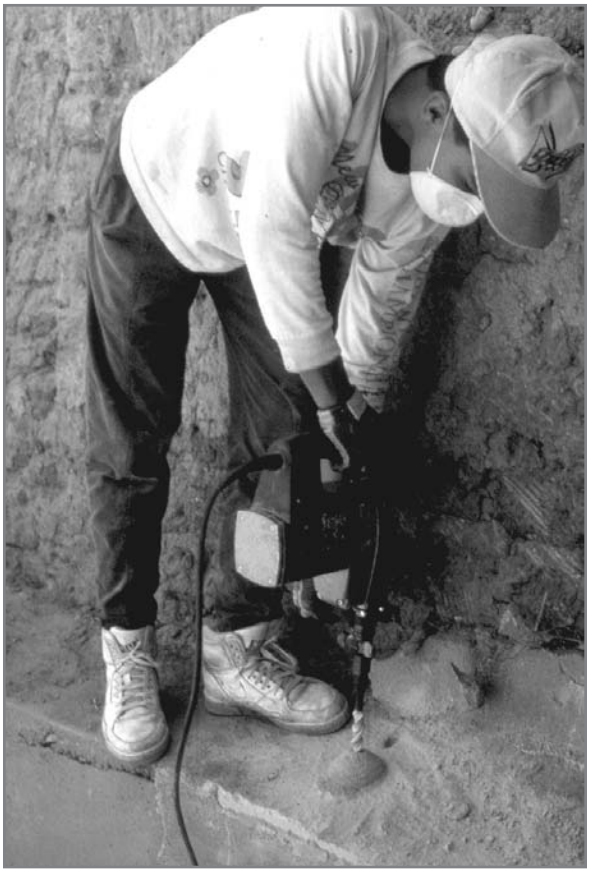
Removal of a *contra pared* usually requires shoring of some kind. Before beginning review Part One, *Emergency Shoring* and *Repairing and Restoring Adobe Walls*.



1. Beginning at the base of an outside corner section four feet in length and extending 12 inches beyond each end of the section to be removed, excavate a 12-inch wide by six-foot long trench extending four to six inches beyond the bottom of the *contra pared* to be removed. Always shim underneath the *contra pared* to prevent it from shearing off the wall and collapsing into the trench.

Collect, identify and bag any artifacts recovered during the excavation process. Note the wall section location and record the depth below the surface at which the artifact was found.

To avoid the possibility of the wall's collapsing dig the trenches in alternate sections with a minimum of four feet between each section.



2. There are different options for laying out the drill holes and removing the concrete in chunks. One layout technique is to drill holes at a slight downward angle 12-inches on center up the vertical face and across the top toward the wall at the point you want the break. If the section is small enough, break it completely away from the wall using a wood block for torque and a small sledge hammer and chisel. Then break it into smaller chunks and remove.

Or, using a hammer drill, drill a one- to one and a half -inch diameter holes 12 inches deep (or 3/4 the depth of the collar) along the center of the top of the four foot section.

Or, drill holes at a 45 degree downward angle 12- to 16-inches on center all the way across the four foot vertical face of the section.

Also, look for cracks in the concrete or weak areas where cement was poured at different times resulting in poor adhesion. These are ideal places for drilling. Very large elements may require repetition of the processes in order to break out the entire the section.

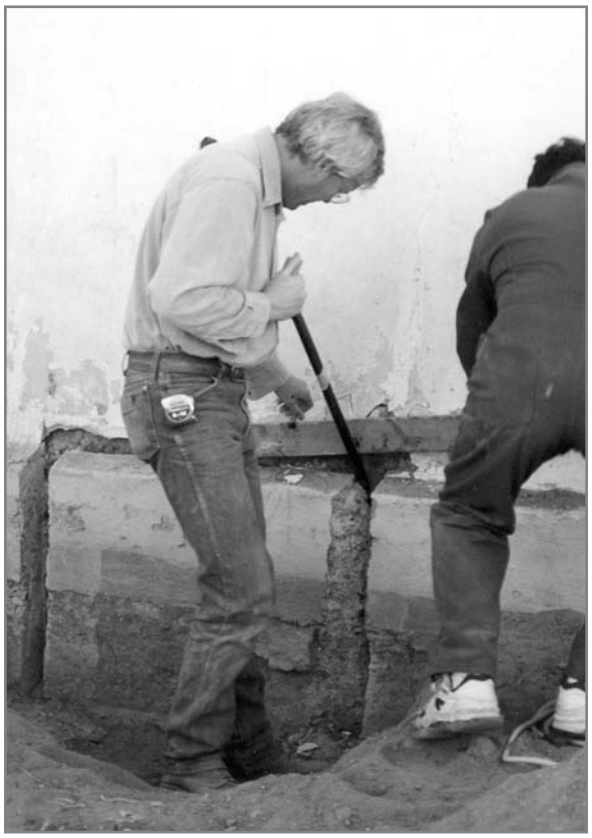
3. When you do not have the option of starting at an outside corner, or you must start on a wall that does not have an outside corner, prepare the four-foot section of the *contra pared* in the same manner as above, trenching in front of the *contra pared*. At its base, draw a low arch and drill holes at a downward angle every 12 inches along the curve of the arch. Following the instructions below, pour in the mixed Betonomite® and let it expand and crack along this low arch. Remove the debris and repeat the process with another arch above the first until the entire arched section has been removed.

4. Wearing gloves, goggles and a mask, carefully mix the Betonomite® following the manufacturer's instructions exactly. This includes monitoring the external air temperature as well as the temperature of the air in the holes drilled in the concrete.

Remember to remove the shims from beneath the *contra pared* section to allow the concrete the necessary freedom of movement once the clay-based chemical begins to expand. Cover the four-foot section with plywood, a tarp or blanket to protect from flying debris as the chemical expands and the concrete begins to move. Allow the chemical process to completely finish its work, approximately 48 hours.

Use common sense at all times and when in doubt, call Cornerstones for advice at (505) 982-9521.

5. When the concrete has cracked, remove pieces of the *contra pared* with a sledgehammer and chisels. NOTE: Avoid using heavy equipment adjacent to the wall. The wall is probably wet and vibration and other stresses could lead to collapse.



6. Carefully inspect the wall for moisture problems, allow it to dry, and proceed with repairs. Complete the repairs to one section prior to opening the next section. Avoid repairing the collar in a single stretch. Skip over sections and return to them after adjacent sections have been allowed to dry.

REPAIRING AND RESTORING ADOBE WALLS

Improperly maintained adobe walls will suffer from a variety of deterioration problems. Among the most common are wind and rain erosion leading to moisture problems in the walls.

The following sections demonstrate methods for repairing and rebuilding adobe walls. There are different ways to approach the problem and repairs will vary according to the cause and effect of the deterioration. Compatibility of mud mortar and adobes is, however, the key to all repairs.

First it is necessary to determine the cause of deterioration (see Part One, *Interpreting Sources, Processes and Effects of Deterioration*). After identifying the source of the damage there are important preventative measures that should be taken to ensure that further deterioration of a site does not occur. A superficial mud plaster can be applied for temporary protection and a plaster cap can protect the top of a wall that is vulnerable to the elements.

One of the most detrimental sources of deterioration is seismic activity. A variety of methods have been used in the past to increase the stability of earthen structures in earthquake zones. Rods, bamboo, wooden bond beams, and nylon netting are among the most accepted methods for preventing seismic damage. For more details, refer to the Getty Seismic Adobe Project: **www.getty.edu/conservation/science/seismic/index.html**

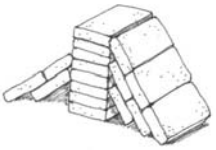
Partial collapse of a wall at the historic Gutiérrez-Hubbell hacienda near Albuquerque was successfully repaired following the procedures outlined here. (Jim Gautier, 2004)

NOTE: The methods for repairs described in this chapter are recommendations. Before beginning, aways assess the thickness of the walls and the modifications necessary to maintain stability of the existing wall. Shoring may be necessary prior to performing repairs on a collapsed or damaged wall or room system (see Part One, *Emergency Shoring*).

If only the base of a wall needs to be repaired begin by removing just enough of the cement plaster to do the basal repairs. Wait until the base of the wall is repaired before removing the rest of the wall plaster on a wall.

Always remove the wall plaster in small sections. See Part Three, *Removing Cement Plaster*, for details on plaster removal.

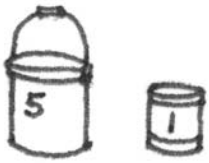
TOOLS AND MATERIALS REQUIRED


Adobe bricks

Axe

Bones

Brick layer's (mason's) trowel



Containers

Circular saw and blades

Drill and masonry bits

Gloves

Goggles

Gravel

Hard hat

Lime

Level

Measuring tape

Mixer

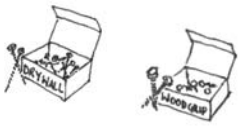
Nails

Paint brush

Paper cups

Plaster brush

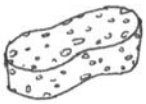
Screen



Screws (drywall and wood grip)

Shovel

Soil


Sponge

Stone

String

Water (potable)

Wheel barrow

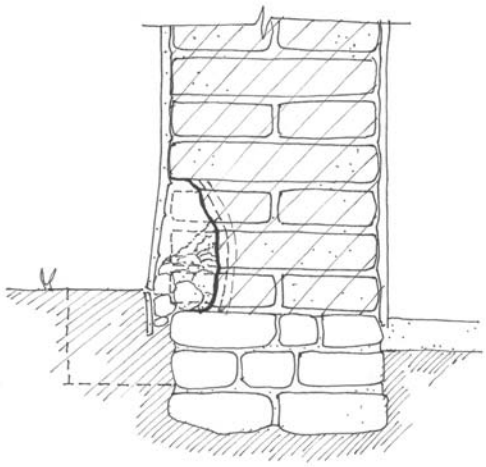
BASAL REPAIRS AND STABILIZATION

This section includes technical instructions for repairing adobe walls built on a foundation that is either at or below grade. Basal erosion, or erosion at the base of a wall, is the result of capillary action moving water up and into the wall. It is often aggravated by the addition of a concrete element, such as a collar or *contra pared*, on the exterior of the building (see Part One, *Interpreting Sources, Process and Effects of Deterioration*).

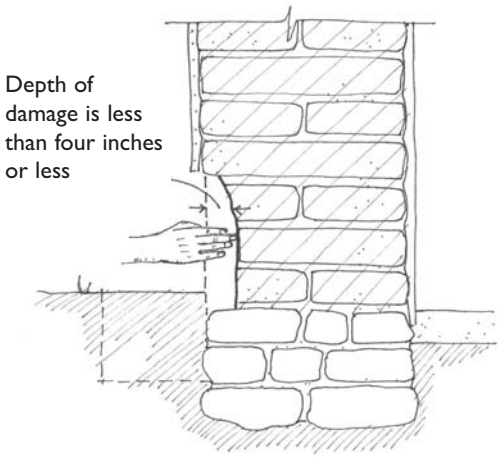
When carrying out basal repairs the process of removing deteriorated adobes must proceed with attention and care. It is essential to balance the need to replace those adobes that have lost structural integrity with the need to retain as much of the original material of the building as possible.

NOTE: For maximum adhesion do not use additives or amendments in the adobes or the mud mortar used to make repairs. Amended adobes can behave in the same noncompatible manner with earthen materials as repairs made with cement. Whenever possible the guiding principle is to use soil that is very similar in grain size, composition, color, and texture as the existing wall material.

BASAL REPAIRS USING MUD PLASTER

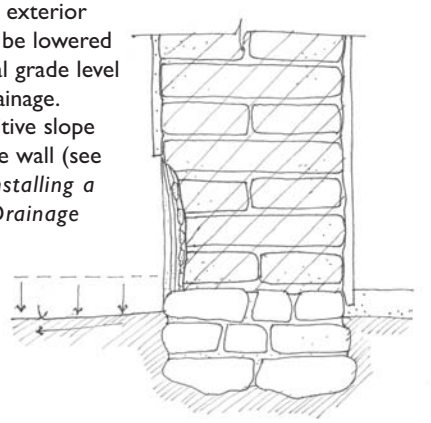


1. Basal deterioration occurs as capillary action wicks water up and into an adobe wall. Concrete plasters, collars and *contra paredes* trap this water in the wall and cause the adobe bricks to lose structural stability.



2. If the damage is caught early, it may be limited to the first one to four inches on the exterior of the wall. In this situation, you can make repairs by layering the damaged area with a compatible mud plaster.

Note: A high exterior grade should be lowered to the original grade level for better drainage. Create a positive slope away from the wall (see Part Three, *Installing a Subsurface Drainage System*).

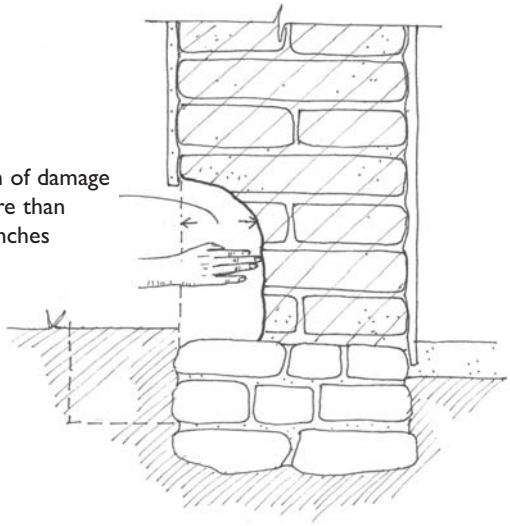


3. To make a shallow repair, scrape loose material from the surface, then brush clean. Fill the void in layers with a compatible mixture of mud plaster and small chunks, or batts, of adobe brick. Each layer should be no more than 3/4-inch thick. Allow each layer to dry completely before applying successive layers, and dampen the area with water just before applying the next layer.

4. To apply each mud plaster layer, make sure to throw, or hurl, it into the void, rather than trowelling in on. Hurling the plaster creates a stronger bond between the wet plaster and the dampend wall.

BASAL REPAIRS USING ADOBE BRICKS

Depth of damage is more than four inches

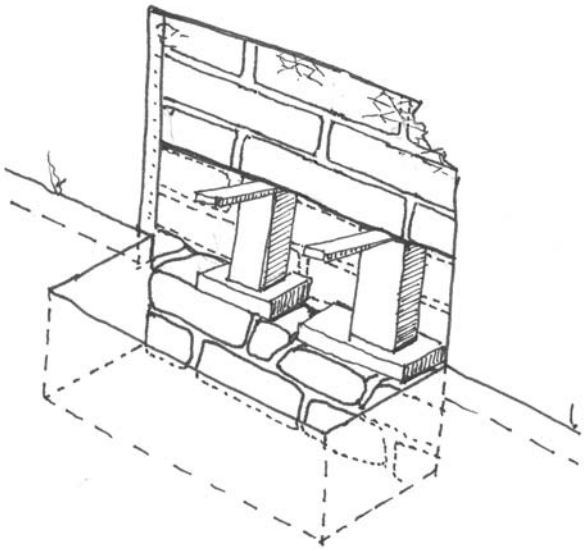


1. Basal voids that are deeper than four inches cannot be repaired using the layering method described in steps one through four. Rather, the damaged bricks will need to be removed and replaced with new adobe bricks as described in the following steps.

Exterior shoring

Interior shoring

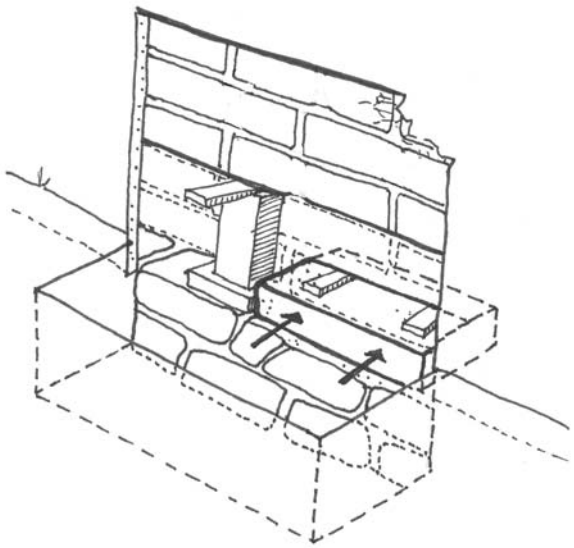
2. Provide shoring to exterior and interior to support roof loads or walls if deemed necessary. Remove deteriorated adobe in sections that are a maximum of four feet long. This will prevent removal of too much at one time which might cause a structural failure. If plaster, especially cement plaster, exists, carefully remove it by cutting to expose the affected area (see Part Three, *Removing Cement Plaster*).



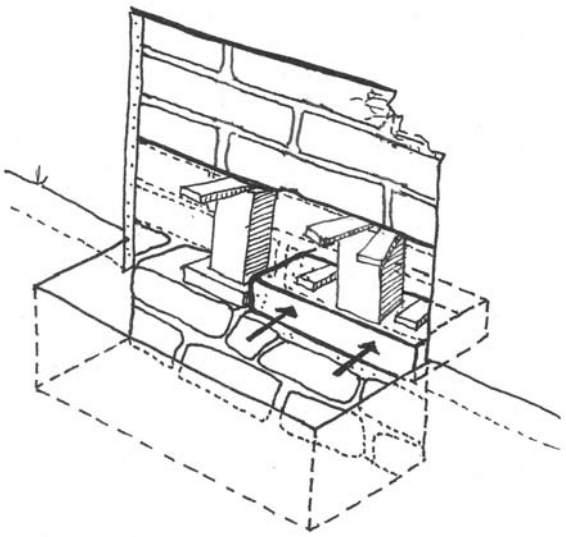
3. Dig a small trench at the base of the wall in affected area. Keep trench to a minimum workable size and to a depth that will expose the foundation, if any, or good, sound adobes at the base.

NOTE: If archeological remains are exposed, stop all work and call appropriate authorities (see Part One, *Archaeological Sites and Burial Grounds*).

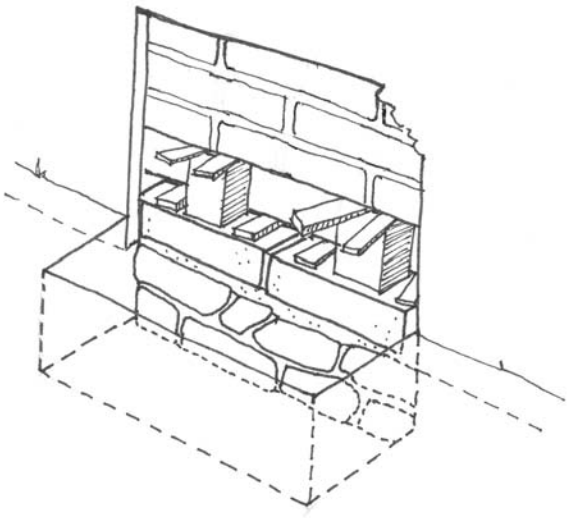
4. While cleaning out the deteriorated debris (adobe melt) shim the existing adobes to prevent collapse, fractures, or cracks using wood blocks and shims. Establish a flat base or a base that is slightly inclined into the wall for the new adobes. If rain is expected, keep trench covered with plywood or sheet metal, or to otherwise keep rainwater from accumulating in the trench.



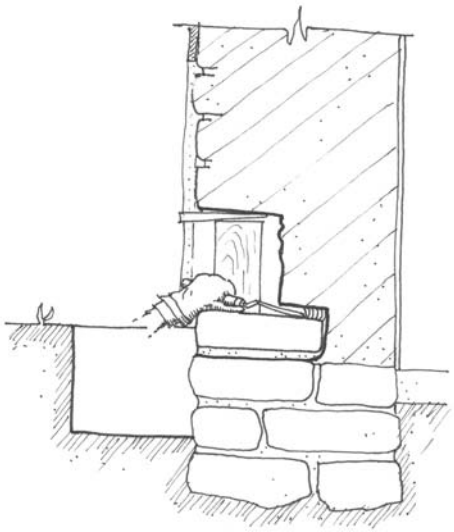
5. Study the existing adobe coursing in order to determine placement of new unamended or sound recycled historic adobes. New adobes should be compatible in material and size wherever possible in order to duplicate existing coursing pattern. Once the adobe pattern has been determined, if necessary use a string line guide in order to lay the adobes as straight as possible. If the wall is crooked or curved, follow the existing contours. Using a drill with a masonry bit or a crowbar, remove several inches of plaster to expose the area where the new adobe is to be installed. Insert adobe into new opening and allow a space of approximately 3/4 of an inch around the adobe in order to insert mortar. Remove the adobe and dampen the side of the adobe facing down, or any face that will be in contact with mortar, and the area receiving the mud mortar. Place mud mortar over dampened area and set the new adobe(s) into the wall. Push and press adobe over mortar and install wood shims snugly along upper mortar gap.



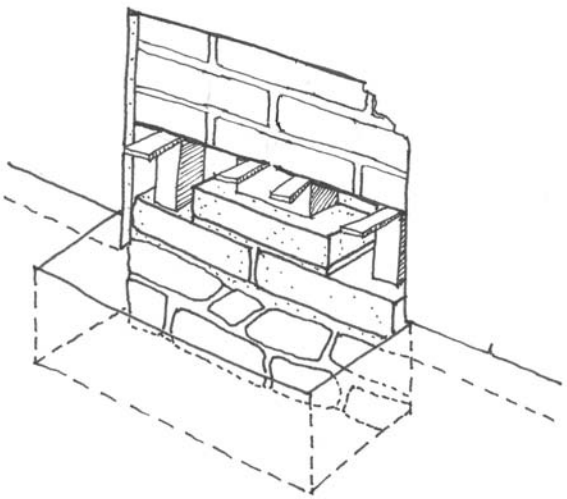
6. When new adobe is in place install wood blocks and shims to prevent existing adobes from loosening, collapsing or fracturing while new mud mortar dries and sets.



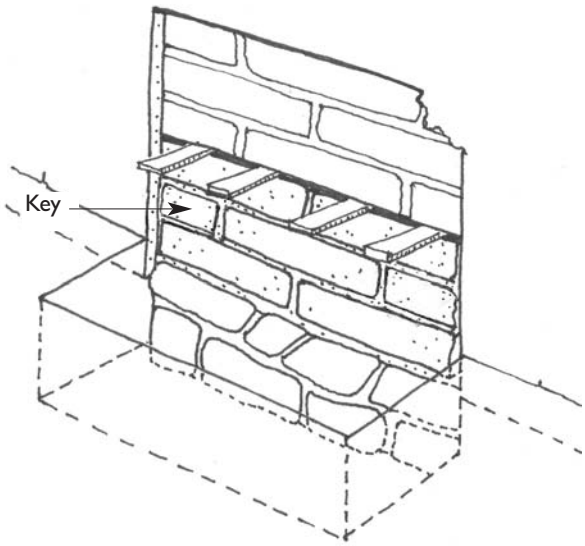
7. Repeat step five and shim as seen in the illustration above.
NOTE: Tighten the shims and blocks as the mortar continues to dry.



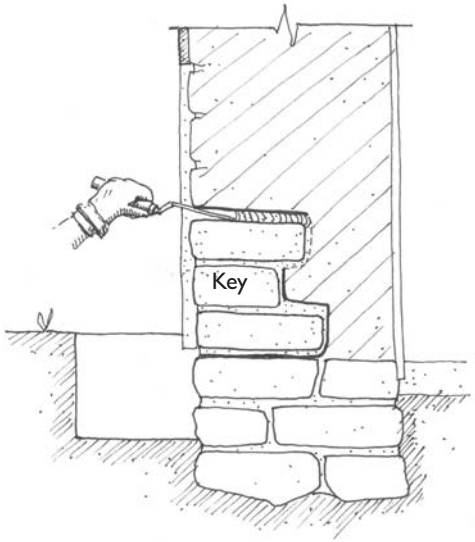
8. Once the mud mortar has dried, the upper mortar gap should be dry packed (see information on dry packing that follows). Use a margin trowel or a slender piece of wood to push the dry pack mortar into the void and fill it tightly.



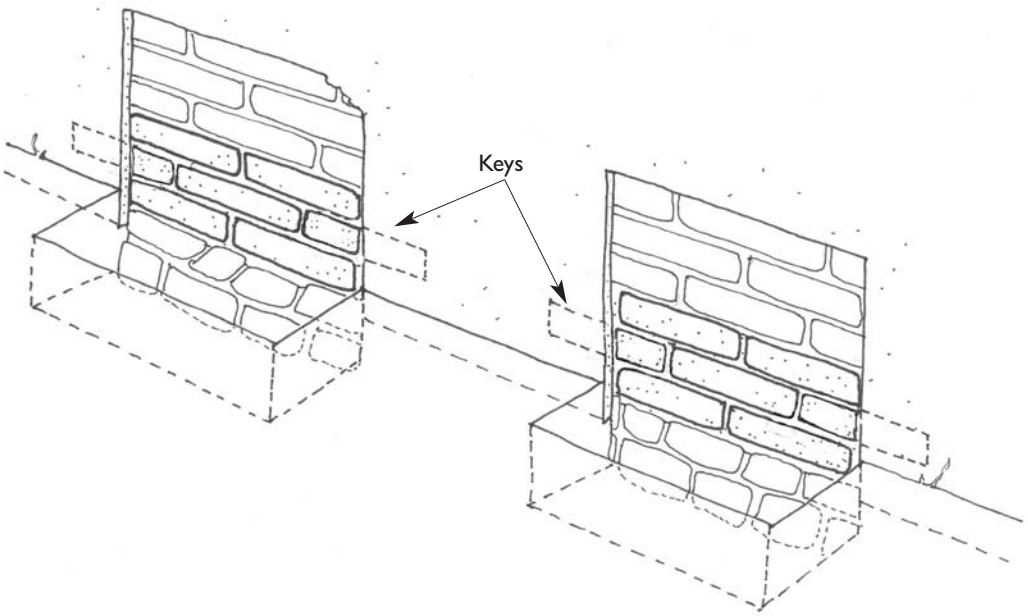
9. When all adobes have been dry packed and the wall cavity shimmed, repeat the process in step five. Notice now that the new adobes duplicate the same coursing as the existing adobes and there is a good overlap with the previous course. The minimum overlap is four inches. When this adobe is installed in mud mortar make sure to block and shim while it dries.



10. The next important step is installation of the "key" adobes. These are usually half adobes that will eventually be removed in order to insert a full size adobe when tying the repaired wall segments together as seen in step 12 below. The keys are laid in mud mortar and dry packed as described in steps five and eight. Once dry and in place, the last course of adobes, laid as explained in step 5, should be shimmed tightly, allowing the mortar to dry.



11. When the mortar has completely dried, drypack the remaining gap or opening and allow to dry. Do not remove wood shims from the gap all at once; remove only enough shims to be able to dry pack a segment at a time.



12. The illustrations in this step show the completion of two wall segments, ready to be joined at the center when the intervening wall segment is opened. Notice how the "key" half-adobe will be utilized to key in the new adobe coursing to form a continuous wall repair. The trick is to key the new adobes into the old by coursing them in such a way as to avoid a series of vertical joints.

DRY-PACK MORTAR

Dry-pack mortar is essential to the basal repair process. Dry-packing allows repairs to occur with a minimal amount of shrinkage, which leads to the successful tranferring of the weight of the wall above the repair. A dry-pack mortar consists of dry dirt that has been screened. Do not use sand. The screened dry dirt is then added to the normal, wet mortar mix until the wet mortar mix feels almost completely dry to the touch, i.e. the resulting mix will hold its shape when a handful of it is squeezed together (a moisture content of about 5%). If the dry-pack oozes between your fingers when you squeeze a handful of it, it is too wet; add more screened dirt to the wet mortar and remix until the required dryness is obtained.

When packing the dry-pack, remove one shim at a time from the work area. Clean out the mortar joint you intend to dry-pack, moisten all surfaces, then using a 1/4-inch margin trowel, pack the dry-pack into the crack between the old adobe wall and the final course of newly-laid adobes. Use a shim or other thin piece of wood to tamp or pack the dry-pack as tightly as possible. Repeat this process until the gap between the new and the original adobes is filled. Remember, always moisten all surfaces before dry-packing. This creates good adhesion.

SUPPORTING AND SHIMMING

When one or more courses of deteriorated adobes have been removed, always support the remaining original material with pieces of 2x4 studs, plywood pieces and wood shims. This temporary support system must be adjusted (shortened, and re-shimmed) as each subsequent course is laid. Replace the damaged adobes until solid, original adobes are encountered. Support at this point will consist of shims placed in the void between the new adobe courses and the old. Snug the wood shims by hand to avoid excessive vibration (do not use a mallet or hammer to install the shims). Periodically check the shims for snugness throughout the entire process, particulary at the beginning and end of each work day. Allow the newly-laid section to dry completely before moving to the next section.

Note key adobe pieces

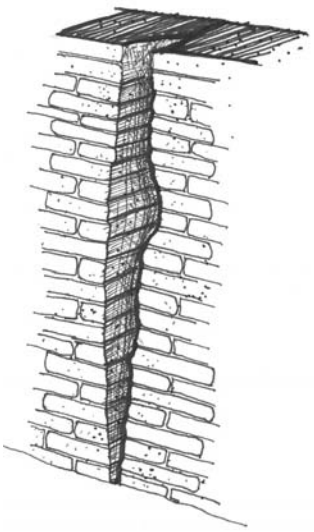
REPAIRING EROSION AND STRUCTURAL CRACKS IN ADOBE WALLS

A wall that has been severely eroded by the channeling of water is one of the most frequently encountered problems in earthen architecture. Cracks can be caused by structural settlement, movement, or erosion. For more detail in identifying the causes of structural cracks, see Part One, *Interpreting Sources, Process and Effects of Deterioration*.

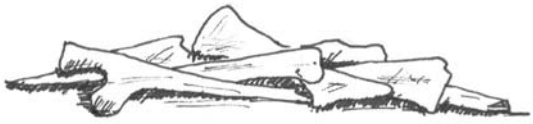
There are several methods for repairing cracks in adobe walls. If the erosion crack is minimal (only four inches in depth or less), the crack can be infilled with mud plaster in one-inch layers. In some cases where erosion has penetrated the full thickness of the wall, the old adobes can be selectively removed in a "toothed" pattern, and replaced with new bricks interlocking with the old. This method is referred to as "stitching". In other cases where walls have become free standing, adobes can be removed in a "stepped" configuration on both sides of the damaged area and rebuilt from the footing up (see Part Two, *Reconstructing Adobe Walls*). A traditional method for crack repair involves the use of dried animal bones to fill the voids in adobe walls.

The following section will explain this traditional technology used by a community where erosion had removed one-half to two-thirds of the thickness of the adobe wall. The community recalled this method as a tradition used by their ancestors and chose it as a way to maintain the structure's historical integrity. Instead of cleaning and sculpting the damaged area to receive adobes or chunks of adobe, and rather than applying thin layers of mud repeatedly to fill the voids, the community used irregularly shaped, dried animal bones to repair the voids of the damaged adobe walls.

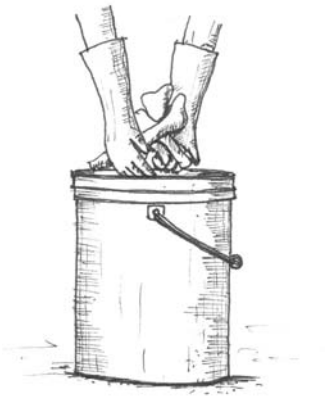
This method has been used for centuries throughout various regions. The Moché Culture pre-Columbian Peru utilized a similar method to shape earthen relief in an artistic manner. In the Huaca del Brujo located northwest of Lima, the feet of an earthen relief known as *El Brujo* were shaped from embedded femur bones. Whenever possible, drawing upon community knowledge of regional traditional building practices allows for a more sustainable restoration.



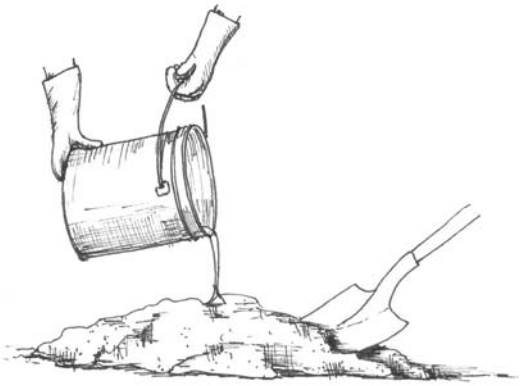
This method of crack repair should be used where erosion has removed 50 to 60% of the thickness of the adobe wall. This was the case at La Capilla de la Sagrada Familia (a above) at Pajarito, New Mexico, which Cornerstones and the community preserved from 1991 to 1995.



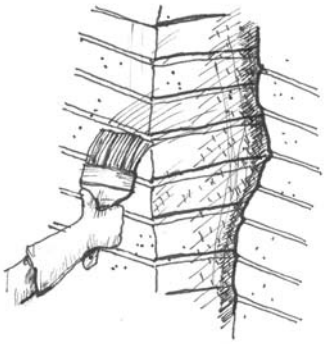
1. Dried animal bones are collected and sorted roughly by size and shape.



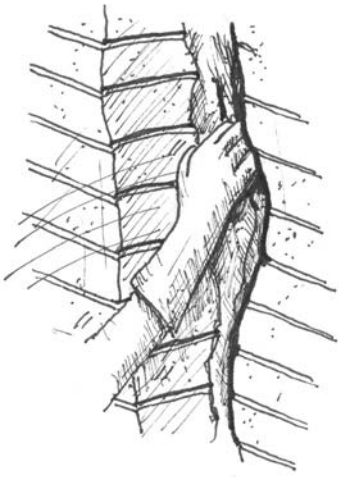
2. Place a full cup of Type "N" or Type "S" lime in a five gallon bucket 1/3 full of water. Place the dried animal bones into the bucket and allow them to soak.

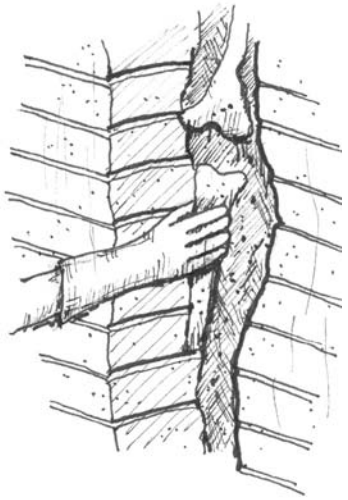


3. Find a good compatible soil to use for the mud mixture. Use the lime-water solution to mix the soil and sand to a workable consistency (see Part Two. *Adobe Material Selection and Testing*, and *Mud Plastering*).



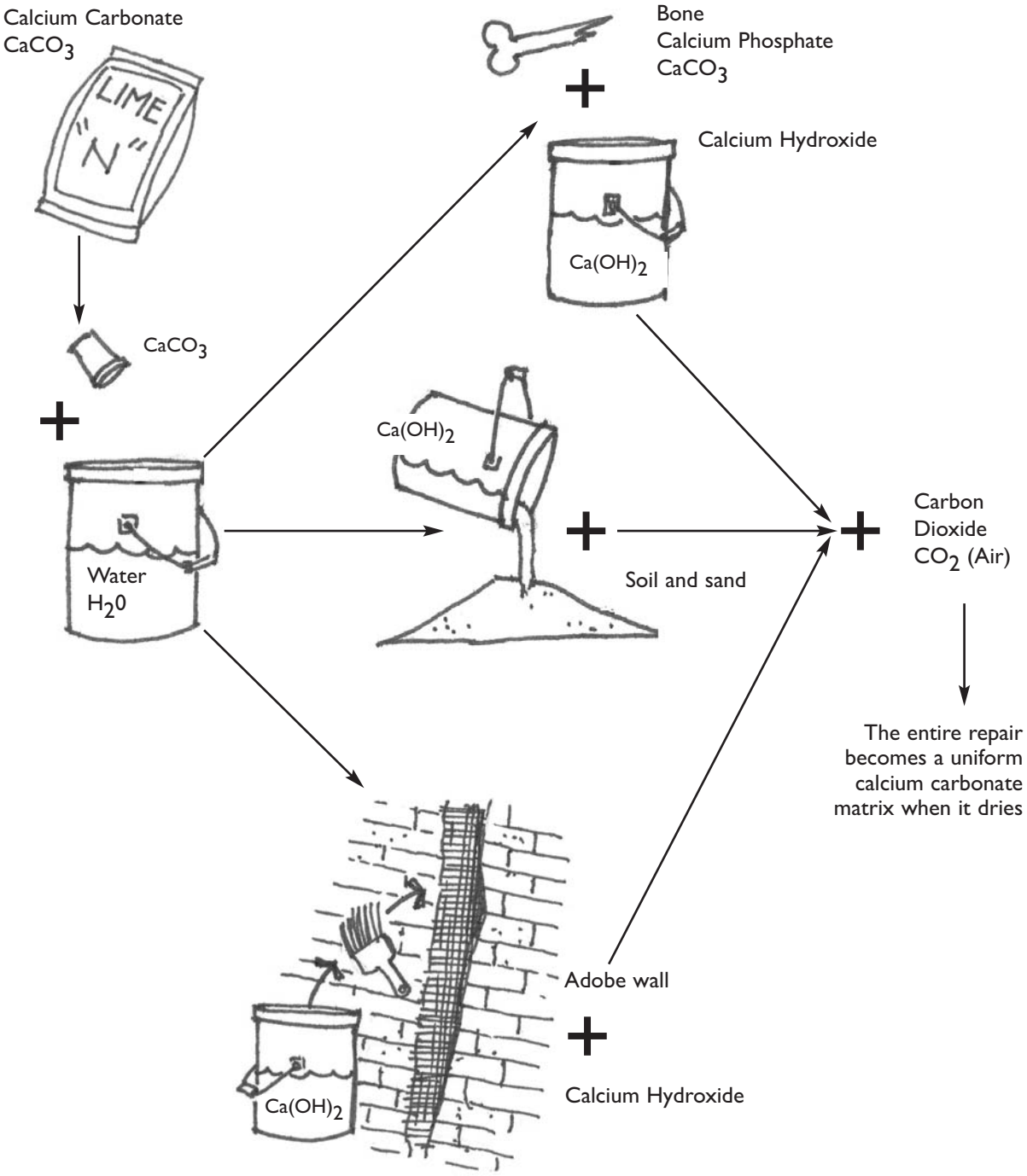
4. The damaged wall area should be thoroughly soaked with the lime-water solution.





5. The mud mixture should be thrown forcefully into the crack to improve adhesion to the damp adobes. With several inches of mud in place, embed the wet bones in the mud. In some spots, place the bones to form a bridge between protrusions of existing adobe. Where mud is thickly applied, the wider, flatter bones should be embedded to prevent the mud from sagging or pulling away from the wall.

The technical reasons for the success of this method have both mechanical and chemical components. The irregularly shaped bones embedded in mud act like rebar in cement.

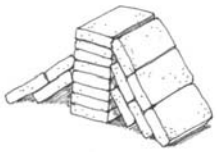


FIELD NOTES

RECONSTRUCTING ADOBE WALLS

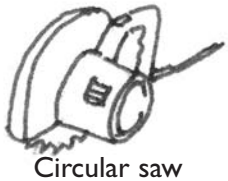
When it is impossible to repair the adobe wall because of excessive structural damage, it is then necessary to reconstruct the wall. The following section gives a step-by-step pictorial narrative for the reconstruction process.

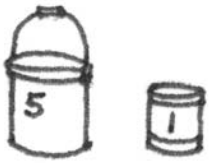
TOOLS AND MATERIALS REQUIRED


Adobe bricks

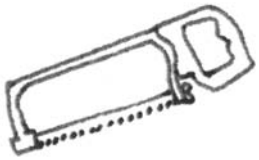
Axe

Brick layer's (mason's) trowel


Circular saw



Containers


Hacksaw

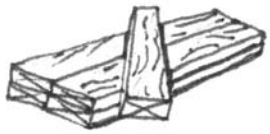
Handsaw

Hammer

Hydraulic jack

Ladder

Level


Lumber

Measuring tape

Mixer

Nails

Plasterer's trowel

Plumb bob

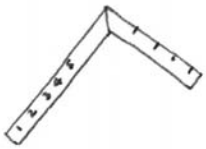
Rock hammer

Scaffolding

Shovel

Soil

Screen



Square

Water (potable)

Wheel barrow

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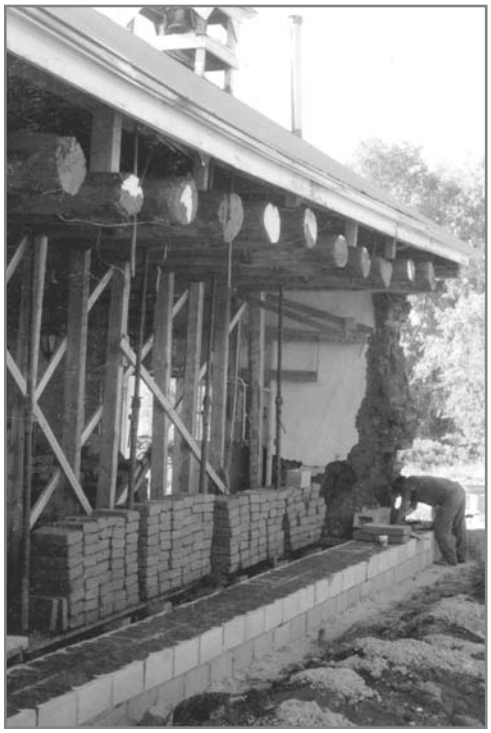
1. Shore up roof prior to work (see Part One, *Emergency Shoring*).

2. Remove fallen wall material.



3. Rebuild the footing following the existing pattern or consult a structural engineer for a new design. In high water table situations there are a variety of methods to alleviate the water table problem. In this particular case the engineer chose to use a concrete and block footing. Traditional stone footings (below), however, are recommended for use whenever possible (see Part Three, *Installing a Subsurface Drainage System* for more suggestions regarding high water table damage).

No footing

River cobble footing

Sandstone laid in mud mortar footing

Traditional stone footings

4. Gravel Footing. Dig a trench 12 inches in depth and the width of the wall. Evenly spread the river cobbles over the floor of the trench. Cover the cobbles with one to two inches of gravel. The first mortar joint should be laid directly on top of the gravel with no moisture barrier between. This gravel bed is an effective capillary break for ground water as well as a conduit to the permeable soils below for any water entering from above. This method can *only* be used where good drainage conditions exist on the site.

5. Determine the pattern of adobes to be laid. Match the existing pattern.

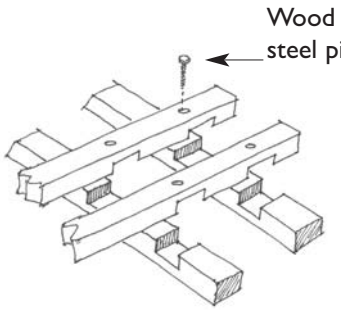
An example of adobe bricks with alternating joints

6. Pour the mud mortar and level by hand or with a trowel a half to one-inch thick. Lay adobes so that the joints alternate from course to course.

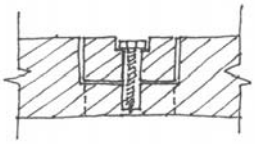
7. A maximum of three to four courses can be laid every two to three days, depending on weather conditions. Allow ample time for the mud mortar joints to dry. Adding too many courses in a short period of time may cause the adobes to shift.

8. Determine how to best key in the new wall with the existing wall. For best results always key back to the existing wall.

9. Replace wooden lateral and corner ties if they exist in the original construction. Fill in with full size adobes or custom cut adobes.



Half lap joint detail



Section of half-lap joint with loose lag bolt fastener.

10. Use half-lap and cross-lap joints to tie in lateral ties at corner. Loosely pin them together. They should be able to move and settle with the wall.

11. After placing the wooden bond beam (rough beam) to match the existing wooden bond beam if it is being replaced, reinstall the existing corbels using jacks or a pulley system to lift the *vigas*. Set the bond beam to the lowest measurement from the *viga* to allow the corbels to fit beneath the *viga* and rest on the bond beam. Insert shims between the corbels and the bond beam for any that do not meet the corresponding *viga*. Moving the roof could cause problems.

12. Replace *vigas* that cannot be spliced or repaired with new ones to match the existing. Slide the *viga* through one side of the building to the other then set the *viga* on the corbel (see Part Three, *Repairing Vigas and Corbels*).

13. Infill between the corbels and *vigas* with adobe bricks and mud mortar.

14. Apply a mud plaster when the wall has been completed (see *Mud Plastering* below).

NOTE: In historic adobe building construction, bond beams should be wood.

FIELD NOTES

LINTEL REPAIR, REPLACEMENT AND INSTALLATION

A lintel is a horizontal architectural element, typically made from a strong wood beam that spans the top of a window or door opening and carries the load of the wall and roof above the opening. The successful installation of a lintel in an adobe or stone structure, whether it is for repair of an existing door or window or, as we discuss in the next section, for a new door or window opening, depends upon the correct transfer of the weight loads above it. The sizing and installation of the replacement lintel is very important in successfully carrying that weight. Keep in mind that the weight load above the window or door opening must be supported while the installation process is going on.

As with every procedure discussed in this handbook, the first step is to identify the source of the problem that has caused the old lintel to deteriorate. Typically a lintel needs to be replaced because it has rotted, cracked or broken, or was undersized to begin with and is incapable, therefore, of supporting the load it must carry. In some cases the lintel may be missing altogether.

You must also keep in mind that an old lintel contains valuable information about the building it is part of, and therefore you should seek to repair before you replace it. Clues to the age of the building, or at least of the age of the lintel, can be obtained from observing whether it was cut by hand with an ax or adze, or with a saw. Also, experts may be able to determine when the old lintel was cut using dendrochronology - the tree ring dating system. Always check with your State Historic Preservation Office before working with the wooden elements of an historic building. They can advise you on correct procedures for inspecting, analyzing and, if necessary, archiving historic wooden materials.

Lintel repair and replacement was an important part of the preservation project completed in 2005 at the mid-19th century mission at Soccoro, Texas. (Pat Taylor, 2004)

TOOLS AND MATERIALS REQUIRED

Brick layer's (mason's) trowel

Conduit pipe

Drill

Goggles

Hammer

Hard hat

Level

Lumber

Margin trowel

Masonry drill bit

Measuring tape

Screen

Shovel

Soil

Water (potable)

Wheel barrow

Whisk broom

Wrecking bar

REPLACING AN EXISTING LINTEL

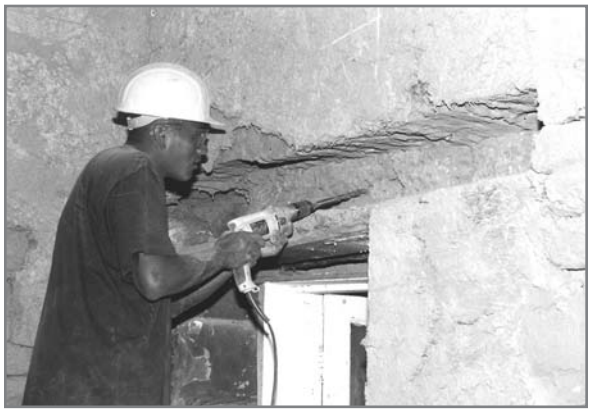
1. The space below the lintel must be shored up. If a door or window rough buck is in place, it should be left in position until the replacement lintel has been installed.

2. Determine the correct length for the replacement lintel by measuring the width of the window or door opening. The lintel must span the opening and extend beyond it on each side of the opening for a minimum of one-third of the width of the opening. For example, if the width of the opening is four feet (48 inches), then the lintel needs to extend for a minimum of 16 inches into the adjacent wall. If the opening the lintel needs to span is wider than the typical three- or four-foot window or door opening, we recommend that you consult with an experienced tradesperson or structural engineer to determine the optimum dimension for the replacement lintel.

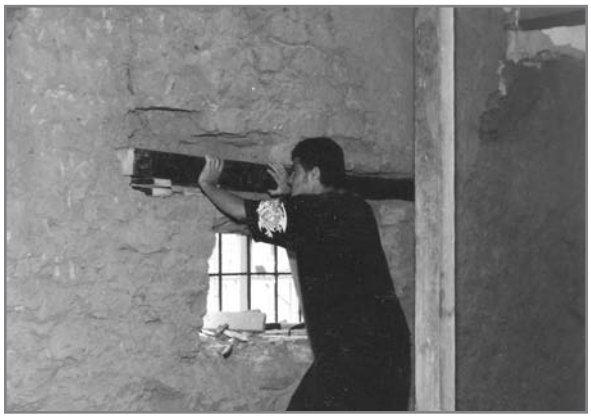
3. For a standard three- to four-foot opening, a six-inch lintel is adequate. If an existing lintel of a lesser height is in good condition, not deflecting, broken or deteriorated, do not replace it.

4. The depth of the wall will dictate the number of pieces of lumber you will need to create the lintel. You will need at least two identically sized pieces of lumber, one for each side of the wall, and in cases where the wall is particularly deep, you may need to build the lintel from more than two pieces of wood. Figure out how many you will actually need and have them nearby.

5. Remove the damaged or rotten lintel on only one side of the wall at a time. (Always remove just the amount of wall plaster and material necessary to create a space large enough to remove the old lintel and to insert the new.) If you need to remove any adobe or stone from the area in order to fit the new lintel in place, make sure you only remove them from a space equal to one-half the wall depth. This is essential for correctly transferring wall loads and for your safety. Remember: Never remove more than half the depth of the wall at any point in this process. If rough buck and window are in place, do not remove adobes first from above because they help support the wall load. In that event, remove adobes from the opposite side first.



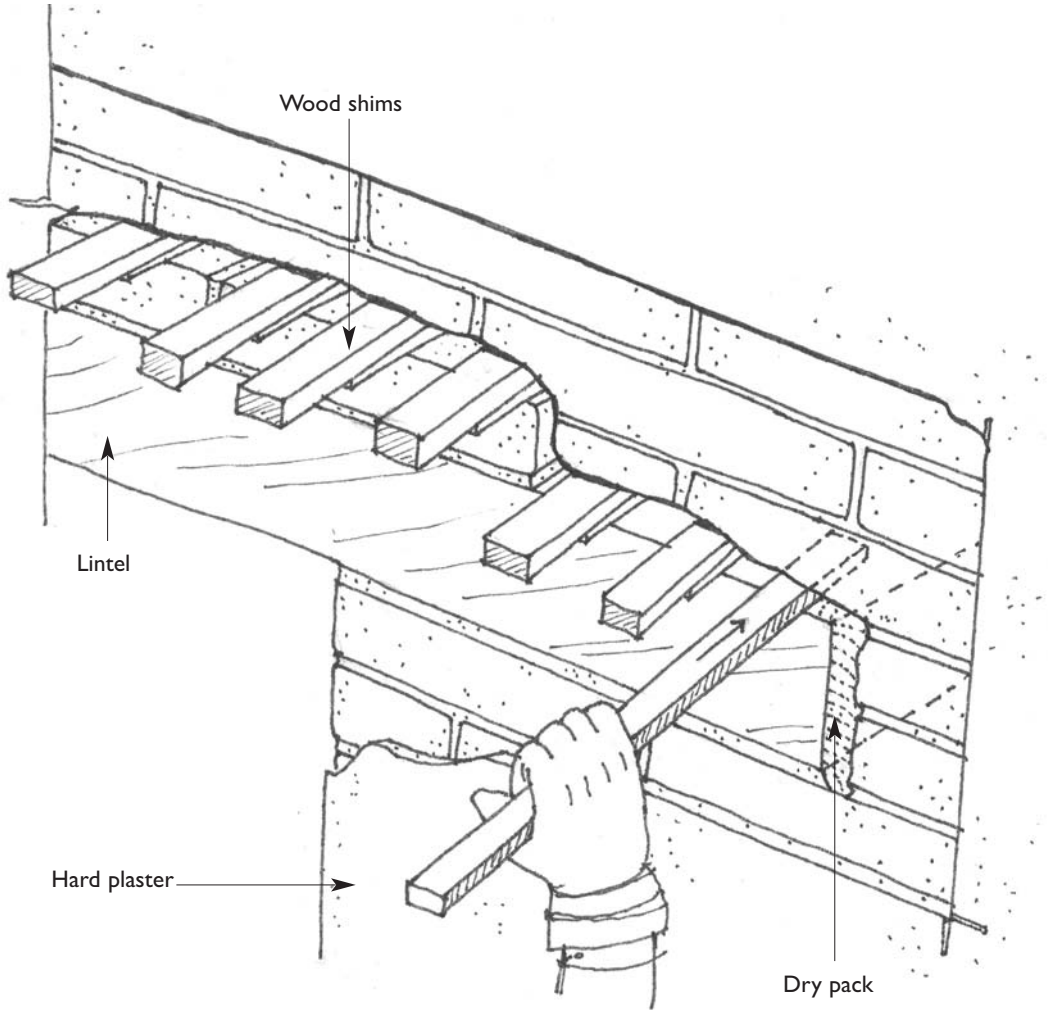
6. A wrecking bar, hammer, trowel, and/or a drill with a masonry bit can be used to remove material. It is very important to keep vibrations to a minimum when removing material. Do not do any heavy banging on the wall. If the material is too difficult to remove, the drill and masonry bit can help in drilling out the mortar joints in order to get started. Clean out the opening with a whiskbroom as soon as one side of the old lintel and any extraneous wall material have been removed.



7. Place the first piece of the lintel in the opening you have created. Check to see that you have an even space of 1/2 to 3/4 inches all around the lintel. Make sure the base of the lintel where it bears on the wall is flat and level. If the depth of half the wall is deeper than just one lintel install the first lintel all the way to the back of your cleaned out opening. If your work has to stop for the day, or be otherwise interrupted, shim the lintel with wood shims so that your space is even all the way around it. Place shims every four to six inches and snug them tight.

8. When you are certain the new lintel fits well into the space and is level, lift it out of the space and wet all of the wall surfaces around the space where the lintel will fit and lightly wet the surface of the lintel. Spread a thin layer of mud mortar (no more than 3/4 of an inch thick) on the surfaces of the opening and then insert the lintel into the space. Place wood shims between the top of the lintel and the walls every four to six inches. Make sure they are snug and tight and then allow the wet mortar to dry.

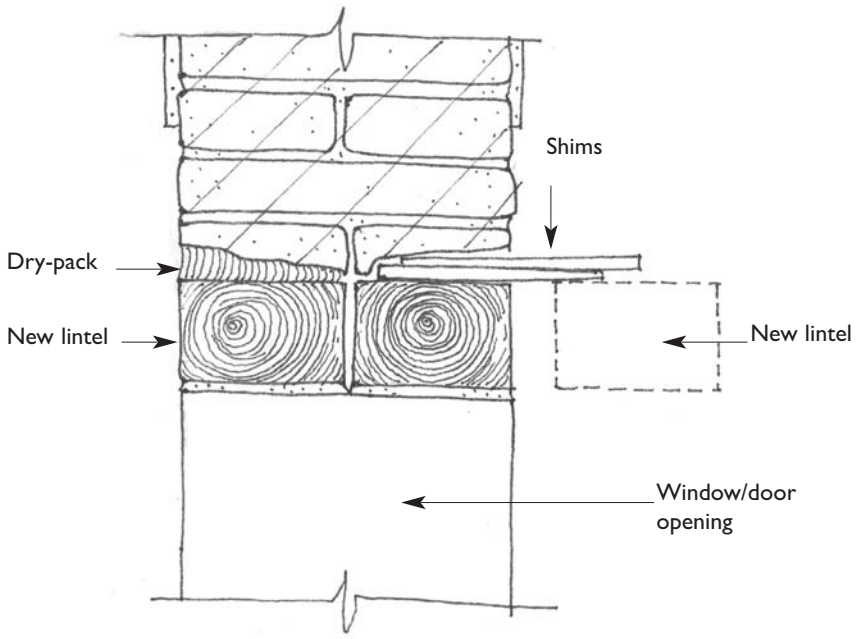
9. Fill in the space around the lintel with dry-pack mortar. It is preferable to make the dry-pack mortar from the same material that the adobes, stones or brick were originally mortared with. When using mud, mix the material well and add some of the dry material to it. The dry material should be screened so that it will mix well with the wet material. Mix your mortar thoroughly so that it is not wet, but just moist enough so that when you close your hand around it, it will keep its form and will not squeeze out between your fingers (see Part Two, *Basal Repairs*).



10. Using a 3/8-inch margin trowel push the dry-pack mortar into the space around the lintel. Do not remove your shims just yet. Make sure the dry-pack is pushed the entire way back into the space around the lintel. A push stick may be needed to get this material all the way to the back. As you push this material in, you want to pack it tightly and slowly build it out to the face of the lintel. Double check that you have it forced back all the way and that it is well compacted and keeps its shape.

NOTE: The reason for using a dry-pack mud mortar is that if you used a wet mix it would shrink and not evenly carry the weight of the wall above it. If the packing mortar is too wet it will shrink and leave a gap as it dries, which will eventually result in the lintel cracking or even failing sometime in the future. In cases where you are using a lime rather than a mud dry-pack mortar mix, make sure the lime mortar is mixed thoroughly and is not too soupy. A lime mortar mix can have a little more moisture in it than a mud dry-pack. As a lime mortar dries, one needs to to push or pack it back into the space being filled. This will ensure that the lime mortar does not create problems as it dries out and shrinks. Remember that the material the adobe, stone, or brick was laid with originally will dictate the type of mortar to be used around the replacement lintel.

11. As soon as the material has dried, pull the shims out one at a time. Then dry-pack the space that is left until you have completely set the lintel. The amount of time it takes for the dry-pack mortar to completely dry will depend on weather conditions.



12. If you need to set in another piece of lintel on this side of the wall, repeat the steps followed for inserting and dry-packing the first piece of the lintel.

13. When one side of the wall is finished and has been allowed to dry, begin the other side. Using a drill and a long, thin masonry bit drill holes just above and below the new lintel and at each of its corners all the way through to the other side of the wall. The exit holes created on the opposite side of the wall will act as guides when work begins on that side.

14. Move to the other side of the wall and find the holes just drilled. Remove the wall material that is outlined by the drill holes created from the other side of the wall. Use a chisel to remove the wall plaster covering the remaining portion of the old lintel on this side of the wall. This can also be done by using a large masonry bit to drill holes about 2 inches apart that create a pattern of squares. Then use a small crowbar or chisel to slowly break the wall material apart within each square. (Whichever method used, always remove just the amount of wall plaster and material necessary to create a space large enough to remove the old lintel and insert the new.) Continue to excavate in this manner into the wall until the remaining portion of the old lintel is located, if it still exists, or the backside of the lintel installed from the other side of the wall is encountered.

15. Adjust the opening being created so that everything lines up correctly. Then install the remaining piece or pieces of the new lintel by repeating the steps carried out on the other side of the wall.

NOTE: Remember to insert blocking or shims as major portions of the old lintel or surrounding wall material are removed so that the weight of the wall above the opening being made always remains supported.

INSTALLING A NEW LINTEL

The process for creating an entirely new opening for a door or window in an adobe wall is similar to that described in the preceding section. However, you should never create a new opening in an historic building without first consulting with preservation experts at Cornerstones or your State Historic Preservation Office. They will advise you about how to do this in a manner that does not compromise the historic and architectural integrity of the old building. There are also certain building codes that you must comply with and you may need professionals to help you understand them.

It is also important to remember that a new door or window opening in an adobe building must never be placed too close to the corner of a room, nor too close to the point of intersection with another wall. Should this be done, excessive strain will be placed on the adobe walls in the vicinity of the new door or window.

Before beginning refer to the preceeding section and the illustrations included in it.

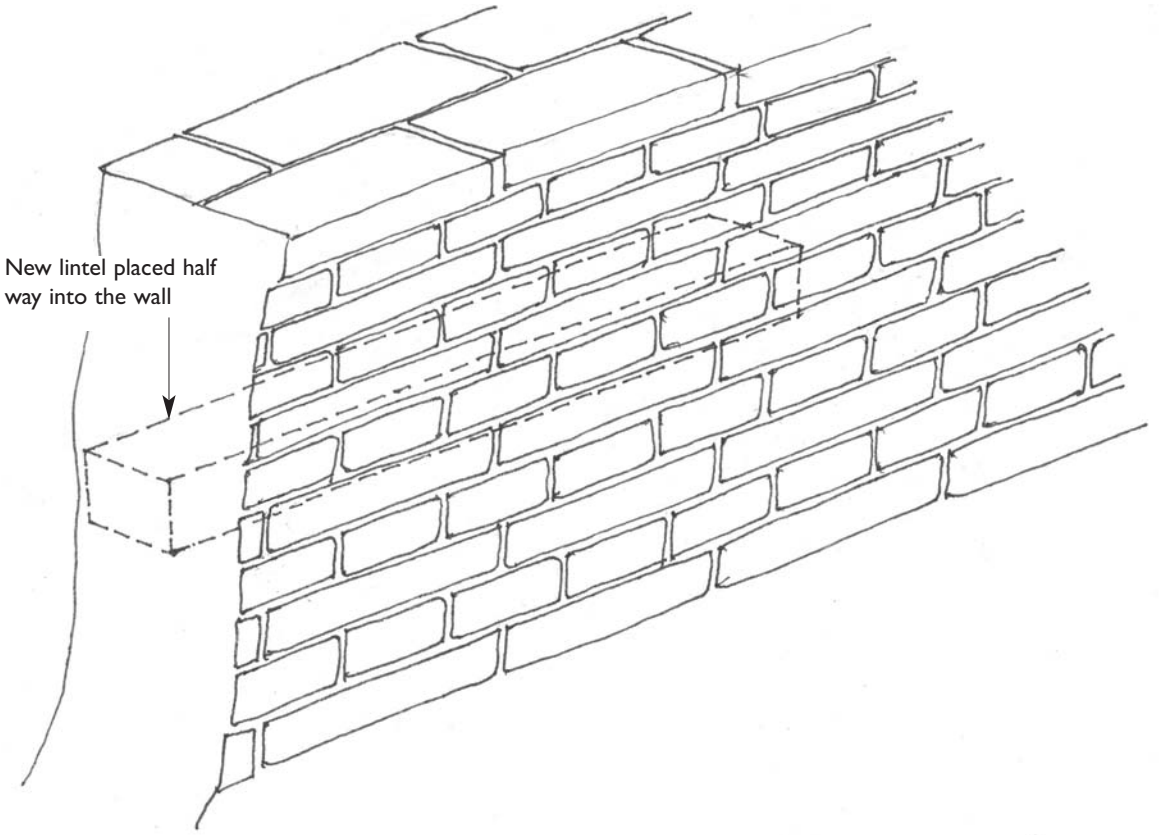
1. Determine the width of the opening needed for the window or door that needs to be installed. Actually draw it out on the wall using a tape measure, level and pencil. Review the information on loading in the previous section. Remember, that a minimum of one-third the width of the window or door is required on each side of the new opening to ensure that the new lintel will properly support the weight of the wall above it.

2. The height dimension of the lintel should be determined by the width of the opening and the load of the wall above. Typically, the height dimension of the lintel will be dictated by the coursing of the adobes. Usually a two course height of adobe will provide an adequate lintel height for a modestly sized (three to four feet) door or window. If the width of the opening is wider than a typical door or window opening seek the advice of an experienced tradesperson or engineer. And remember, a new opening should not be located next to a corner or an intersecting wall. Stay at least the width of the opening away from such a corner (See *New Mexico Historic Earthen Buildings Code*).

3. Now score the lintel dimensions on top of the opening you drew on the wall. Draw the length and height and allow an extra 1/2 or 3/4 inch space around your actual lintel. This extra space will be important when you install your lintel so that you have enough room to maneuver and also for shimming and dry-packing. The depth of the wall will dictate the number of lintel members you will need. At least two members are needed; one for each side of the wall. Figure out how many are actually needed and have them nearby.

4. Install the lintel in two steps by inserting it into a space that is half the depth of the wall in each step. Start on one side of the wall by removing the adobes within the first half of the depth of the wall. This is essential in order to transfer the wall loads and for safety. Never remove more than half of the wall depth at any time.

5. The assortment of tools that can be used to remove the material include a crowbar, hammer, trowel, and/or a drill with a masonry bit. Keep vibrations to a minimum when removing the material. Do not do any heavy banging on the wall. If the material is too difficult to remove, the drill and masonry bit can be used to assist in drilling mortar out of the joints in order to get started.



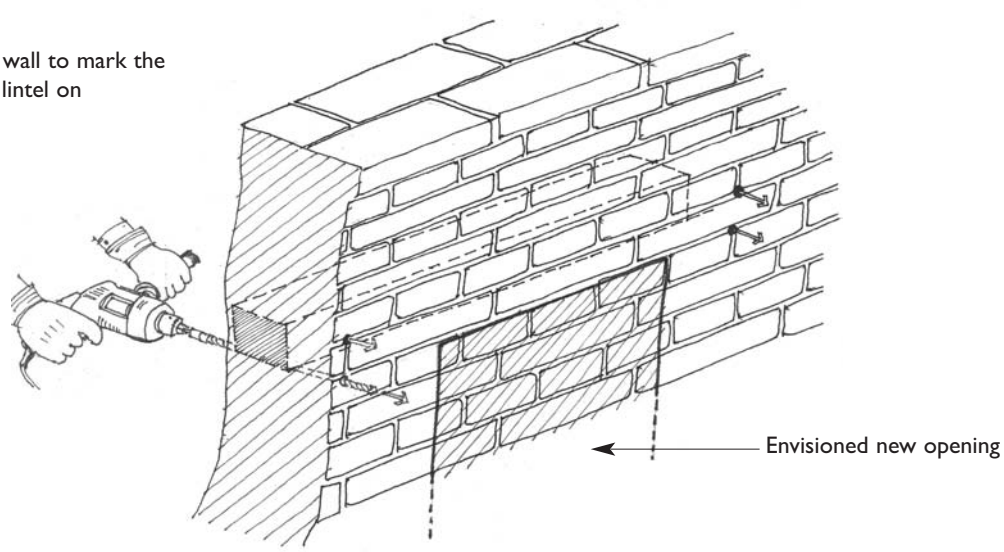
6. Once the material is removed, clean out the space with a whiskbroom and place the lintel in the opening created. Check to see that an even space of 1/2 to 3/4 of an inch exists around the lintel. Make sure the base of the lintel where it bears on the wall is flat and level. If the depth of half the wall is deeper than just one lintel install the first lintel all the way to the back of the cleaned-out opening.

7. Shim the lintel with wood shims so that your space is even all the way around it. Place your shims every four to six inches and snug them tight. Make sure the base of the lintel remains flat and level.

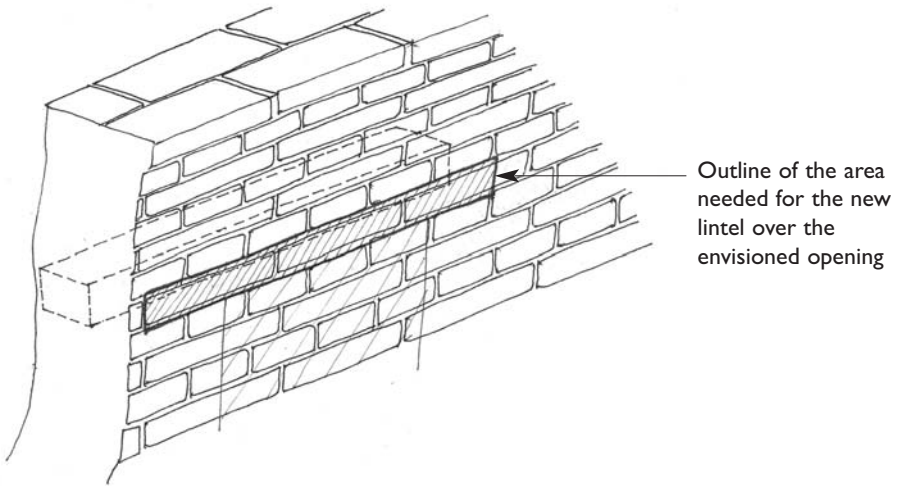
8. Now you are ready to fill in the space around the lintel. It is preferable to fill this space with the same type of material that the adobes are mortared with. When using mud, mix the material well and add some of the dry material to it. The dry material will be the same type of material used for mud mortar, but screened in order to mix well. Mix it thoroughly so that it is not wet. Rather, when you close your hand around it, it should have enough moisture to keep its form but not squeeze out between your fingers. Using a 3/8-inch margin trowel push the dry-pack material into the space around the lintel. Do not remove your shims just yet. Make sure the dry-pack is pushed the entire way back into the space around the lintel. You might need a push stick to get this material all the way to the back. Pack the material in and slowly build it out to the face of the lintel. Double check that the material has been forced back all the way, and that it is compacting well and keeping its shape.

NOTE: The reason a dry-pack mud is used is because a wet mix will shrink and not carry the weight of the wall above it evenly. When using a lime mortar mix make sure it is mixed thoroughly and that it is not too soupy. This mix can have a little more moisture than the mud dry-pack. You will be able to push in the lime mortar as it dries to ensure that it does not create problems as it shrinks. Remember that the material you use will be dictated by the material with which the adobe, stone, or brick was laid. See Part Two, *Basal Repairs* for more information on using dry-pack mud.

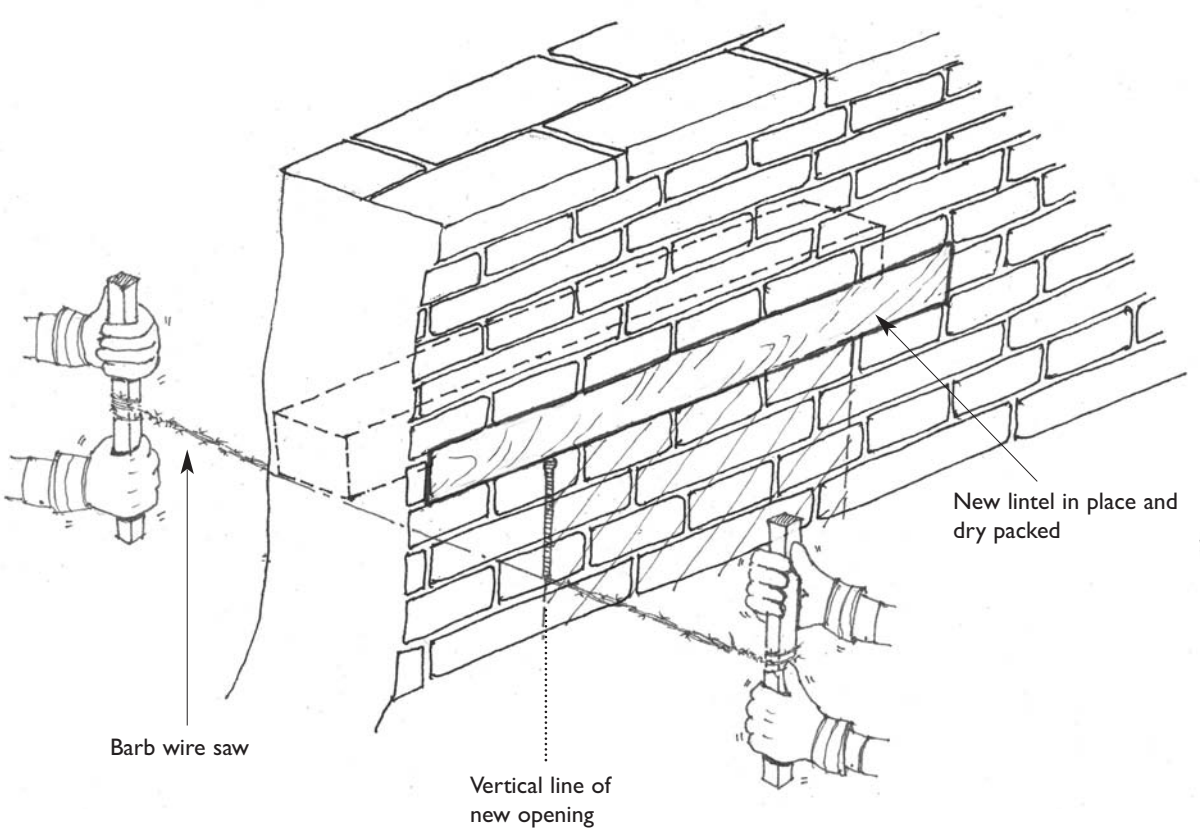
9. Once the material has dried, pull the shims out one at a time and dry-pack the voids left by each shim until the process is complete. Repeat this process if you need to set another lintel in place because the depth of half the wall is greater than the depth of the first lintel installed.



10. Now that you have finished one side of the wall, you are ready to begin the other side. Using a drill and a masonry bit, drill through to the other side at all four corners of the new lintel and at the outside width of the new opening . You can also use a section of electrical conduit pipe, driving it through the wall a few inches at a time with a hammer and occasionally removing the dirt from the conduit with a hammer and/or a screwdriver. If the wall is stone or brick, a conduit pipe or drill will not be effective. In that case, you will need to measure up from the floor or down from the ceiling and/or from the corners to determine placement of the new lintel and opening.



11. Using a measuring tape, level and pencil, layout the placement of the opening and the lintel. Double-check the measurements. Make sure everything is going to line up correctly. Start the removal of wall material from each end of the lintel space. Once you have dug back into the wall and located the backside of the new lintel on the other side, adjust your opening so that everything lines up. After that, it is a straight-forward process; just repeat the installation instructions above.



12. Once you have installed the lintels on both sides of the wall you can cut out the opening for the new door or window. There are several ways to do this. In an adobe wall the easiest way is to make a saw out of several strands of barbed wire twisted together and fastened to wooden handles at each end. The "saw" will need to be at least three feet longer than the depth of the wall in order to prevent you from scraping your hands and fingers against the rough wall as you pull the saw back and forth. First cut a hole that is just big enough to get the barbed wire saw through just below the lintel and at the edge of the opening . Once the barbed wire saw is ready to go locate someone to help you on the other side. Then just start sawing back and forth keeping an eye on the vertical line drawn for the opening.

13. When you have finished one side, set up and start on the other. Wear dust masks and goggles, and have a fan going to move the dust from the area. If you are working inside, cover and protect anything you don't want to get dirty. Allow time for the mortar to sufficiently dry before starting the other side. Leave the middle mass of material in the opening to help support the bearing weight until all your mortar work is dry.

INSTALLING EARTHEN FLOORS

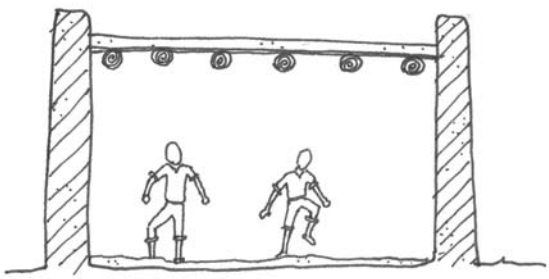
Earth was the first material used for floors in the Southwest; it was used in both Pueblo and Spanish structures. Women, known as *enjarradoras,* mudded the floors by hand. They kneaded and rolled straw, soil, and water together to produce the flooring material in the same manner in which they prepared bread dough. This method shortened the drying time of each of the layers of mud that had to be applied to the floor and compacted into place.

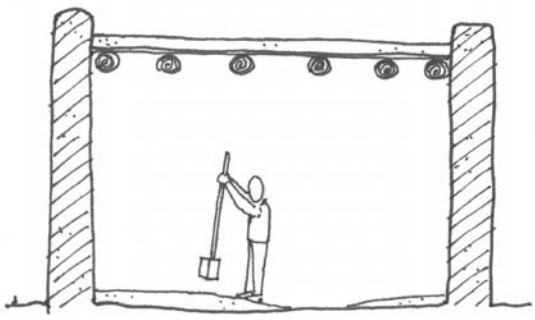
After the first layer dried, the second layer was rolled on, pressed into any cracks and then smoothed with a damp sheepskin. The third layer was a finish of ox blood combined with manure, ash, clay, or wheat paste. The finish coat would harden the floor and provide some color. Traditional earthen floors were compacted with hand tools or by foot.

A traditional compacted earth floor contains soils with up to 35% clay. A ratio of 80% sand and 20% clay and silt is used today for poured floors.

Wood floors began to replace earth floors as early as the 1840s. Today, poured earth floors are preferred to compacted earth floors, both for convenience of installation and because producing a level, smooth final surface is somewhat easier. Today earth floors are often finished with linseed oil rather than with ox blood.

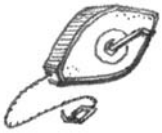
The following section will explain natural additives used in traditional earth floors and will give the reader information on pouring and finishing an earth floor.

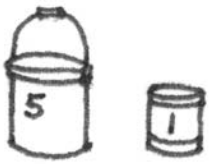




TOOLS AND MATERIALS REQUIRED

Broom


Chalk line



Containers

Dust mask

Gloves

Goggles

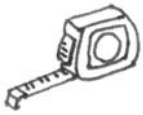
Gravel

Hammer

Knee pads

Level

Lumber


Measuring tape

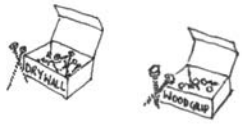
Mixer

Nails

Plasterer's trowel

Plywood

Sand



Screws (drywall and wood grip)

Shovel

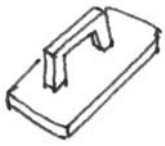
Soil

Straw

String

Water (potable)

Wheel barrow


Wood float

<u>Additional materials:</u>
Linseed oil
Keroseen

AGGREGATES

The strength of an earth floor depends on the aggregates it contains. Clay, silts and other materials serve as binders in the flooring material and linseed oil can be used as a final finish to make an earth floor even harder. Common aggregates that can be added to an earth floor include:

Straw

A double handful of finely chopped straw in a wheelbarrow of mud helps minimize shrinkage and cracking (see Part Two, *Mud Plastering*).

Wheat Paste

Approximately one pound for every ten square feet.

Cactus Mucilage

Mucilage (prickly pear or cholla) mixed with the soil and sand (see Part Two, *Earthen and Lime Finishes,* for informa tion on making cactus mucilage).

When preparing to pour an earthen floor, first determine the level of the finished floor. If the desired finished floor level is more than nine inches from the existing sub-grade, a fill is needed to raise the existing sub-grade level.

To indicate the finished floor level, a chalk line may be snapped on the surrounding walls. Sand, gravel, crushed stone or pea-size pumice are good infills over which to pour the mud since they break the capillary action of the subsurface moisture.

You may also use string to indicate the level of the mud, or grade stakes that you will remove as you work your way out of the room. Today, a very efficient method of leveling is to use a laser level that displays a line around the room and can be used for both phases.

Poured mud floors work very well over radiant heat installations.

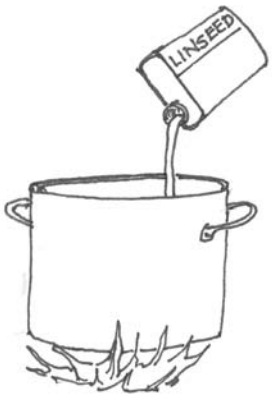
INSTALLATION

1. A poured floor may be done in two phases. Pour the first phase to within l/2 inch of the final level. The first phase will always crack because of shrinkage. After it has dried thoroughly, sift the same ratio of very fine sand and soil through a window screen and use the mix to fill in the cracks by sweeping it back and forth across the cracks until they are full.

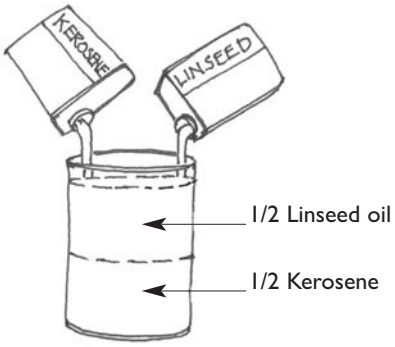
2. The second phase is hand plastered onto the base using the finest sand and soil possible. Screen the sand and soil through a window screen and do not add straw. If the mix is correct there will not be any cracks in the finished floor. Trowel the surface until the finish is perfect.

HARDENING THE FLOOR

3. For a harder finish, linseed oil is very effective.



4. Boil the linseed oil before applying it as a hardener to the earth floor. Boiled linseed oil is also available for purchase.



5. Thin the first coat with 25% mineral spirits. The second coat should also be linseed oil diluted with mineral spirits. This fast drying coat helps penetrate the first coating. Several coats will produce a shiny floor. Diluted wheat paste may be used as an alternative to linseed oil for a more traditional look, although it can be difficult to obtain and requires more maintenance.

6. Pour and brush or roll the oil mixture onto the surface. The linseed oil will dry faster in some areas; therefore additional coats should be applied until the oil remains on the surface. Make sure the oil is brushed or rolled again to prevent puddles from forming. Puddles will never cure properly. Allow two to three days for the first coat to dry before applying the second coat. Try to air out the space for a faster drying time.

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NOTE: To remove an existing floor and replace it with an earth floor, see Part Three, *Removing a Concrete Contra Pared* for information on concrete slab removal and *Installing Wood Floors* for information about how wood floors are constructed.

FIELD NOTES

MUD PLASTERING

Throughout history, many materials have been used as natural additives to protect earthen buildings. Among the most common were lye soap, alum, pine needles, cactus, straw, dung, rice fibers, animal blood, egg yolks, oil, stones, ceramic tile, lime, cement, asphalt emulsion and chemicals. In New Mexico, by in the 1930s, many adobe buildings had been plastered with cement. The use of this material was thought to be an economical and permanent solution to the regular cycle of mud plastering.

The reality is that cement plaster does not allow the adobe wall to breathe. Walls that breathe act as a heat exchanger, warming incoming air before it enters the living space. This porous membrane also keeps indoor air safer. Earthen walls regulate interior temperatures, absorbing vapor in high humidity and moistening the environment in drier air. Because the expansion of the earthen plaster is the same as the adobe wall in damp weather, it is far more pliable than cement. The accumulation of moisture trapped by cement plaster has destroyed some buildings and threatened many of the others it was intended to protect.

The use of non-natural additives to "stabilize" mud plaster should also be avoided when using mud as a coating on historic adobe buildings. Such additives are usually cement, acrylic, or petroleum products. They are historically inappropriate and functionally incompatible with natural adobes. Such additives trap moisture within the walls.

It is an oft-heard saying among the old *adoberos* of New Mexico that, *"Un adobe sin paja es un adobe sin alma"* (an adobe without straw is an adobe without soul). In other words, this was a method of saying "use straw" in the mud mix without explaining why. It is understood that

straw performs certain functions, including balancing the soil mix in adobes. Straw helps the sand and clay particles dry evenly. Omitting straw will lead to excessive cracking as the adobes dry.

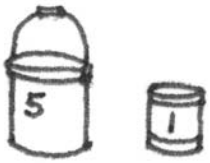
The greatest threat to an unprotected adobe wall in the Southwest is erosion by water. Summertime convection storms may unleash violent torrents that, though of short duration, are intense mechanisms of destruction. Water flowing down a vertical surface, unless it is deflected from a straight path, will rapidly cut a channel in the mud plaster and expose the adobe fabric beneath. The exterior mud plaster is what is caledl a "sacrificial" coating

NOTE: Select the right soil (see *Adobe Material Selection and Testing* above).
(1) A thin, 1/4 inch "binder" coat applied to the original material is critical to the successful adhesion of successive layers.
(2) The first "scratch" coat applied to the final binder coat should crack because of a higher percentage of clay.
(3) Brown or "leveling" coats will usually have less cracking because sand is added to the mud mixture if needed.
(4) The final or "finish" mud coat should not crack if a balanced mixture of clay, straw, and sand has been used (see "Shake Jar" Testing above).

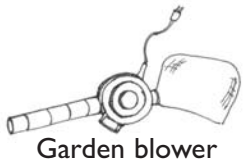
A FEW FINAL WORDS: Experiment! Apply and observe plaster test panels. Select the best recipes to suit particular situations based upon your tests.

TOOLS AND MATERIALS REQUIRED

Brick layer's (mason's) trowel



Containers


Garden blower with vacuum

Ladder

Lawn mower

Machete

Mixer

Plasterer's hawk

Plasterer's trowel

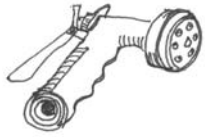
Sand

Scaffolding

Screen

Shovel

Soil

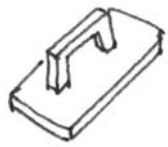

Spray attachment and hose

Sprayer

Straw

Water (potable)

Wheel barrow


Wood float

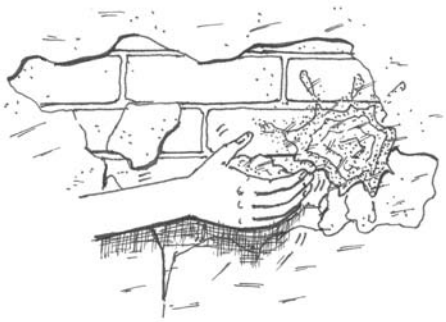
1. Set up scaffolding and equipment.

2. Screen the soil. Do not screen the soil if wet. (See *Building a Screen* at the end of this section.)

3. Judiciously scrape the walls and remove any loose or "friable" adobe material and brush off dust. Dampen an area of the wall with water using a dash brush, a large cup of water, or a fine, soft hose spray or sprayer. The very first binder coat should contain straw and should be applied in a uniform 1/4- to 3/8-inch thickness. The binder coat will follow the contour of the original fabric after the walls have been scraped and dampened. It is critical that this binder coat adheres, or all successive coats risk failure. Once the initial binder coat has dried and adhesion is verified, thin leveling coats may be applied to the binder coat to bring the pitted or concave wall areas out to plane.

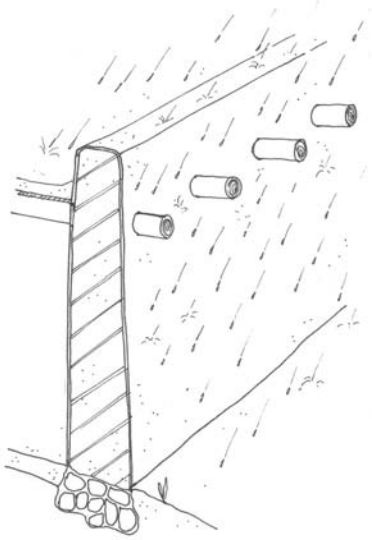
4. When the wall has been brought out to a flat plane, the recipe for the next mud layer should be mixed fairly rich (more clay) so that it cracks slightly. Slight cracking will allow the subsequent coat(s) of mud to penetrate this plaster layer for better adherence. Add straw (not hay or alfalfa) to the plaster layer applied to the binder coat. See *Methods for Cutting Straw* at the end of this section.

NOTE: Excessive cracking may cause the mud plaster to lose its adhesion to the previous layer. Excessive cracking indicates more sand is needed and that the mix is too rich in clay.

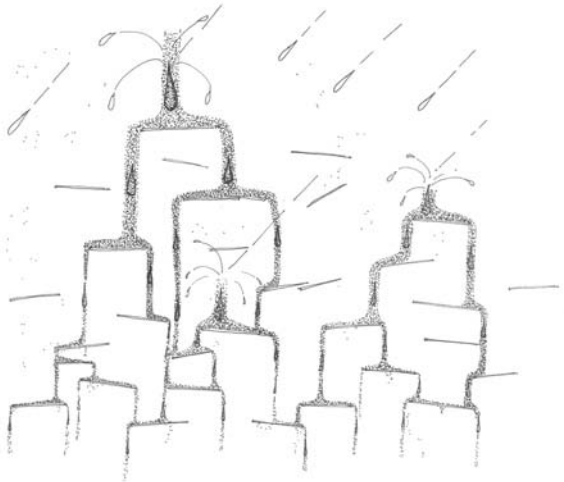


5. If no mud plaster exists, throw the mud onto the wet adobe wall surface by hand or hurl with a brick trowel. Scrape the excess mud and re-throw, filling the concave areas and following the contours of the wall. Always apply thin (never greater than 5/8-inch thick) coats to ensure adhesion. When a large void under four inches deep is encountered, fill it by hand with mud in successive layers of 5/8 of an inch or less. Be patient. Build out with several passes, allowing each layer to dry in between passes. Do not try to build up low areas with a single application of mud. If the void is deeper than four inches, new adobes will have to be inserted.

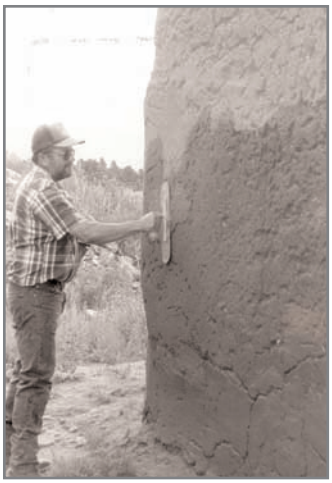
6. Using the heel of the hand or side of a trowel, work upwards in a low arching motion away from the body. The print should be that of a half rainbow. The straw will align horizontally or nearly so.



7. Water flowing down a vertical surface, unless it is deflected from a straight path, will rapidly cut a channel in the mud plaster and expose the adobe fabric beneath.



8. The rivulet beginning at parapet height encounters a straw barrier across its path and is diverted. The downward velocity is broken and erosion reduced. Straw causes water to spread out or "sheet" over the surface of the wall.



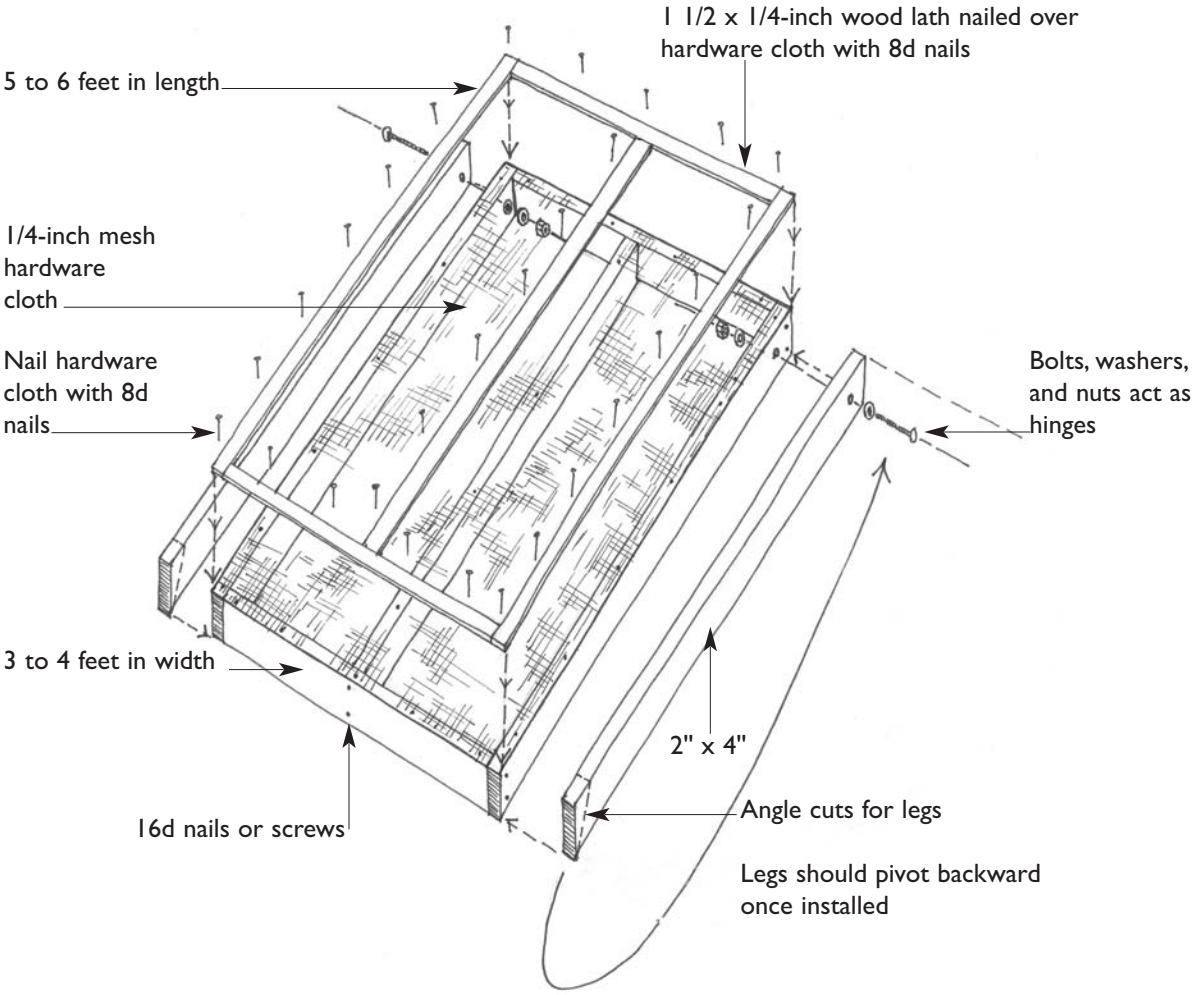
9. Apply the scratch coat approximately one- to one and a half-inches thick with a brick trowel or by hand. Allow the mud plaster to completely dry and crack one to two days before continuing. A plaster trowel may be used if mud plaster exists. Before each application wet surface of wall immediately before plastering.

10. Add straw to the second or "brown" coat mix. This coat should be 3/4-inch thick and have few or no cracks. Allow the brown coat to dry one to two days before continuing. A plaster trowel can be used to apply this coat.

11. The third or "finish" coat should be 1/4-inch thick. Straw is essential to this stage. Mix the mud plaster for the finish coat with pieces of straw that are no more than one-`inch long. Apply the finish coat so that the majority of straw pieces on the surface are aligned horizontally (parallel to the ground).

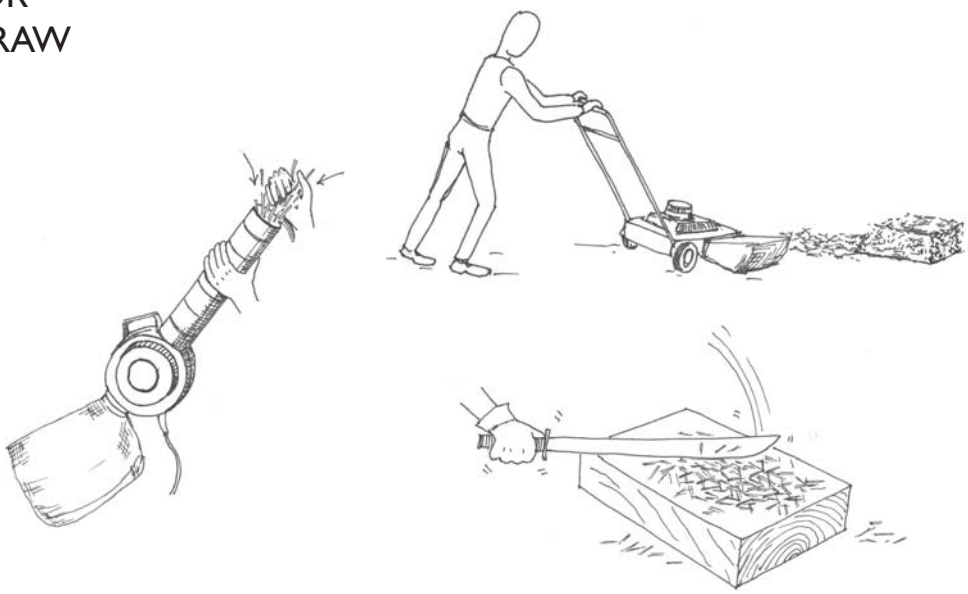
12. Wet the surface of plaster with a damp sheepskin or sponge and smooth over any small cracks that have appeared. This process can also be used for a sand-floated finish.

BUILDING A SCREEN



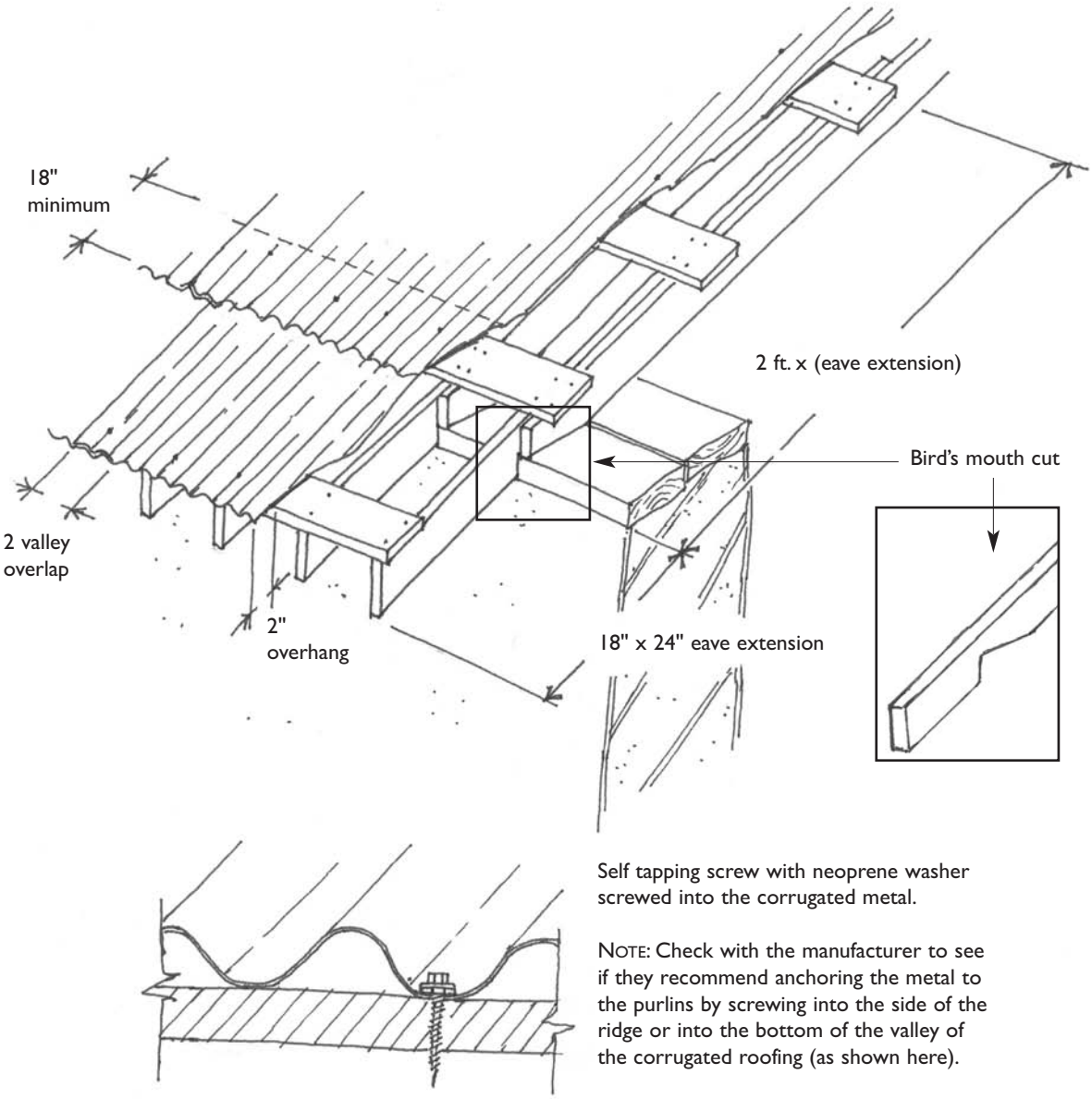
METHODS FOR CUTTING STRAW

Cut straw should not be more than one and one half-inches long when it is mixed into the mud plaster.



EXTENDING THE EAVES

Eaves that do not extend sufficiently beyond the plane of the walls they cover are a common source of water damage to the bases of adobe walls (see Part One, *Interpreting Sources, Processas and Effects of Deterioration*). Extending the eaves ensures that the water dripping from them is directed well away from the base of the building and will help alleviate this common source of deterioration.

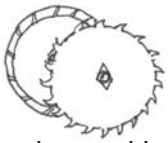


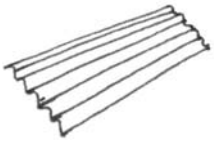
Self tapping screw with neoprene washer screwed into the corrugated metal.

NOTE: Check with the manufacturer to see if they recommend anchoring the metal to the purlins by screwing into the side of the ridge or into the bottom of the valley of the corrugated roofing (as shown here).

TOOLS AND MATERIALS REQUIRED

Circular saw


Circular saw blade, diamond blade


Corrugated metal

Drill

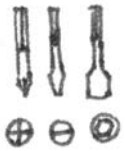
Gloves

Goggles

Hammer

Handsaw

Hard hat

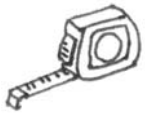

Hex bits

Jigsaw

Ladder

Level

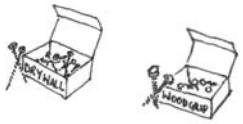
Lumber


Measuring tape

Nails

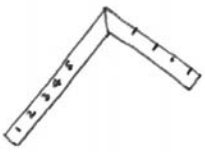
Plumb bob

Scaffolding



Screws (drywall and wood grip)

Sheet metal shears


Square

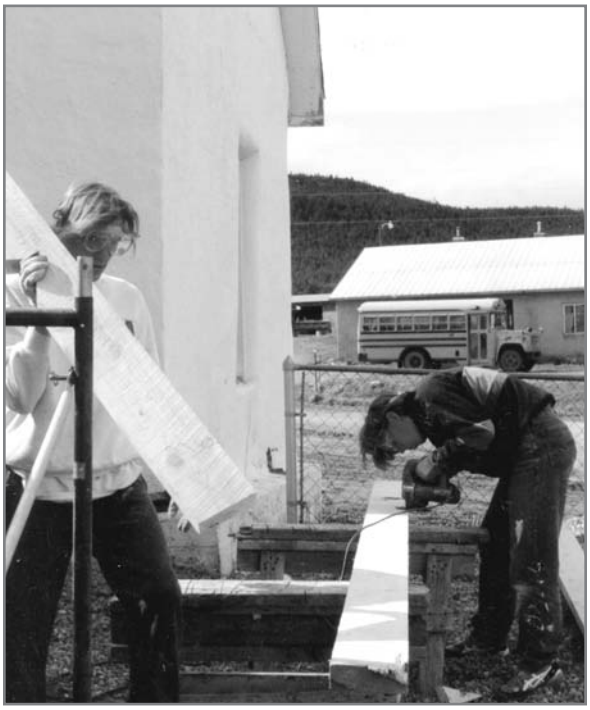
String

The following steps outline the process of extending the eaves to adequately funnel runoff away from the structure:

1. Hang a plumb bob from the existing eaveline to measure the dripline at the base of the wall. The dripline should be 18 to 24 inches from the wall.

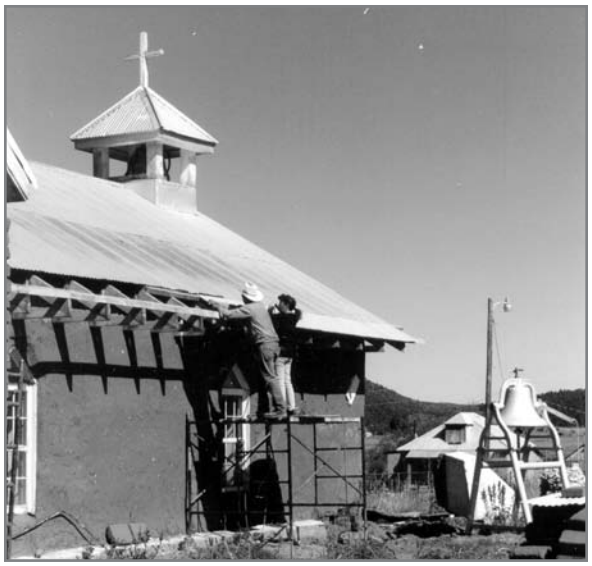
3. A new board should parallel the existing rafter for a minimum of three feet plus the lenght of the extension. Nail or screw the new board to the existing rafter.

4. Use a string guide to ensure all of the eave extensions being installed project an equal length beyond the wall plane. Extensions may also be cut after they have been installed, in which case they should be cut parallel to the building.

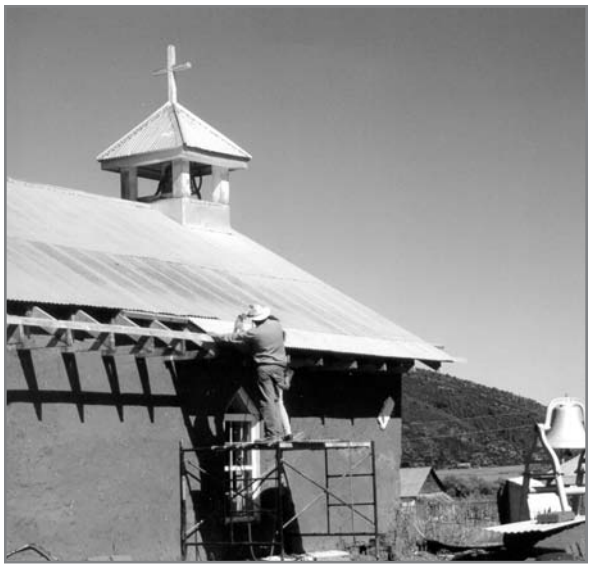


2. If the eaves are shorter than 18 inches, extend them to a minimum of 24 inches. The ultimate length of the overhang will depend upon the proportions of the building. Choose a length that is both functional and aesthetically pleasing.

5. Any new purlins that are installed should match the existing purlins. Purlins are perpendicular boards spanning the rafters (see Part One, *Architectural Terminology,* for an illustration of purlins).



6. The existing corrugated metal roof should overlap the new corrugated metal a minimum of 18 inches. The new corrugated metal should extend past the new wood a minimum of two inches and a maximum of three inches.



7. The corrugated metal should lap two valleys over the adjacent sheet. Secure them with one inch or longer self-tapping screws and leak-proof neoprene washers. The new corrugated metal must match the existing roof or the addition will not lap correctly.

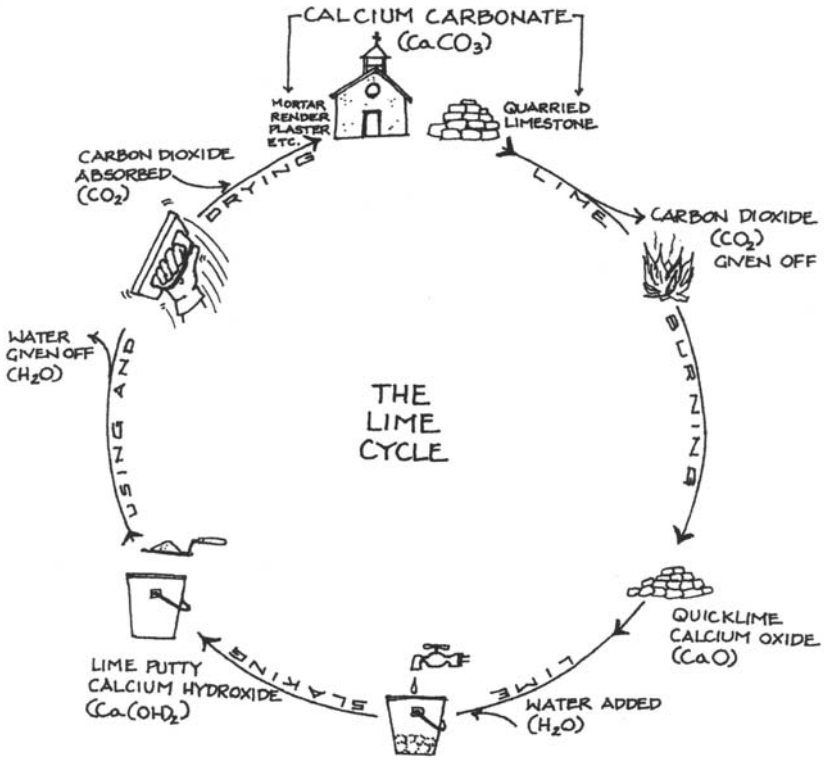
NOTE: *Canales,* spouts, or *gargolas* may also be a problem and may be extended if necessary. A catchment with gravel may also be installed under the dripline. Another solution to prevent coving due to splashing is to install large rectangular flat stones leaning against the base of the wall. Stones should not be laid flat against the wall but should have an airspace between the wall and the stones should be separated from each other a minimum of 1/2 inch.

FIELD NOTES

LIME PLASTERING

The use of lime plaster and render has been lost as a building tradition in the Southwest. In recent years, however, there has been a renaissance of lime use in New Mexico. Lime plaster predates recorded history and its use has been verified by excavations worldwide. Spanish settlers coming north from central Mexico commonly used lime for both plasters and mortars. During the 16th century in Mexico slave Indian labor provided the necessary workforce to produce an abundance of lime. At that time, lime production was in such high demand that it became a moving force in the economy of Mexico City (Kubler, *Mexican Architecture of the 16th Century*: 170). Due to the Spaniards' reverence for lime technique, many missions throughout the Southwest were lime plastered. Although this technique is known to have existed during pre-Columbian times in the limestone-rich areas of Central America, South America and Central Mexico, it did not experience widespread use in the American Southwest.

Despite the abundance of limestone in New Mexico, the use of lime mortar was not developed in the Southwest until the late 19th century (Kubler, *The Religious Architecture of New Mexico*: 24). However, we know that the Socorro Mission in Texas was lime plastered by 1860. Spanish Colonial census statistics suggest that population decline prevented the labor-intensive process of producing lime from being a viable building option except for some locations in the southern New Mexico. The production of adobe continued to be the most efficient method of construction considering the lack of human resources. Small quantities of lime were used, however, for the production of corn tortillas and some religious art.



By the late 19th century, with the continual influx of Americans from the east, technology was finally available to begin local lime production. Throughout the American period, lime became popular as a mortar and plaster on adobe buildings. It is now recognized that *caliche*, a naturally occur-

ring precipitate of calcium carbonate, was used to amend mud for adobes and plasters in northern Mexico and the Southwest. As lime technologies became more prevalent during the American Period, the material, in large part, replaced mud mortar for use with stone and fired brick masonry. Interior framed walls covered with wood lath were commonly rendered with lime and finished with calcimine paints.

Although not widely recognized, lime plasters were fairly prevalent in New Mexico prior to the introduction of Portland cement in the 1900s. Though more common in the southern part of New Mexico because of its close connection to the mother country, lime plasters are also found in the north, and in particular in the Mora Valley north and west of Las Vegas, New Mexico. Historic lime quarries and kilns have been identified in many parts of New Mexico, and a few slaking pits dating to the 1920's are also known. With the coming of the railroad and the increasing availability of Portland cement, both mud and lime were displaced as renders.

The following section defines the chemical and mechanical advantages of lime renders on earthen walls. There are many benefits to working with lime instead of a non-permeable material such as cement. One of those advantages is its vapor permeability, which makes it an optimum material on earthen walls. In their book, *Building with Lime*, Holmes and Wingate outline some of these characteristics:

Stickiness – Lime binds gently, adhering to surfaces without the use of a metal lath.

Workability – Lime remains smooth and moldable even against suction it may experience from porous building materials.

Durability – Lime is very durable. The Roman temple known as the Pantheon has a lime-based concrete dome spanning 43.2 meters that has endured for nearly nineteen hundred years.

Soft texture – Lime mortar cushions joints between stones and brick, prolonging their life by eroding before the structural element does.

Breathability – Lime dries out buildings and avoids condensation problems.

Low thermal conductivity – Lime is warmer than cement plasters in cold weather and also improves conditions in hot weather.

Autogenous healing – Lime develops many small cracks instead of individual large cracks that occur in cement plastered buildings. When water penetrates these fine cracks, it dissolves "free" lime and brings it to the surface. As water evaporates, the lime is deposited and begins to heal the cracks itself.

Protection – Lime protects earthen walls from severe rain.

Compatibility – Lime is one of the most compatible materials for use with earthen structures.

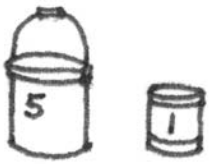
NOTE: The process of firing drives the moisture and carbon dioxide out of the limestone. In this state, referred to as "quicklime," the material is extremely caustic and must be handled with care. Contact with skin can result in severe burns as the lime draws moisture out of the body. Always use eye and skin protection when handling quicklime, and wear a filtering mask when you are exposed to lime dust. Do not pour large amounts of water into the mix when slaking quicklime! The violent chemical reaction could result in an explosion. And, never bend over a barrel of lime; stand upright when working with lime!

In very warm, dry weather when temperatures are above 90° F., the plaster can dry too rapidly and fail to re-carbonate thoroughly. The result will be a plaster with a chalky consistency that will tend to delaminate from the wall. In areas where temperatures remain in the 90° range or above for weeks or months at a time, it is advisable to wait for cooler weather. Conversely, do not apply lime plaster within 45 days of freezing weather.

To produce the most durable, as well as the most workable material, the quicklime should be as white as possible. Discoloration in quicklime is indicative of impurities. The material should be fired at a temperature of at least 900º Celsius/ 1,652º Fahrenheit for a minimum of 36 hours. Time will vary based on the burning process and amount of lime being burned.

TOOLS AND MATERIALS REQUIRED

Brick layer's (mason's) trowel



Containers

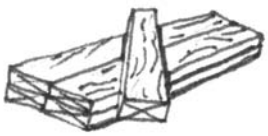
Drums, 55 gallon

Dust mask

Gloves

Goggles

Lime putty



Lumber

Mixer

Plasterer's hawk

Plasterer's trowel

Sand

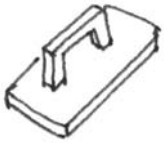
Scaffolding

Screen

Shovel

Water (potable)

Wheel barrow



Wood float

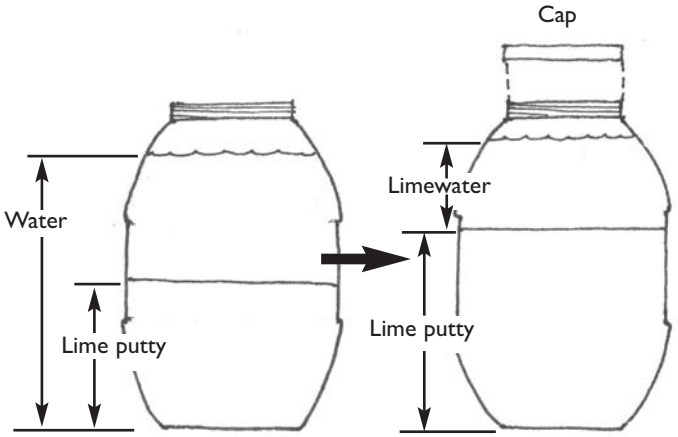
PREPARATION OF LIME

The following steps outline the process of preparing lime for plastering.

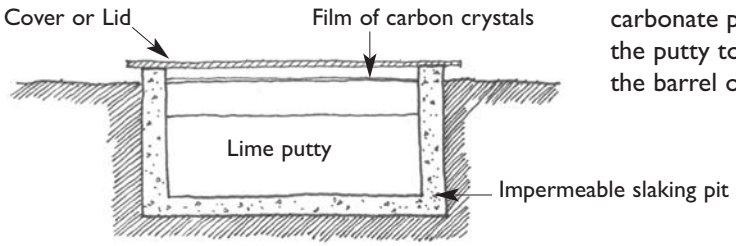
1. Slaking begins when quicklime is immersed in an excess of water. Fill a five-gallon bucket half full with clean water. Alternatives are to use a slaking pit or a wood box for hydrated lime. Add small lumps of quicklime. NOTE: If too much lime is added to the bucket at one time, it is possible for the resulting heat to melt the plastic container. The reaction will be volatile as the lime absorbs the water and turns to calcium hydroxide.

2. Mix constantly and thoroughly. Maintain enough water in the bucket to keep the material liquid.

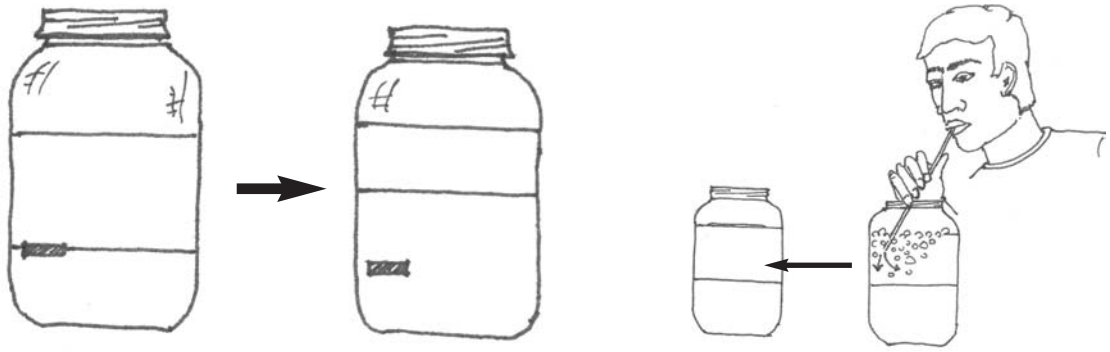
3. As the "boiling" dies down, screen the liquid through 1/4-inch mesh screen into plastic barrels. NOTE: Metal barrels cannot be used because they corrode before the slaking process is complete.



4. When the barrel is half full, top it off with water. This will help ensure that the lime does not come into contact with the atmosphere and begin to re-carbonate prematurely. It will also allow room for the putty to "grow" as it absorbs water. Tightly cap the barrel or cover the lime pit.



5. The longer the lime slakes, the higher its quality becomes. Some master craftsmen use only lime that has been slaking for decades. In the Southwest there is no documented tradition dictating a minimum period for aging, but experience dictates that a minimum of 90 days is necessary to provide both the characteristics of plasticity and durability that are desirable. Three or more years of barrel or pit slaking provide a very high quality product. NOTE: It is imperative that the lime putty be kept in airtight containers as a safety precaution with several inches of water over the top. Periodically uncap the barrels or lime slaking pit to verify that the putty is covered with water.

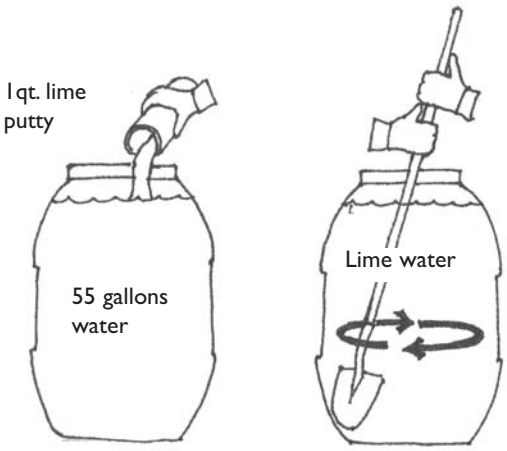


6. Hydrated commercial lime and lime putty are alternatives to quicklime and may be easily tested for quality. For best results with commercial hydrated lime, buy the freshest lime available. To test quality, fill a jar one third full with hydrated lime. Mark your jar to indicate original volume. Then fill the jar two-thirds full of water, shake or mix, and observe it for several days to see if the lime putty expands. Good lime putty will expand twice its original size. Sacklime or hydrated quicklime should also undergo a minimum of one-week slaking process in a drum, lime pit, or wood box. Water is added to the putty to achieve workability for use as a plaster or wash.

NOTE: Using powdered lime right out of the bag is also an alternative. Recent laboratory tests conducted using Chemstar brand Type "S" bagged lime confirmed that the powder can be mixed with water to the desired consistency and used right away. This particular brand of lime is double-bagged for dampness protection and Cornerstones has had very good results using it. Comparable brands of powdered lime will need to be tested for quality and freshness prior to large-scale use.

7. When the wall to be re-rendered still retains all or part of a previous cement-plastered system, the old material must be removed down to the substrate of the wall; i.e. all the way to the adobes. This process should be done with care to protect original materials (see Part Three, *Removing Cement Plaster*).

8. If the wall is adobe, any loose or shattered material, or any surface area of the blocks that has delaminated from moisture of freeze-thaw cycles, must be removed. Loose material can easily be scraped or extracted using a mason's trowel and should be washed with the use of a gentle spray of water from a low-pressure hose.



9. All water used in the process of preparing for the application of lime render should contain as low a percentage of lime as possible. Begin with clean water in a 55-gallon barrel. Add a quart of lime putty and agitate with a shovel handle, a clean board or a drill with a paddle. Water that appears milky will have an excess of 5% lime in suspension. After the solids have settled, the clear water will still have up to .05% lime in suspension.

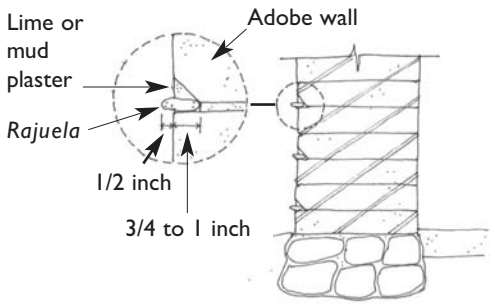
PREPARING THE WALL

1. The use of limewater in wetting the substrate and mixing the mud for repairs helps increase the adhesive and cohesive characteristics of the mud. A chemical bond is formed between the lime and the mud, as the limewater dries and re-carbonates in the adobe walls.

2. In preparation for application of the lime leveling coat, the header and bedding joints in an adobe wall that will receive a *rajuelar* (natural anchoring system) should be scraped to a depth of 3/4 of an inch, sprayed clean and left open. In most *rajuelar* systems, all header and alternating bedding joints are treated. The building may also be mud plastered with the *rajuelas* embedded into the mud as lath.

NOTE: Although lime plaster may be applied directly to the adobes without the use of a *rajuelar* system, binding and adhesion between the plaster and the adobe substrate is greatly enhanced when a natural anchoring system is used. "Natural" refers to the use of compatible materials (e.g., porous lava rock, angular local stone, bone) rather than materials that do not share similar properties of expansion and contraction, and/or are prone to deterioration or corrosion over time (e.g., metal lath).

3. Brush wall clean with a broom and dampen using limewater prior to lime plaster application. Mud or lime mortar should be thrown into adobe joints in the wall. If it is mud, it should be mixed, either by hand or in a mechanical mixer and left soaking overnight and covered. For best results mix with limewater. The mix should be forcefully thrown into the voids in the joints and onto the surface, and then worked smooth with the heel of the hand or a brick layer's trowel.



4. The rocks should be inserted in the header and bedding joints of the masonry units of the wall. After the joints have been filled with mix, each header joint should receive one or several stones where possible; every second bedding joint should receive a continuous row of stones.

NOTE: Avoid using metal lath or stucco mesh with lime plaster, for maximum long-term cohesion and minimum corrosion.

LEVELING COAT

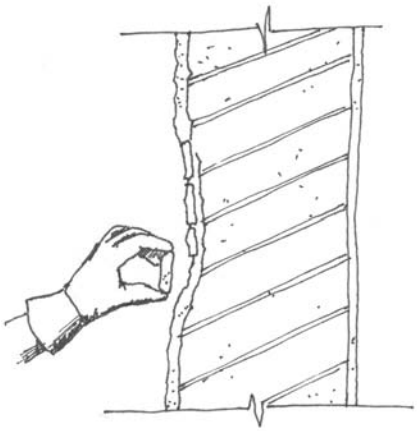
1. Use a clean motor-driven paddle or mortar mixer to prepare the mix. The ideal mix is three parts washed concrete sand or clean arroyo sand to one part lime putty. According to sand particle size, the mix may vary. Add lime putty and then the dry aggregate. Use water to obtain the correct consistency. If more water is needed, add it last. The consistency of the mix should be such that it does not cling to the paddles of the mixer but falls off the rubber wipers when they come around to the vertical position. Mix only the quantity of lime plaster that can be used within a day as long as it is kept wet/damp. It is acceptable to premix lime plaster. When ready for use, however, remove the water on the surface and thoroughly re-mix the plaster. Once mixed, applied to the wall, and exposed to the atmosphere, the lime plaster begins to re-carbonate. The plaster can also be mixed and covered and left overnight to be used the following day. If the plaster is not used before it dries, it must be discarded.
NOTE: Old material cannot be reconstituted or re-slaked.

2. Before the leveling coat is applied, thoroughly dampen the wall with limewater or lime milk. This may be accomplished with a mason's dash brush or with a small container used to splash water onto the surface. In a hot, dry climate, the moisture will quickly evaporate. It is advisable, therefore, to dampen only small areas at a time. Walls may be dampened repeatedly, a practice that helps assure bonding of the lime to the wall.

3. The leveling coat serves to fill low spots and small voids and to provide a flat, uniform surface for application of the final coats. Plaster should be applied with force. In no instance should the aggregate exceed 1/4 inch in any dimension. The lime-leveling coat should be applied to a thickness that thoroughly covers the exposed *rajuelar* system if one is present.

4. In situations where the wall has deep hollows, embedding flat, non-glazed tile or brick fragments in the leveling coat is permissible to help bring the vertical surface into plane. Porous stones or chunks of adobe may also be used.

NOTE: It is very important to use a mason's or harling trowel to "sling" the lime forcefully onto the wall. Do not use a plaster's hawk and trowel to apply the lime because of the potential for adhesion problems.



SECOND AND THIRD COATS

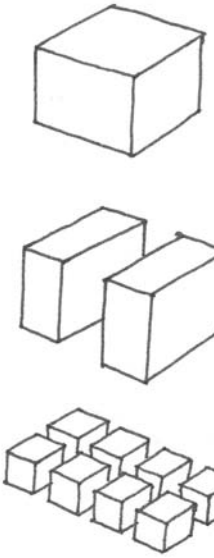
1. The second coat should be applied with adequate force to prevent cracking and then leveled with a straightedge or darby to a thickness that covers irregularities in the leveling coat. A single application of plaster should not exceed 3/4 inch in thickness. Minor hairline cracks may be disregarded. If large cracks appear, the mix may be too rich (excessive lime) or the plaster may be drying too quickly. Areas of cracked plaster exhibiting weak adhesion should be removed and replaced.

2. Lime begins to dry or re-carbonate as soon as it is exposed to carbon dioxide in the atmosphere. The render will become firm within thirty minutes of application, and hard within six hours. It is a characteristic of lime that the render gains strength through repeated wetting and drying cycles. The drying time can and should be retarded by repeated dampening or shading the surface with a tarp or a burlap cloth. Taking these precautions will slow the re-carbonation process and result in a more durable plaster.

3. The finish or set coat of lime plaster can be slightly richer (use more lime) than the leveling or second coat. Some plasterers prefer to trowel on the final coat using a hawk and metal trowel. This coat may also be thrown or hurled onto the previous coats of lime plaster and leveled using a darby. The finish or set coat should have no aggregate that will not pass through a number eight sieve. A two to one (2:1) aggregate to lime putty is typical. The finish or set coat of lime is typically thin, seldom more than 1/8 to 1/4 inch in thickness. Natural pigments may be used in the mix to add color to the wall, (see *Earthen and Lime Finishes* below for more detail).

4. Most lime rendering systems have a "hard" trowel finish. This is accomplished by working the material with a dampened rigid wooden trowel until it is smooth.

NOTE: If using a hawk and trowel to apply the finish coat, do not use the steel trowel to work the finish. Metal trowels tend to create adhesion problems by drawing the fine aggregate particles to the surface. Instead, use a wooden trowel soaked in water to achieve the desired finish.

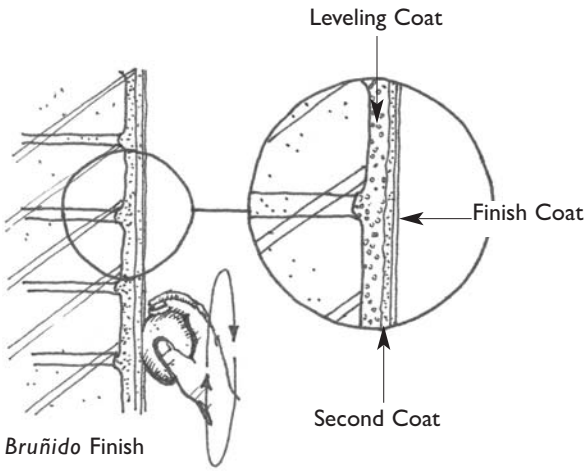


Leveling coat
Large aggregate surface to cover

Second coat
Larger aggregate surface to cover

Finish coat
Largest aggregate surface to cover

5. This drawing shows why proportions of aggregate to lime change. The cubes represent the aggregate (sands) surface. The larger the aggregate, the smaller the surface area, thus the less lime you need to cover the aggregate. The finer the aggregate, the larger the surface area, therefore the more lime you need to cover the aggregate. For this reason, you should always experiment with your mix on a test panel prior to beginning the actual plaster job.



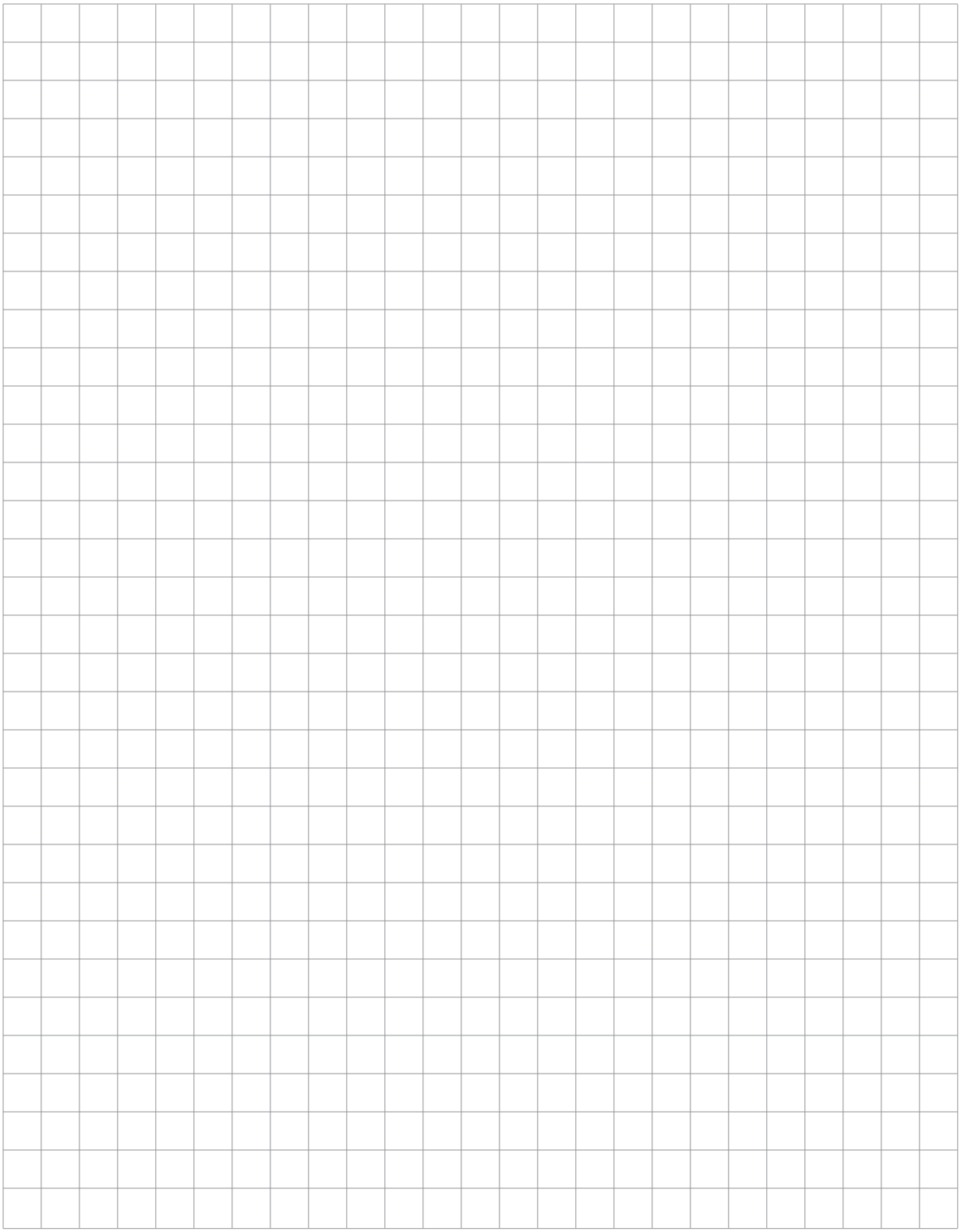
Bruñido Finish

6. If a finer hard finish is desired, a smooth river rock can be used to work the damp finish coat. This method is known as a *bruñido* and is usually used to finish interior walls or exterior barrel vault roofs and domes. This method is not advisable for exterior walls, since the plaster needs to be as permeable as possible.

7. Cracks in the finish coat will appear from time to time over the life of the plaster. It is one of the characteristics of lime that it is self-healing. Hairline cracks tend to disappear and reappear in different locations over time. Expansion and contraction are often the cause of cracking, and absorption of moisture from the air during humid times is often the catalyst for "healing."

NOTE: It is important to finish the wall with a lime whitewash or pigmented lime wash to complete the job. See the following section on how to apply a lime wash.

FIELD NOTES



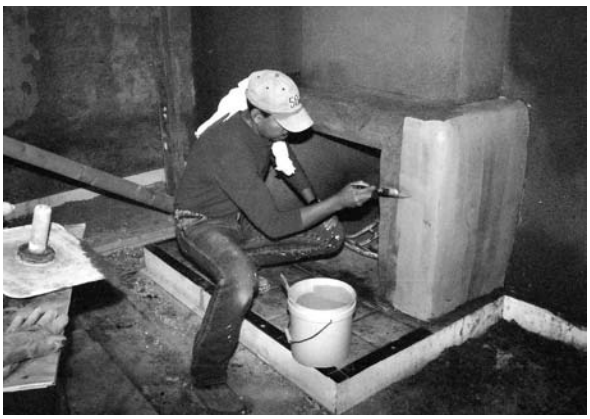
EARTHEN AND LIME FINISHES

This section explains the use of natural soils and pigments for finishes on earthen walls. One advantage in using these natural materials is that they allow the adobe wall to breathe. The traditional method of painting earthen walls goes back to ancient times. Frescoes throughout Europe were executed on wet lime plaster with natural pigment paints. The Pueblo Indians used natural pigments and clays to paint interior murals and to finish their walls. During the Colonial era, the Spanish and Mexicans brought to New Mexico the technology to produce lime that they used for decorative painting and perhaps for other household reasons. There is little evidence, however, that lime was abundantly produced during the colonial period in New Mexico, especially for plasters.

An earthen finish is typically a colored clay wash applied to interior mud plastered adobe walls. The colors are obtained by using different colored clays and naturally occurring oxides. *Tierra amarilla*, *tierra colorada* and *tierra blanca* are the names for three earthen finish colors. These colored clays are found in different locations in New Mexico. Other materials such as *jaspe* (gypsum) were also used as a white wash or color wash with a gypsum base.

According to Dr. Anselmo F. Arellano in the article "Rincón de Yerbas" (*La Herencia del Norte,* Spring 1997), gypsum, or hydrated calcium sulfate, was a product in high demand in early times. The pride of every lady of the house in the old days was to have a tidy attractive home, regardless of how small and humble it might be. For this reason, women usually applied whitewash to interior walls and to the walls of outside covered porches. This *japse* or *yeso* (gypsum) whitewash was typically applied with a sheepskin that had been tanned with the wool left on it.

Although the *jaspe* whitens mud-plastered walls, it is easily rubbed off. In some houses a



light red cotton cloth was hung against the lower part of the wall to protect the inhabitants' clothing. Later, when the Santa Fe Trail brought calico from the U.S., it was used for the same purpose and was often seen lining the walls up to a height of four feet.

Another technique is *encalado* or lime whitewash. This technique uses a diluted lime putty to which pigments have been added to create calcimine paints. According to Kubler in his book, *Mexican Architecture of the 16th Century*, lime was indispensable to the great architectural accomplishments of the 16th century in Spanish Colonial Mexico.

Historic architecture in southern New Mexico towns (Mesilla, for example) are more likely to exhibit lime technologies due to their proximity to on-going lime traditions in Mexico. Historically, the use of lime for whitewash was not common in other parts of New Mexico until the American occupation resulted in the construction of local lime kilns.

This section provides a basic knowledge of the finishes that can be applied, and of ways to polish them. It is worth noting that application of these finishes on earthen walls is a tradition that has almost been lost. Many structures with these finishes continue to vanish from the landscape.

NOTE: Earthen finishes can smooth out the texture in plaster. They will not fill cracks, however, unless they are also applied as a thin plaster, and not just painted on.

If a more dynamic and shimmering finish is desired, mica can be added to an earthen finish or wash. Micaceous clays are readily available in New Mexico and can be easily found in most areas.

TOOLS AND MATERIALS REQUIRED

Buckets

Cactus (nopal)

Gloves

Goggles

Lime putty

Mineral oxide pigment

Paint brush

Paint roller

Paper cups

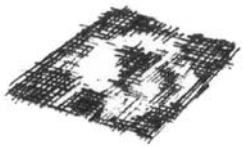
Sand

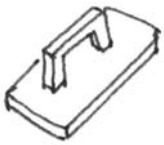
Scaffolding

Sheep skin

Shovel

Water (potable)


Window screen

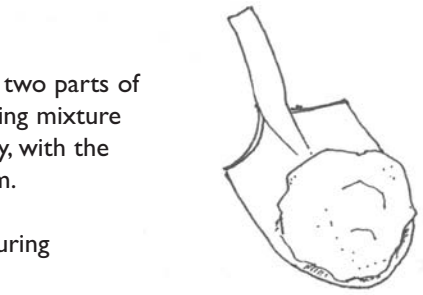

Wood float

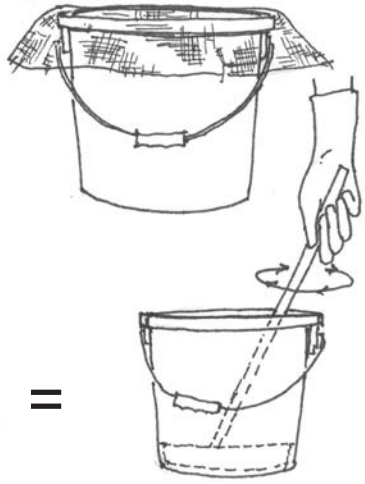
EARTHEN FINISHES

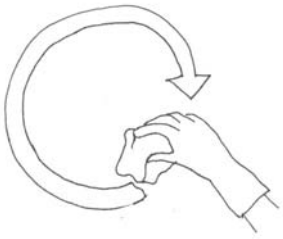
A colored earthen plaster can be applied in very thin coats over mud plaster. In order for this method to work, the correct proportions of clay and sand must be obtained. It is very important that the sand used be comprised of very fine particles (see Part Three, *Mud Plastering*). The mud plaster should be dampened before applying the colored plaster finish. Short straw can be added to the mix to prevent cracking and to add extra texture. This thin colored plaster finish should be hand troweled. Natural oxide pigments can also be added to the clay to produce different colors and finishes. Before application, test panels should be produced to obtain the right clay, sand, straw and pigment proportions. Remember when plaster cracks, it contains too much clay and more sand should be added. When ready to be applied, mix enough plaster to cover the entire wall surface.

Mix one part of clay with two parts of potable water. The resulting mixture will be a milky consistency, with the clay settling to the bottom.

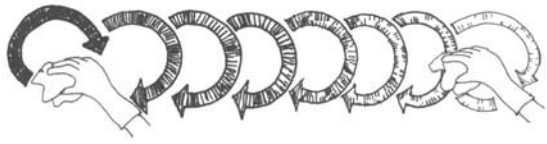
Constantly stir the mix during application.







Dip a sheepskin pad into a shallow bucket of the clay/water mix, stirring up the settled clay. Start at the top of the wall and apply the earthen mix with a circular motion.



The more coats applied, the more solid the finish and the fewer the inconsistencies that will appear.

Allow the previous coat of finish to dry before applying a subsequent coat.

LIME FINISHES

Lime finishes may be applied in different ways. Pigments used should always be mineral oxide tints or sieved earth with a high clay content. Many hardware stores carry lime-compatible pigments. Kremer Pigments, Inc. is a good source for pigments that can withstand the causticity of lime: 228 Elizabeth St. New York, NY 10012 Tel: (800) 995-5501. If using a natural earth pigment such as the ones described in the preceding section, they need to be clean and sieved. The best way to prepare the pigment is to sieve the soil through a window screen then mix with water and sieve again through a panty hose.

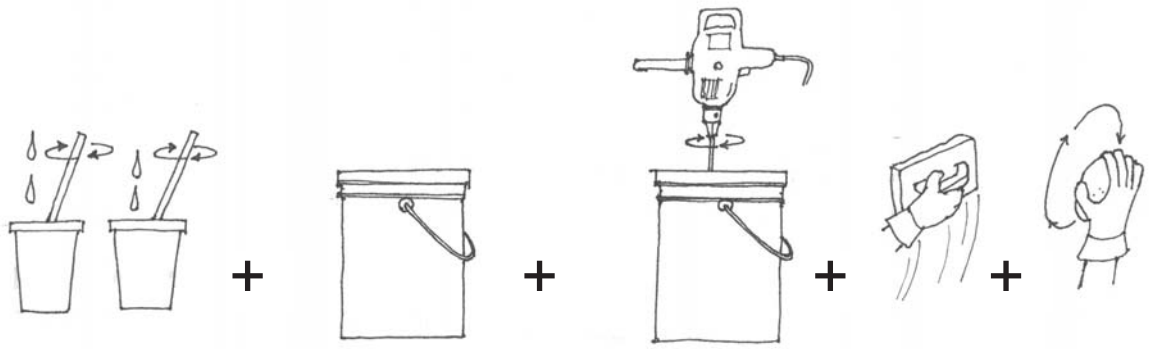
Lime wash should be applied to any exterior lime plaster system. If a pure white finish is desired, the lime wash should be applied without pigment. The wash should be mixed with water and lime putty to the consistency of two percent milk (see *Lime Plastering* above).

Apply the first coat with a soft scrub brush made of natural fibers, and fully work the wash into the pores of the plaster render. After the first coat is well worked in, subsequent coats may be applied with paint roller or wide whitewash brush. Our colleagues in Mexico teach us to strive for a "slapping" sound when using a large mason's brush. With each coat alternate the direction of brush strokes from vertical to horizontal. End on a horizontal roller or brush stroke to help prevent vertical channeling as water sheets down the wall.

For best results mix the pigment into enough lime putty to cover the entire surface to be worked on. The pigment should be diluted in water before being added to the putty. A small handful of table salt mixed into five gallons of lime wash can be used as an additive to improve adhesion of the lime finish to earthen or lime plasters.

NOTE: Do not add salt if salts are already a problem occurring in the wall and plaster structure. The finish coat should be applied in a similar fashion as the whitewash. Test panels should be made to obtain the right proportion of pigment and lime putty mix.

HOW TO PRODUCE A TEST PANEL



Mix two cups of pigment with water

Add the pigment to two gallons of lime putty containing fine aggregate (one-to-one fine aggregate to putty)

Mix the finish or set coat plaster with pigment

Apply with a metal trowel

Burnish the surface. The result will be a more durable color finish

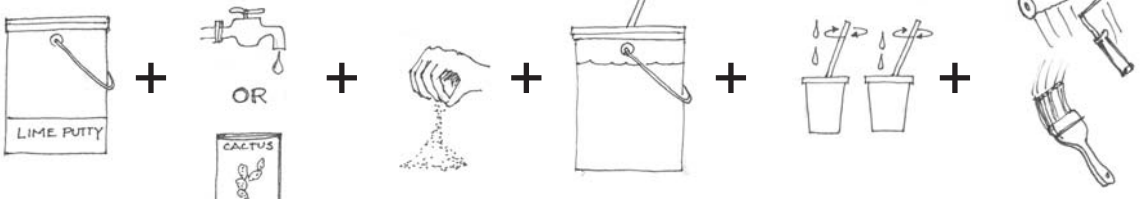
Cactus mucilage, or juice, is another component that may be added to an earthen or lime finish. The cactus juice will provide the lime wash with good adhesive qualities and imbue it with water repellent characteristics.

In the Southwestern U.S. and Mexico, where cacti grow prolifically, nopal (prickly pear), and in New Mexico, cholla mucilage can be used to stabilize earthen and lime plasters. The best mucilage comes from the prickly pear variety of cactus that is characterized by broad flat leaves. Cactus mucilage has a quality that helps plaster to set and adhere. It is an excellent alternative to artificial stabilizers.

To drain the mucilage from the cactus, it should be cut or scored with a shovel or knife. Place the chopped or scored cactus in a steel or plastic container half full of water. Typically, the chopped cactus needs to soak for at least one day in full sun before it will completely release its mucilage. Do not allow the cactus to sit in water too long because it will rot and release a putrid smell. If the temperature is too cold, you may alternatively heat the chopped cactus over a slow flame without allowing it to boil. If the water accidentally boils, immediately remove the metal container from the heat. After the mucilage has been extracted from the cactus, use a screen to separate the cactus from the juice. Use the water from the container with the mucilage to mix the lime wash.

Whitewash or colored lime wash mixed with mucilage may be applied, following the recommendations for applying lime washes, to the damp (green) finish coat. This technique may also be applied to a mud plaster finish.

MIXING WHITE OR COLORED WASHES



5 gallon bucket 1/3 full of lime putty

Add potable water or cactus mucilage with water.

Add a handful of common table salt for every five gallons if desired. The use of salt is optional and allows the wash to cure and adhere better.

Stir to a thinned-paint consistency.

Add desired pigment

Using a heavy vegetable bristle brush, apply the first coat of mix in consistent horizontal or vertical strokes. When the mix has dried, brush the second coat on in strokes perpendicular to the first.

Most lime finishes will be pastel in color with a light matte finish. Color also depends on the quantity and quality of the pigment used.

FIELD NOTES

EARTHEN ROOFS

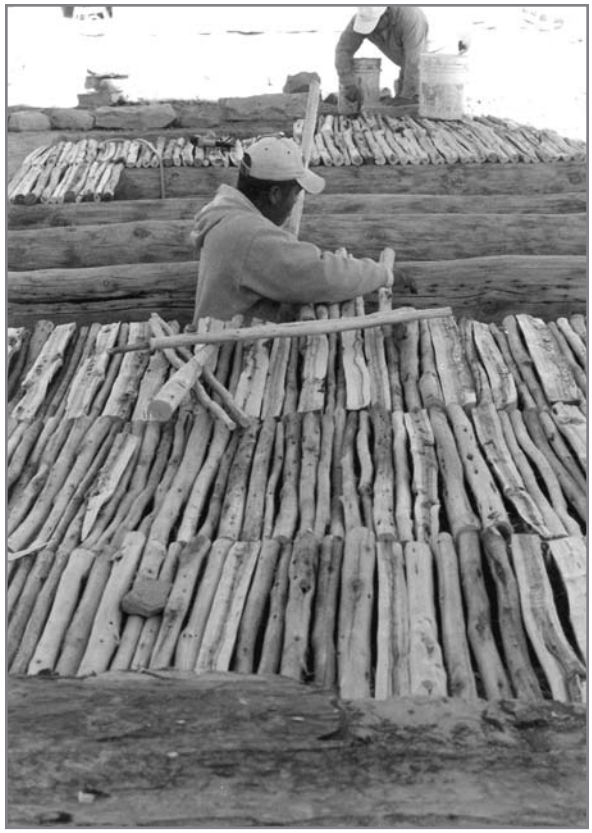
Earthen roofs had been developed by Native American builders in the Southwest and in Northern Mexico as a way to shed water from structures long before the Spanish arrived. Some of the best examples of earthen roofs are at Paquimé in Chihuahua, Mexico and at Taos Pueblo in New Mexico.

These early earthen roofs were applied in layers over a *viga*, *latilla*, and brush system. The layering system usually consisted of mud with a composition similar to that of puddled and molded adobe walls, but perhaps with a higher clay content. The earthen layer in this system is referred to as the *torta* or *terrado*. *Latillas* and *vigas* both varied in type according to region.

In New Mexico many types of *latillas* were utilized, from willow and cottonwood in the south to cedar and pine in the north. Some *latillas* were small peeled logs or branches, others were split branches, and still others were adzed logs that formed flat boards or *tablas*. It was not until the American Period that milled lumber became an alternative to some of these older techniques.

The brush also varied from region to region. Yucca fibers and *carrizo,* or cattails, are just a few of the many types of brush that served to retard the filtration of dirt and dust through the roof and into the rooms below. Some type of local vegetation was probably used to minimize cracking in Native American earthen mixtures. The use of straw arrived with the Europeans.

There are various interpretations as to how these early earthen roofs were constructed. One interpretation is that roofs were layered with wet mud. As each successive layer dried, the roof was shaped to obtain the desired slope toward the *canales* or water spouts. Roofs were constructed in layers, because the walls could not support the weight of all the wet layers of earth simultaneously. Each wet layer is roughly two to three times as heavy as it is when dry.



Working with Cornerstones, the Pueblo of Acoma restored a traditonal earthen roof system to the historic convento adjacent to San Esteban del Rey

Another possibility is that roofs were constructed with dry dirt. The first layer, however, was probably applied wet since this process formed a solid layer over the brush and better prevented dust from filtering through the *latillas*. Once this layer was dry the following layers were probably applied with a minimal amount of moisture in the soil. The dry layers would have been similar in composition to the initial wet layer but contained no vegetation fibers. Here too, the lay-

ers were compacted into place to obtain the correct slope toward the *canales*.

This system, like the first, was finished with a very fine clay mud plaster over the last layer of earth. Some fibers could have been used as a binder to prevent the clay soil from cracking. In Mexico these flat earthen roofs were usually finished with a compressed layer of lime plaster and coated with lye soap and alum for waterproofing.

Parapets, most commonly built with an earth composition similar to that used for walls, were also an important part of the roof system. They enclosed the roof area and allowed drainage to concentrate toward the *canales* or water spouts. These *canales* or *gargolas* were typically constructed of wood or stone.

The design of earthen roofs in New Mexico changed very little with the arrival of the Spanish, except for the introduction of lime, lye soap and alum surfaces. In Mexico, domes and vaults built with stone, adobe or fired brick became a common feature of colonial architecture; however, for various reasons these elements were not adopted by builders in New Mexico. In regions where materials and resources were available, some types of wood shingles and clay tiles were utilized. During the American Period, however, especially in the latter part of the 19th century, roofs in the region changed dramatically. New materials and technologies were introduced, in particular milled lumber that allowed existing buildings to be retrofitted with pitched roofs and finished with board and batten, wood shingles or metal sheathing. These additions revolutionized New Mexican architecture and permitted comparatively low-maintenance roofing systems.

Although traditional earthen roofs required periodic maintenance, they had the advantage of providing excellent insulation. Fortunately, most colonial structures retained their earth roofs when new pitched roofs were installed. The old earthen roofs continued to serve as insulation. Equally important, they stabilized the walls when new lateral loads were created by pitched roof framing. Most new adobe or stone constructions during the American period were designed to receive pitched roofs, but it was very common to also apply thin layers of earth in attics as insulation.

As a result, the problem of dirt filtering through roof surfaces, common during the Spanish and Mexican periods, continued into the late-19th century. Several methods were developed to remedy it. In the Colonial era, *mantas* were utilized as false ceilings. They consisted of cotton cloths that were stretched across the ceiling to cover the *vigas*, then whitewashed with *yeso* (gypsum) or lime to stretch the cloth. Once stretched and dried, the *manta* could be decorated or painted. During the American period, other solutions to this problem were developed, including at the turn of the 20th century the introduction of pressed tin drop ceilings. This type of alteration occured in New Mexico as well as in some parts of Mexico and added a new degree of elegance to interiors.

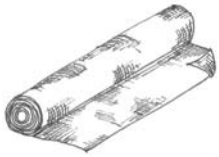
On the roof exterior other new materials were gradually introduced, such as asbestos. Perhaps the most popular and enduring introduction was that of petroleum-based asphalt shingles and rolled roofing. This revolution all but eliminated the use of earth for roofs, except in a few special cases.

TOOLS AND MATERIALS REQUIRED

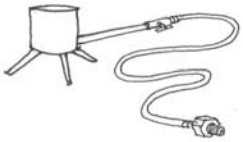
Buckets
(metal)

Alum
(aluminum sulfate)

Drums, 55 gallon



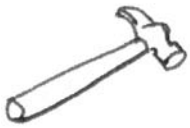
Filter fabric



Gas burner

Gloves

Goggles



Hammer

Hard hat

Knife

Ladder

Lime

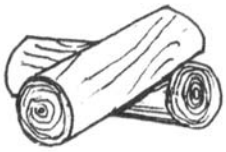
Lye soap

Mop

Plasterer's trowel

Sand

Soil



Vigas

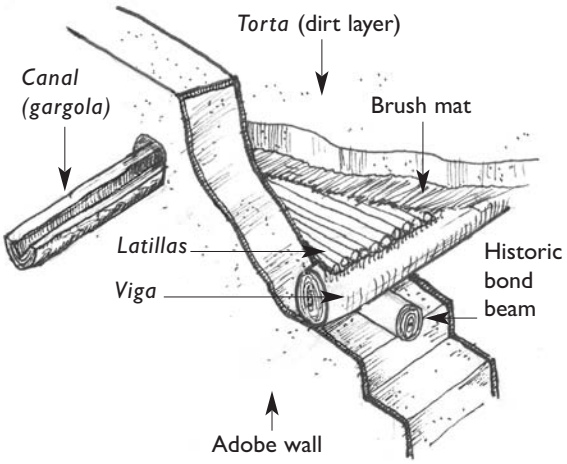
Water (potable)

Shovel

Wheel barrow

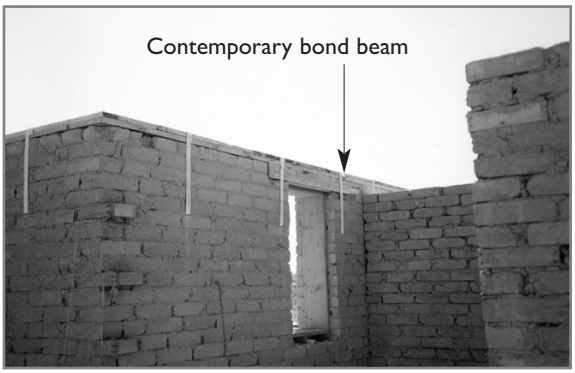
<u>Additional materials:</u>
BoraCare®

The following steps outline the care of existing earthen roofs and the reapplication of earthen roofs that were lost through modernization. NOTE: If the existing or original earthen roof needs to be removed in order to make the necessary repairs, reuse the original materials when possible. If the *vigas* or beams are deflecting or broken, it is usually the result of overstressing or overloading. The weight of a roof greatly increases when it is wet, especially when there is pooling due to poor maintenance. If beams are deflecting yet remain in good condition, they can be reused by turning them over with the hump toward the top. Generally, when the entire *viga* system must be removed and replaced, the parapets have to be removed as well. This is especially the case when a wood bond beam or plate is not present. Therefore, for the most concise explanation, the following steps begin at the plate or bond beam level and proceed to each step from there.



1. Investigate and document the existing earthen roof, *latillas*, *vigas*/corbels, and bond beams/plates, if present, to determine if the earth will have to be removed to repair any existing damage (see Part Three, *Inspecting Vigas and Corbels*).

2. If the roof is in poor condition, it may have to be shored before removals, repairs or replacements are carried out (see Part One, *Emergency Shoring*).



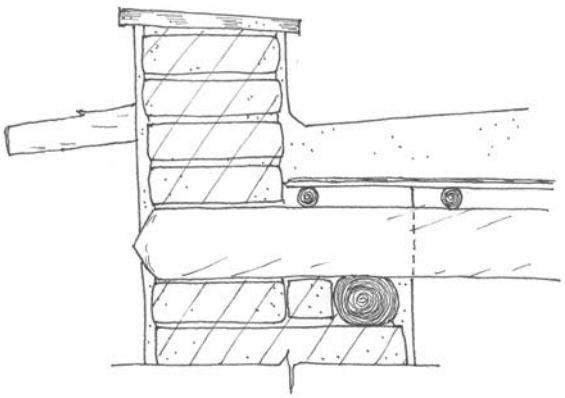
3. When the roof has been documented and the parapets have come down to the bond beam or plate level, careful attention should be given to this particular detail. If *vigas* are removed, make sure they are numbered to confirm original placement during reinstallation. If an historic bond beam is encountered, keep it and repair any deteriorated sections rather than removing and replacing it. If no wood bond beam or plate exists, then one should be installed. The *New Mexico Historic Earthen Building Code* requires a minimum six-inch wood plate for the entire wall thickness. Wood tie beams may be solid in the six-inch dimension or may be built up by applying layers of lumber. No layer may be less than one-inch thick. If the existing wood plate is in good condition, do not replace it. If a section of the plate is deteriorated, cut it out and replace it to match the original. Make sure that the new piece is tied to the old by metal ties or by lapping the wood members. Treat new and existing wood with BoraCare® whenever possible. (See Part Three, *Repairing Vigas and Corbels* for more information on BoraCare®.)

4. The plate can also be strapped to the wall if desired. This process can be done with metal or nylon straps. To insert the strap through the wall, first drill through the thickness of the wall using a masonry bit that is the size of the diameter of the strap. Position the hole at least three to four courses below plate level and at the mortar joint. The strap should then be nailed or screwed to the top of the plate with a spacing of four feet or as specified by the engineer or architect.

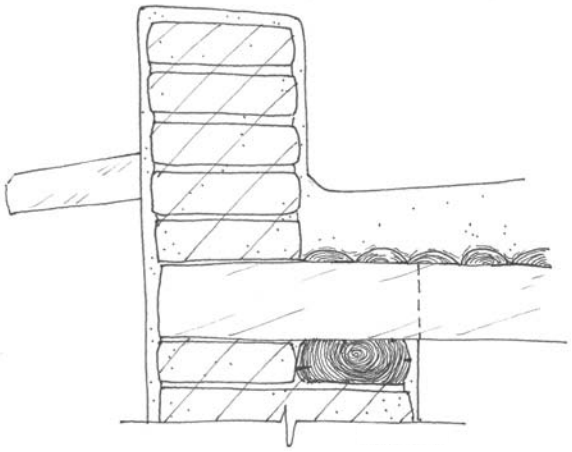
5. The *vigas* should be positioned at their original location whenever possible and placed over the plate. If a deflection exists in an original *viga*, but the *viga* is not damaged, simply turn it so that the hump is facing upwards (but only do this if the *viga* does not contain decoration such as painted or carved designs that would be lost to view when it is turned over). *Vigas* may be fixed to the plate if desired or left unattached since the load of the adobe parapet and the earthen roof will also act to stabilize them.

6. Build the parapet using the old adobes or stones removed from the original parapet if possible. The adobes from the parapet may also be recycled and made into adobes to match those still in use. The adobes should be used to infill between *vigas* and to build up the parapet wall (see Part Two, *Repairing and Restoring Adobe Walls,* for details on how to lay adobes). The openings for *canales* should be built while the parapets are being constructed. The top of the parapet should be slanted inward toward the roof. This slope can be obtained by layering the top courses in a slant and terminated with a sloping mud plaster. New parapets should be constructed to match the height of existing parapets, or to allow a minimum of six inches from the top of the earth layer to the top of the new parapet wall.

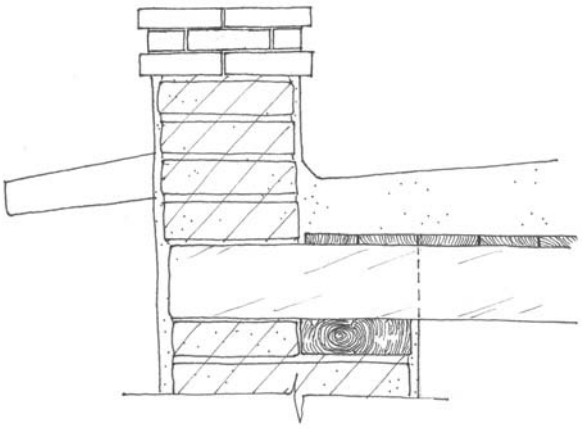
TYPICAL PARAPET DESIGNS AND CAPPING SYSTEMS



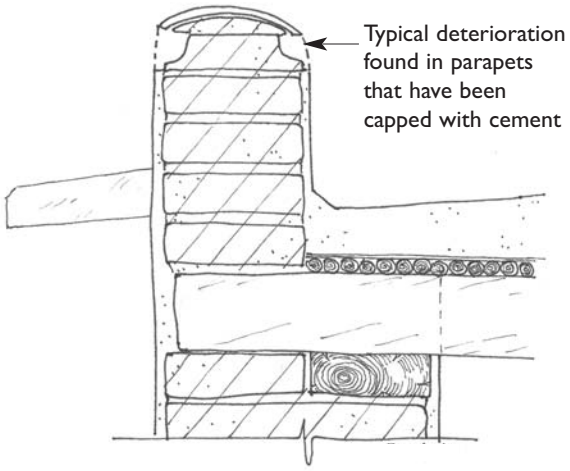
Flagstone



Mud/Lime



Brick



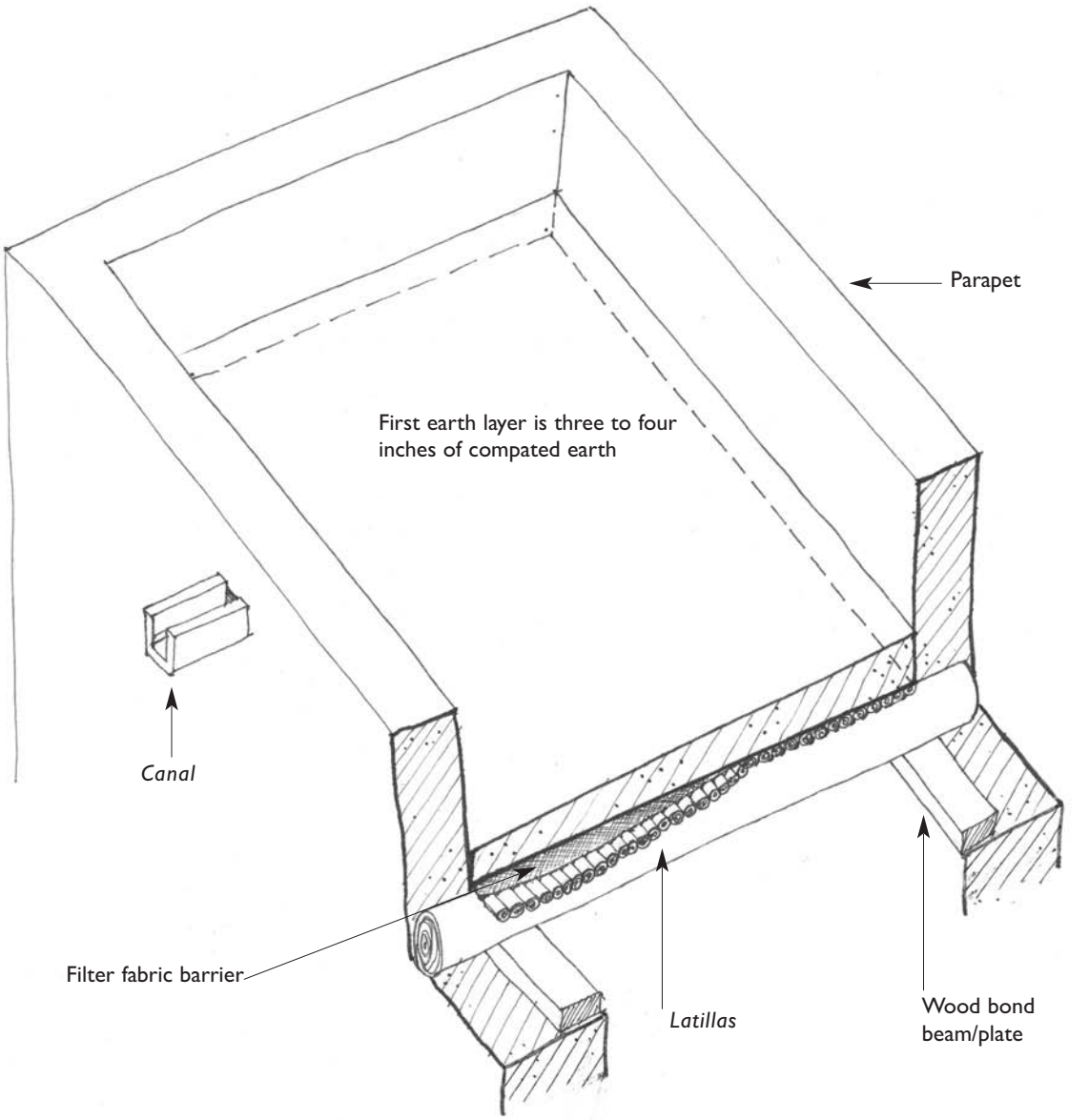
Cement
(not recommended)

7. Install the *latilla* or decking system over the *vigas*. *Latillas* are sometimes more difficult to apply than milled lumber, but they are much more aesthetic. If the *latillas* were originally painted, carefully number them prior to removal, but do not clean them. An art conservator should be consulted first for recommendations on the best method to protect and care for them. A *latilla* should span the gap between *vigas* and extend to the center points of the *vigas*. They should be secured with nails if their surface is to be walked upon before the first earth layer is applied.

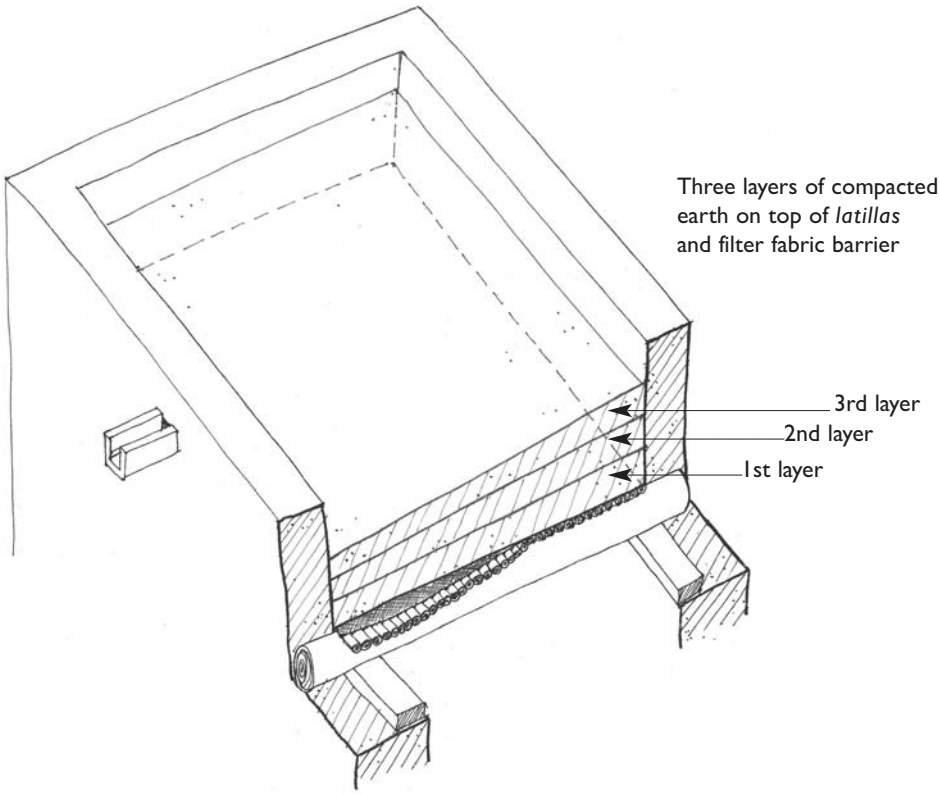
8. Reinstall the brush layer if one originally existed over the *latillas*. Place brush tightly together in a perpendicular fashion over the *latillas*. If decking was utilized, there usually was not a brush or fiber layer.

9. In order to prevent dirt from filtering into the interior, a filter fabric should be applied over the brush or decking. A filter fabric is preferable to a vapor barrier because it will allow the earthen roof to breathe. If the earthen roof is not maintained and another type of vapor barrier is installed, moisture will soak into the earthen layers rather than being dispersed as harmless vapor through the filter fabric. It is also easier to detect roof leaks with a filter fabric. Make sure each section of filter fabric is overlapped a minimum of eight inches.

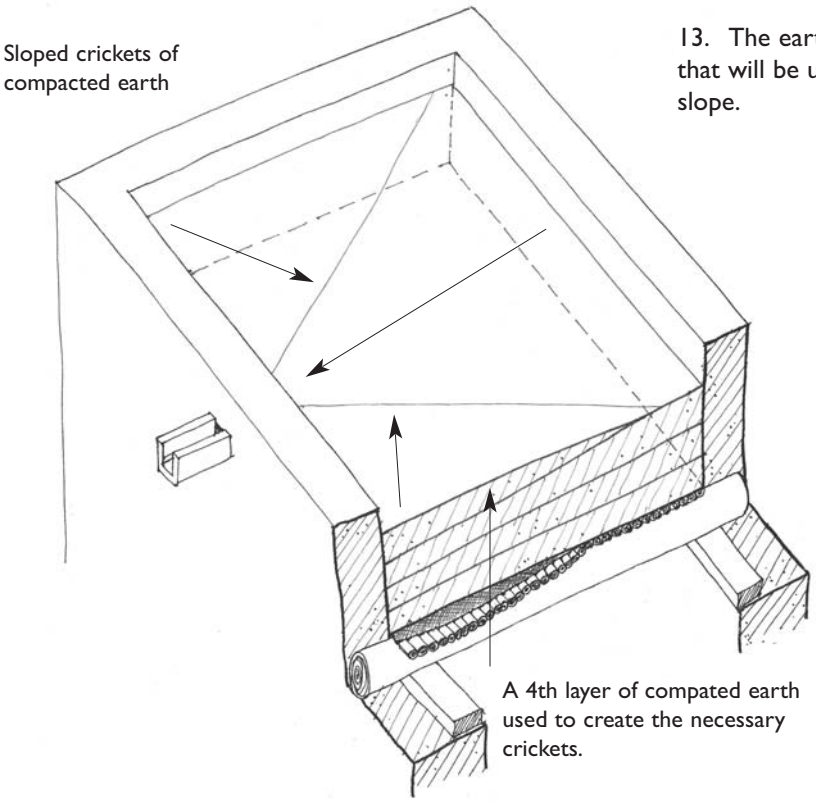
10. Layer earth on the roof using a soil with high clay content or a mix similar to that used for making adobes. Reuse the original earth from the roof whenever possible. Before applying the layers, draw a design that creates the correct slope and roof thickness to match the original. Consult an engineer to determine the amount of earth the *vigas* will be able to hold. Each layer should be three- to four-inches thick. The first layer should be spread evenly throughout the roof area. The earth in this layer should have some moisture in it, approximately 5%. Tamp it into place.



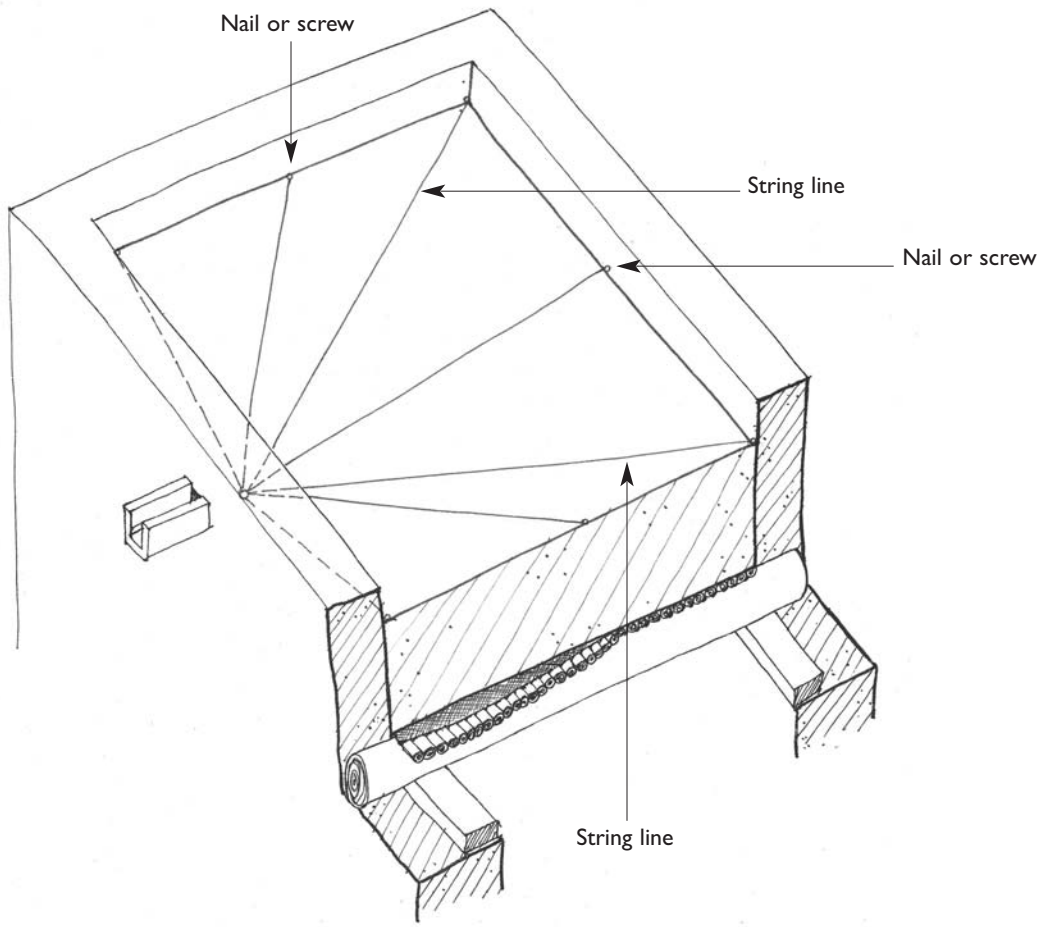
11. *Canales* should be installed over the earth layer and should protrude through the openings created in the parapet wall to contain them. *Canales* should match the originals in design and material. Original *canales* should be repaired and reinstalled whenever possible. These *canales* may vary in type. Historically, stone, wood, metal or a mixture of these materials were used to create them.



12. When each *canal* is set in place, the successive layers of earth should be carefully applied to create the desired thickness and slope around it.

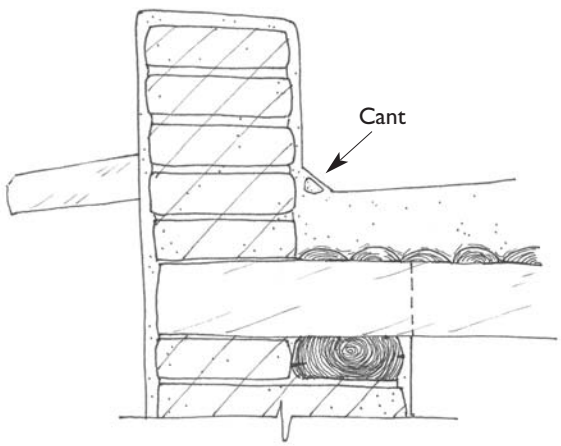


13. The earth roof should have high points that will be used to level and create the roof slope.

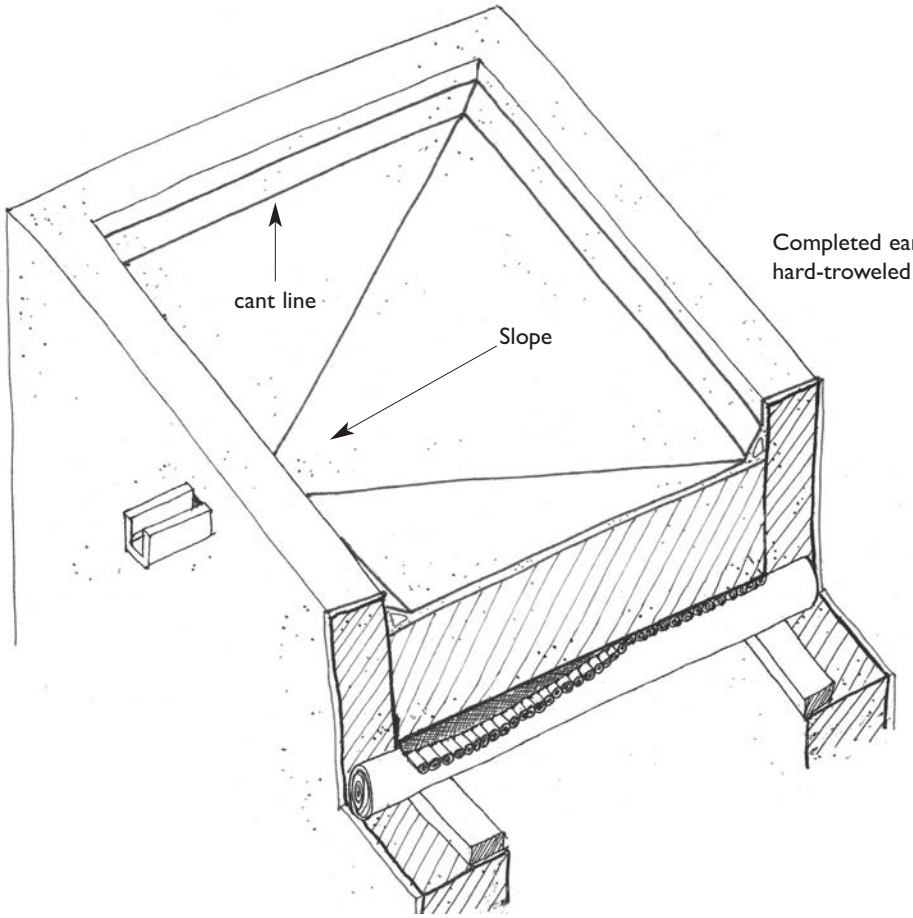


14. Place small screws or nails at all high points of compacted earth around the inside of the parapet. Tie string to each screw/nail and run the each length of string to the *canal*. Place a heavy stone, brick or adobe to anchor the strings tautly in place at the mouth of the canal. The levels of the strings will clearly show the high and low spots on the surface of the roof and show where dirt or lime plaster needs to be added or removed. The resulting earth roof will be quite thick. Mexican architect, Antonio Guerrero, has related his expertise in this matter. According to his documentation of historic structures, the highest point on an earthen roof typically corresponds proportionally to the thickness of the building's walls; however, if an engineer has calculated loads, this may not be the case. Remember, each layer must be moistened and tamped.

15. A coat of mud plaster about two-inches thick should be applied with a metal plaster trowel over the last layer of earth . The mud should have a high clay content and should contain straw. Where the parapet meets the last earth layer, construct a cant strip built with stones or pieces of adobes along the parapet wall.



16. The mud plaster layer should be applied over the cant strip and up over the parapet wall. The mud plaster should slope inward over the parapet wall. If cracking occurs, wet the plaster and hand trowel to obtain a smooth finish.



Completed earth roof with hard-troweled mud finish

17. In order to apply a more durable coat over the dirt roof, lime plaster may be installed. Prepare the lime following the directions found in Part Two, *Lime Plastering*. Apply the first lime coat (about an inch thick) with a metal trowel, just as the mud plaster was applied. Once dry, follow the first coat with a +/- 1/2 inch finish coat of lime plaster. This should be a fairly rich mix. Sift the sand through a 1/8-inch screen and mix one part sand with one part lime to obtain the final coat mix. Dampen the first coat of lime plaster before applying the final coat. Apply the final coat with a plaster trowel and continue to trowel while drying until all cracks are eliminated.

18. The final step is application of a waterproofing layer composed of lye soap and alum over the final dried layer of lime plaster. This technique was utilized in colonial times in Mexico, usually for lime roofs, but may be applied to the traditional earthen roof technology as well. Cut slices of lye soap as small as possible. Heat 100 liters (26.38 gallons) of water in a metal container and add 16 kilograms (35.55 lbs.) of sliced soap stirring until it completely dissolves. If the solution comes to a boil, remove the heat source. The solution should not be boiled or it may lose the desired chemical properties provided by the lye.

19. With a mop, apply the hot solution over the entire roof surface and the parapets. Allow it to dry.

20. Grind rocks of alum with a hammer. Following the same heating procedure, but in another metal container, boil 100 liters (26.38 gallons) of water and add 8 kilograms (17.77 lbs.) of ground alum. Allow the alum to dissolve in the hot water.

21. Apply the alum solution to the roof and parapets in the same manner over the dry coat of lye soap.

22. Six alternating applications of the lye soap and alum solutions should be applied, ending with a coat of the alum solution.

FIELD NOTES

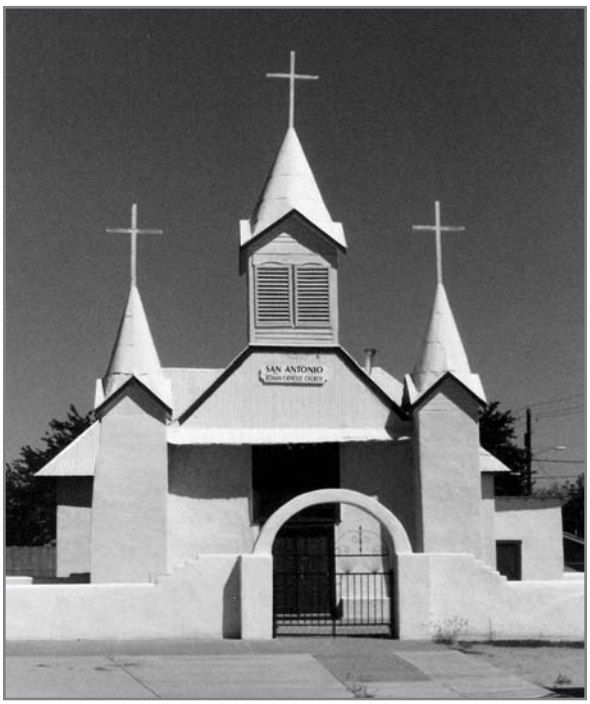
METAL ROOFS

With arrival of the railroad on the western frontier in the late 1800s, new materials were introduced as alternatives to flat earthen roofs. Wood shingles, board and batten, and pitched roofs were all used, but the most popular new material for roofs was corrugated metal. Most structures in northern New Mexico have pitched corrugated metal roofs. Zinc-treated corrugated metal roofing is effective and long lasting, but its expansion and contraction with temperature changes will pull fastenings loose and the wind will lift and distort the sheets. The sheets were often attached with lead-head nails instead of screws. Most leaks occur at roof junctures, penetrations, valleys, and where the nails are missing.

If roof replacement is needed, the existing historic type of metal roofing is recommended over other modern types of metal, such as Propanel®. Historic metal roofing materials should always be replaced with in-kind materials. Most historic metal roofing materials, pressed metal ceilings and ornamentation are being manufactured today, but if they are unavailable install the replacement roof using a material that is as close to the original as possible. Cornerstones has had good experience with pressed metal ceilings ordered from W.F. Norman Corporation in Nevada, Missouri: (800) 641-4038.

Twenty-six is the minimum recommended gauge for metal roofs. It is false economy to install inexpensive thin gauge metal roofing material.

People can accomplish much restoration work with little background in construction. However, roof work is inherently dangerous, especially when it involves corrugated metal panels with sharp edges. Only those with experience and skill should do roofing work.



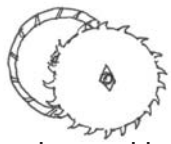
The metal roofs that were added to many early churches in the late-19th and early-20th centuries are often remarkable expressions of folk architecture and should be valued as such. The metal roof on La Capilla de San Antonio de los Lentes, near Los Lunas, NM, is among the best in the region.

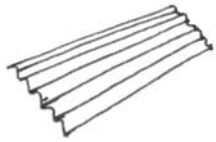
WARNING: Helpers and ground personnel should be warned of the probability of falling objects and should be kept out from under the work at all times. Gloves, goggles, and other safety equipment should be used when handling corrugated metal. Since all roof work involves heights, safety precautions are called for. Cleated plywood walkways, safety ropes, and "chicken" ladders should be used where appropriate.

TOOLS AND MATERIALS REQUIRED

Awl (punch)

Circular saw


Circular saw blade, diamond blade


Corrugated metal

Drill

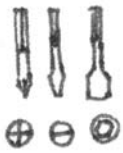
Gloves

Goggles

Hammer

Handsaw

Hard hat


Hex bits

Jigsaw

Ladder

Level

Lumber

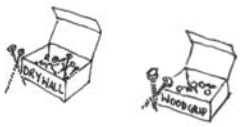
Measuring tape

Nail puller (cat's paw)

Nails

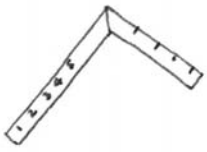
Ridge cap

Scaffolding



Screws (drywall and wood grip)

Sheet metal shears


Square

String

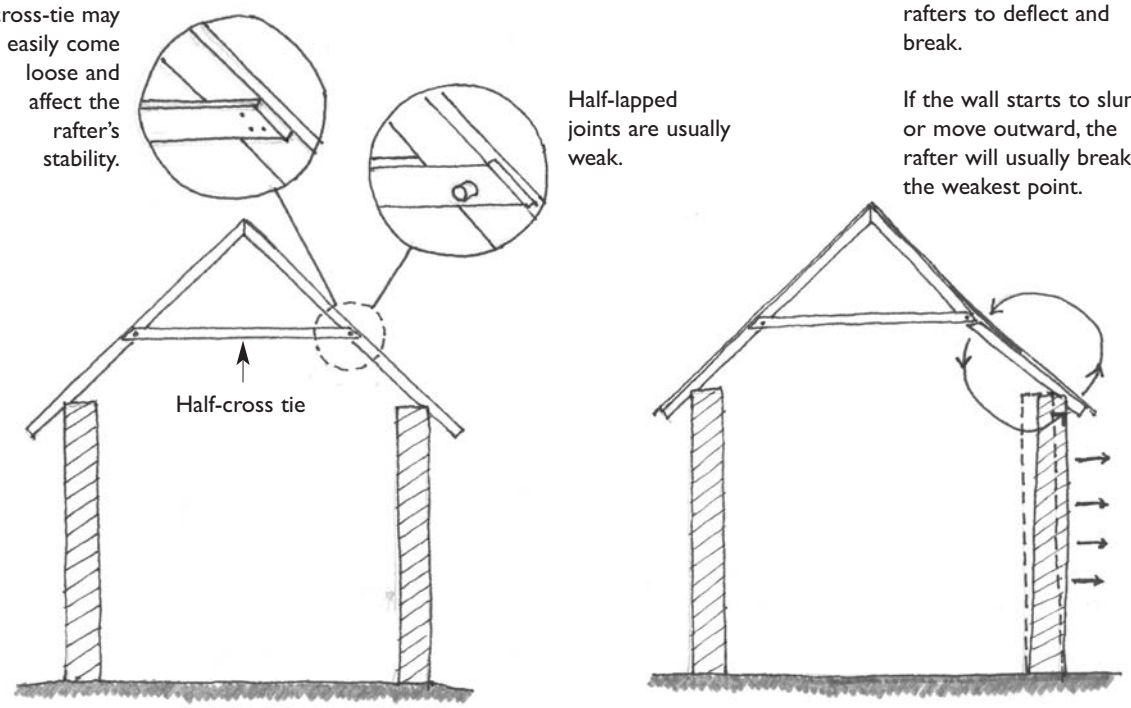
Examples of damage to metal roof panels.

A poorly nailed cross-tie may easily come loose and affect the rafter's stability.

Half-lapped joints are usually weak.

Snow loads may cause rafters to deflect and break.

If the wall starts to slump or move outward, the rafter will usually break at the weakest point.



There is a high risk of wall movement when *vigas* are not present. *Vigas* provide stability similar to tie rods if well connected. It is very important to apply the new metal sheathing on sound wood rafters and purlins.

1. Set up scaffolding on a firm base. Tie scaffolding to the building if it exceeds two sections in height. Consult with Occupational Safety and Health Administration (OSHA) regulations when setting up scaffolding.

2. If corrugated metal is steep or slippery, nail or screw plywood boards over work areas adjacent to the metal that is being replaced.

3. Another method is to use a ladder that rests flat on the pitch and extends over the peak of the roof to the other side.

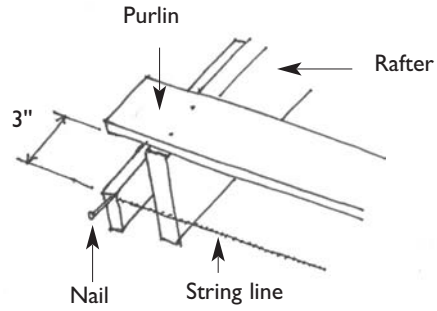
4. Carefully remove all existing nails using a cat's paw (nail puller) and hammer.

5. Remove the sheets only over roof area that can be repaired in the time period available. Make sure people are not working below when sliding old metal to the ground.

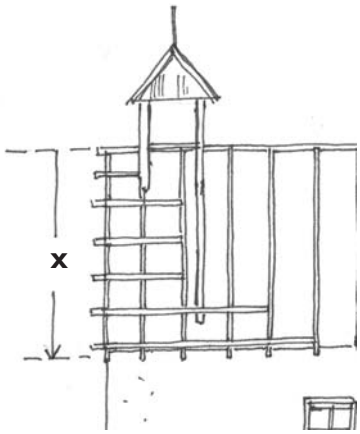
6. Once the purlins are exposed and assuming they are in sound condition, they will make a good stable work surface for continued removal of existing metal.

7. Replace all deteriorated and broken purlins with new lumber to match the existing. If all purlins are damaged, nail new purlins adjacent to the old before installing the new corrugated metal. Inspect rafters to see if they are connected to the top plate. Rafters can be toe-nailed, or Simpson Hurricane Ties® may be used.

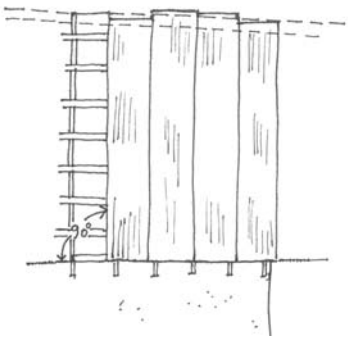
NOTE: If the spacing between rafters is excessive, a new rafter to match the existing can be added between the existing rafters. The new rafter can extend from the ridge to the existing eave and can be placed on nailers perpendicular to the rafters, if they cannot extend beyond the top plate. Crossties or members are important to stabilize and reinforce rafters.



8. Nail a board extending no more than three inches beyond the end of the rafters. Drive a nail at the end and attach a string.

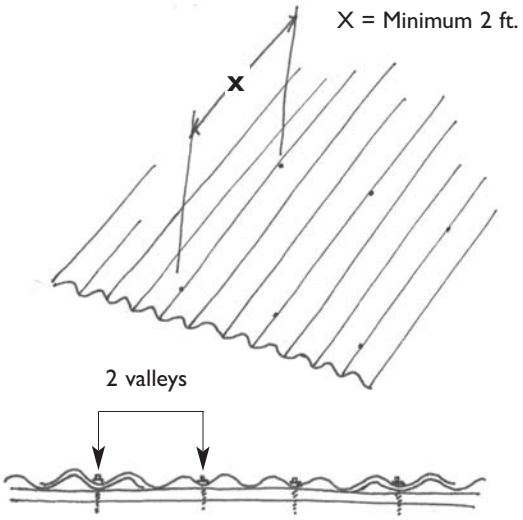


X represents the distance from the string to the ridge board (see drawing to left). This will indicate the length of the metal sheet to be used. Sheets must be long enough to allow them to be cut parallel to the building. Start work at the gable end of the building.



The bottom edge of the corrugated metal sheets should be set at 90° degrees to the string. If the roof framing is not square, some of the sheets may be one to two inches short at the ridge or extend a similar distance above it. The ridge cap will cover these.

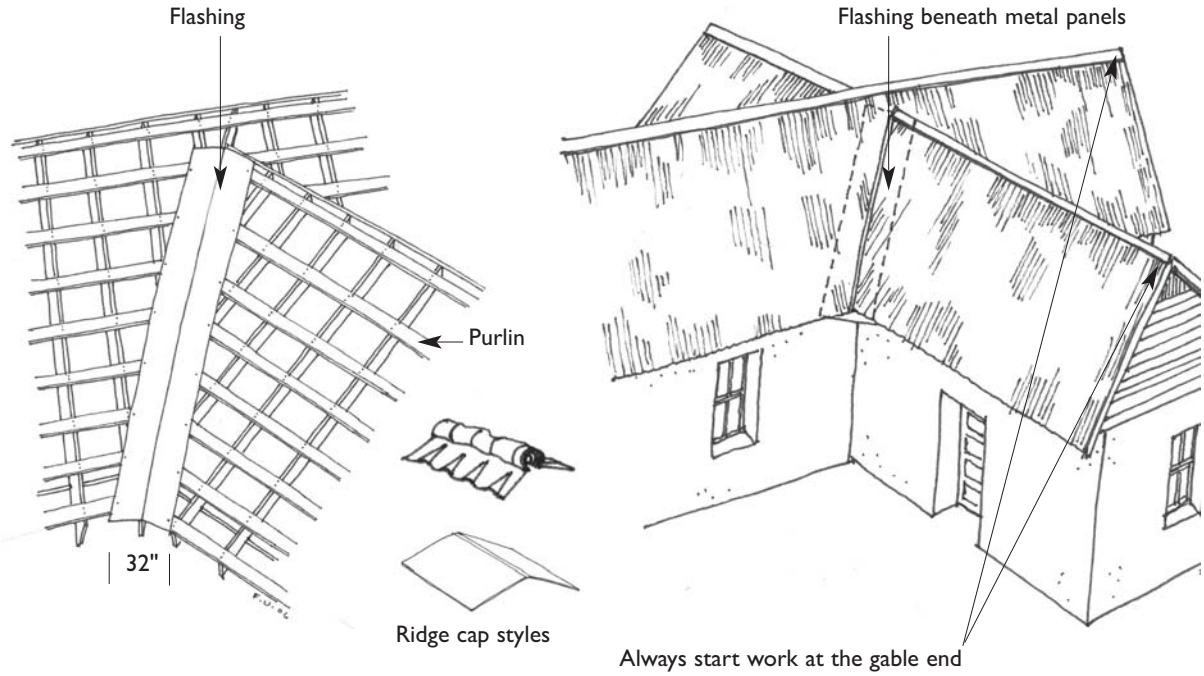
9. Set the first sheet parallel with the gable end. Cut the end parallel with the building. Gloves should be used when handling corrugated metal.



10. Overlap corrugated metal sheets by two valleys and secure at eight-inch intervals using wood grip screws or self-tap screws with neoprene washers. Propanel screws, coarse-threaded galvanized wood grip screws with hex heads and neoprene washers, can also be used.

11. Punch metal to accommodate screws if needed.

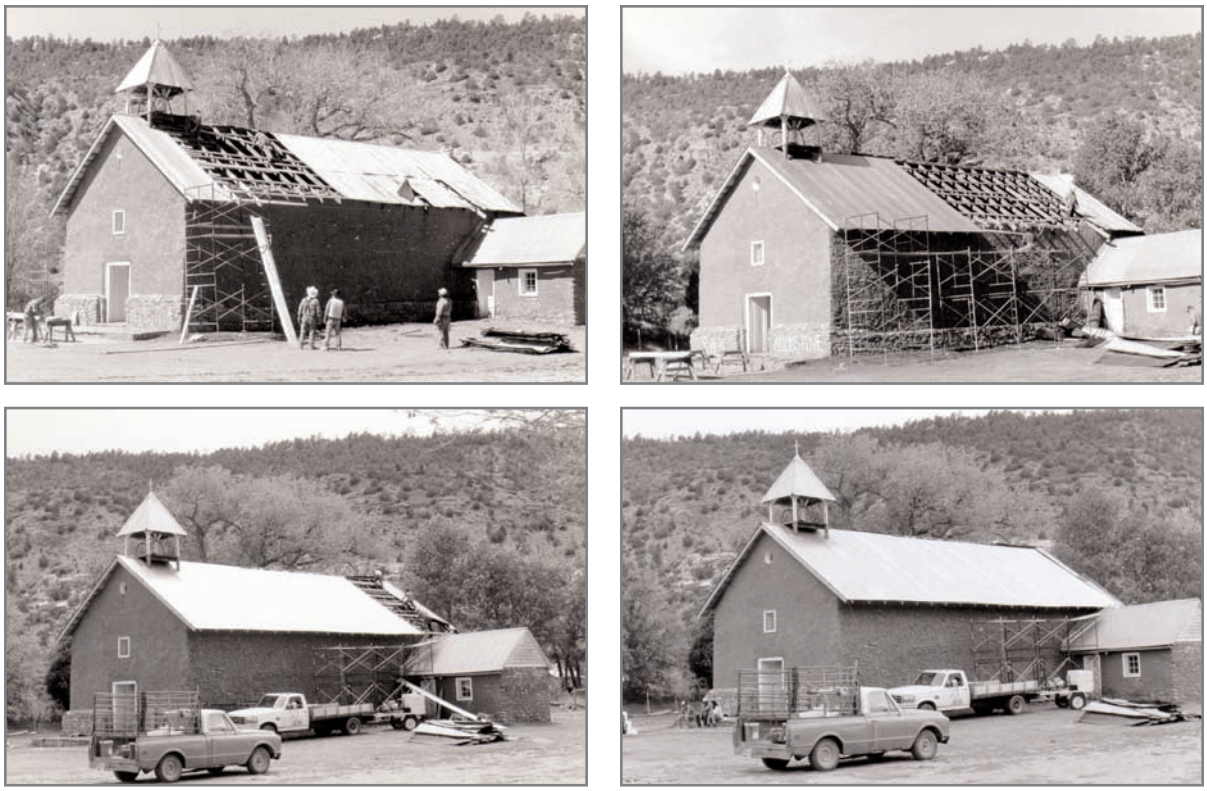
12. Screw the sheets down.



13. If the structure has valleys, nail metal flashing to the purlins before that area is covered by the metal roofing panels. Flashing should be at least 32-inches wide. Once the valley flashing is nailed in place, cut the corrugated metal to fit the pitch angle. Be sure to fit a minimum of two inches above the valley center. Screw in place.

14. When the corrugated metal has been secured, install the ridge cap and screw into place.

NOTE: Certain areas where the metal sheathing meets the adobe walls might be vulnerable to deterioration. Therefore, flashing must be used. Compared to an adobe wall plastered with cement where the flashing can be installed easily and securely, installing flashing directly to an earthen plaster is much more difficult. The adobe should be cut so that the metal flashing can be inserted into the adobe wall. When applying metal flashing around a brick chimney, the flashing should be inserted into the brick mortar joint and stepped according to the drop.



This series of photographs shows how the old corrugated metal is removed while new material is installed.

FIELD NOTES

INSPECTING *VIGAS* AND CORBELS

This section briefly explains how to inspect *vigas* and corbels and how best to preserve, repair or replace them.

The method developed for the repair of *viga* ends uses a threaded glass fiber rod to join new ends to existing *vigas*. The advantage of using glass fiber rods is that pieces of wood replaced in this manner may be unscrewed and replaced again as the need arises. The disadvantage is that this method can only be done utilizing one rod, ideally installed at the center of the cut face of the *viga*, since the new *viga* end is designed to be screwed into place. (See Part Three, *Repairing Vigas and Corbels* for directions on how to obtain threaded glass fiber rods from a distributor in the Southwest.)

Corbels have a decorative value and a structural role in supporting the *vigas* that rest on them. In making the decision to replace embedded corbel sections, it is advisable to first confirm the bearing strength of the *vigas* themselves with a structural engineer. Every effort should be made to conserve as much of the decorated corbel and viga face as possible. Consider performing minor repairs, consolidation, and/or splicing techniques. Other solutions, such as replacement, should be considered only if the *vigas* and corbels are not salvageable or if excessive wood deterioration is found at the mid-span of the *viga*. The *viga*, most likely, will need to be replaced if wood deterioration exceeds 60% of the structural volume of the *viga*.

Before beginning the step-by-step inspection process described below, each *viga* must be assessed for structural stability. Look for failures, damages from moisture, insects or fungus invasions, and any risk of partial or complete collapse.

Above: The pigmented *latillas* and decorated *vigas* in the ceiling of the Socorro Mission in Socorro, Texas. Photo: Ed Crocker.

TOOLS AND MATERIALS REQUIRED

Auger bit

Awl (punch)

Drill

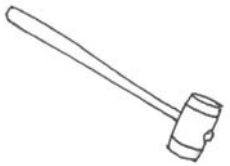
Gloves

Goggles

Ladder

Measuring tape

Pointed hand saw and key hole saw


Rubber mallet

Scaffolding

Wood dowel

Wood glue

Begin by making a general assessment of the *vigas* and corbels in the building.

1. Look for vertical cracks: Verify that the *viga* does not have vertical failures (cracks or fractures). Notice that horizontal failures usually appear as normal, dry checks in the wood fiber structure of the *viga* and typically do not affect its structural integrity.

2. Localize vertical cracks: If vertical cracks occur in the middle load-bearing area of the *viga*, consider asking an engineering consultant to determine the appropriate type of intervention. Furthermore, structural repair in the middle of load-bearing areas may cause adverse visual impacts. If this should be the case, consider removing and completely replacing the *viga* to match the original.

3. Assess erosion: Permanent or casual water infiltration results in moisture retention in the *vigas*. Moisture retention contributes to the growth of fungi spores that aggressively soften the wood and, as a result, attract burrowing insects.

4. Determine extent of erosion: Erosion may be concentrated in specific areas or all along the *viga*. To assess the depth of decayed wood, remove softened wood until solid wood is reached. When the softened wood has been removed, estimate the volume of solid material remaining: If the remaining solid wood is 60% or more of the total original volume, the *viga* should be consolidated (preferably using a dutchman). If this is not the case (less than 60% of the original volume is solid wood), consider splicing the decayed section of the *viga* only at its end. For more information on using a dutchman or *viga* splicing, see Part Three, *Repairing Vigas and Corbels*.

Once a general assessment has been made of the structural stability of the *vigas* and corbels, a reflected ceiling plan of the building should be drawn. Use the example below as a guide to the rest of this section. Inspection sheets are provided for your use at the end of this section. The following step-by-step guide outlines how to inspect *vigas* and corbels for deterioration and rot.

5. Pick at the *viga* or corbel with an awl to assess deterioration. Looking for soft wood that indicates rot.

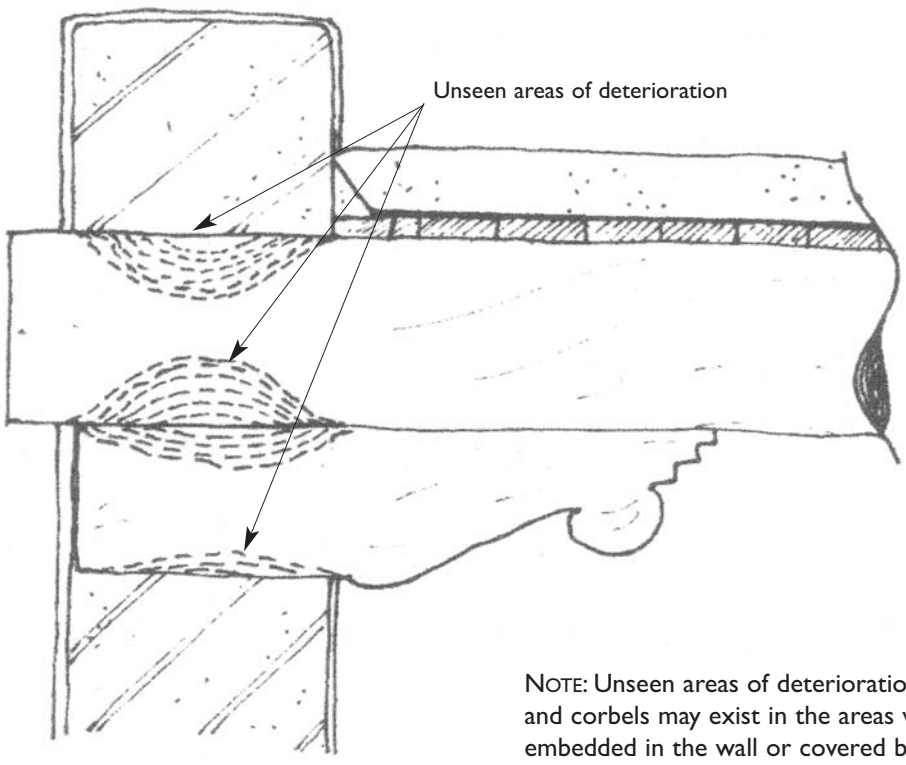
6. Set up scaffolding or a ladder close to the *vigas* to be inspected. Begin by lightly tapping the *viga* and corbel from all sides with a mallet. Carefully listen for a hollow or solid sound.

7. Using a 1/4-inch self-feed auger bit, drill into the *viga* at a 30° to 45° angle from the point where the *viga* meets the face of the wall. The wood is sound as long as the bit self feeds If the bit fails to feed, there is a likelihood of rot. Remember to drill the outside ends of the *vigas* as well.

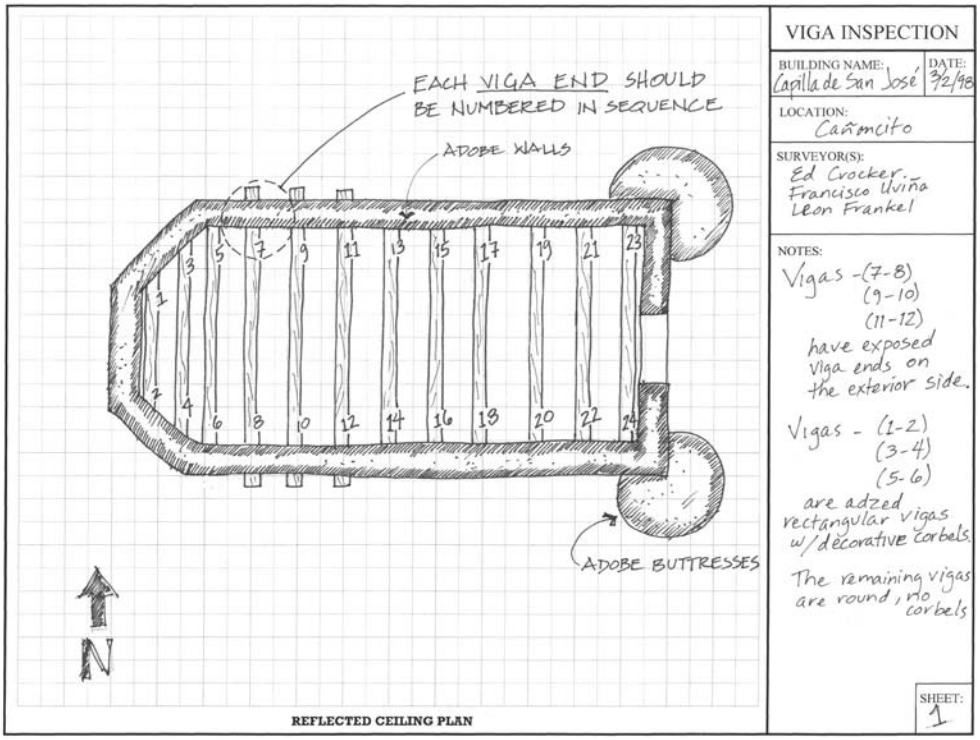
8. The cuttings from the drill will tell much about the condition of the wood. Sharp, curly cuttings with good color and a strong pine or pitch smell indicate solid material. Dry, faded and crumbly cuttings with no scent indicate rot.

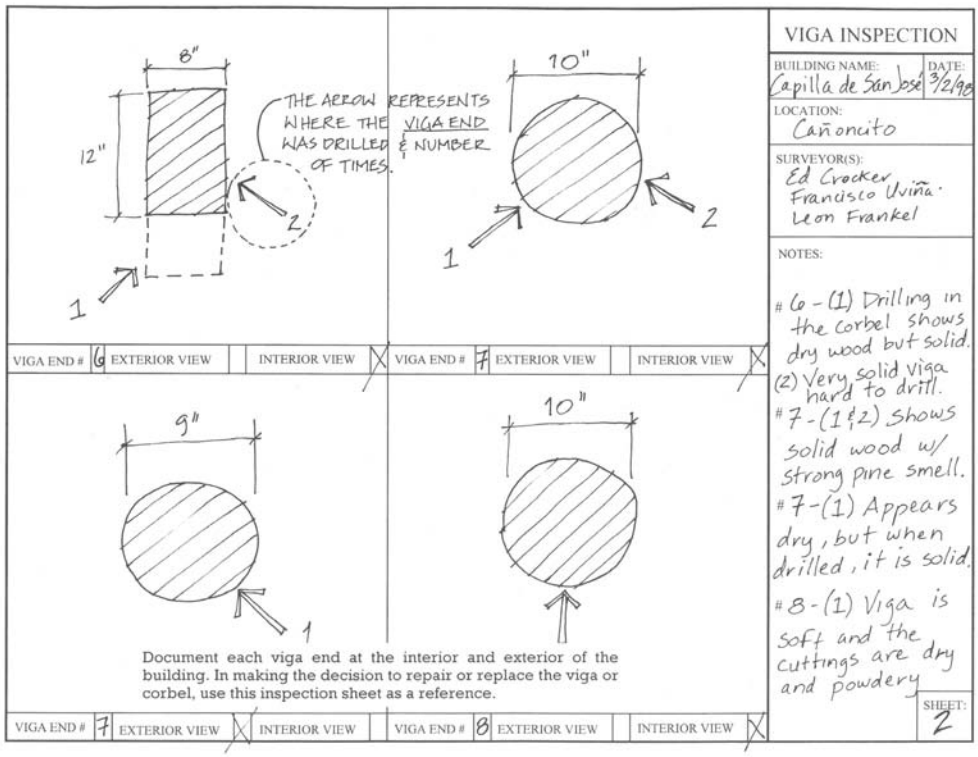
9. Plug the hole using a 1/4-inch wooden dowel. Apply wood glue three inches from the end of the dowel and spread with your finger. Push the dowel into the hole as far as it can go. Cut the dowel flush with the *viga* using a keyhole saw.

10. Repeat the process and document your work following the sample diagrams provided. *Viga* ends or corbels that are damaged should be exposed for a more precise assessment and should be repaired or replaced according to the extent of the deterioration present (see Part Three, *Repairing Vigas and Corbels).*

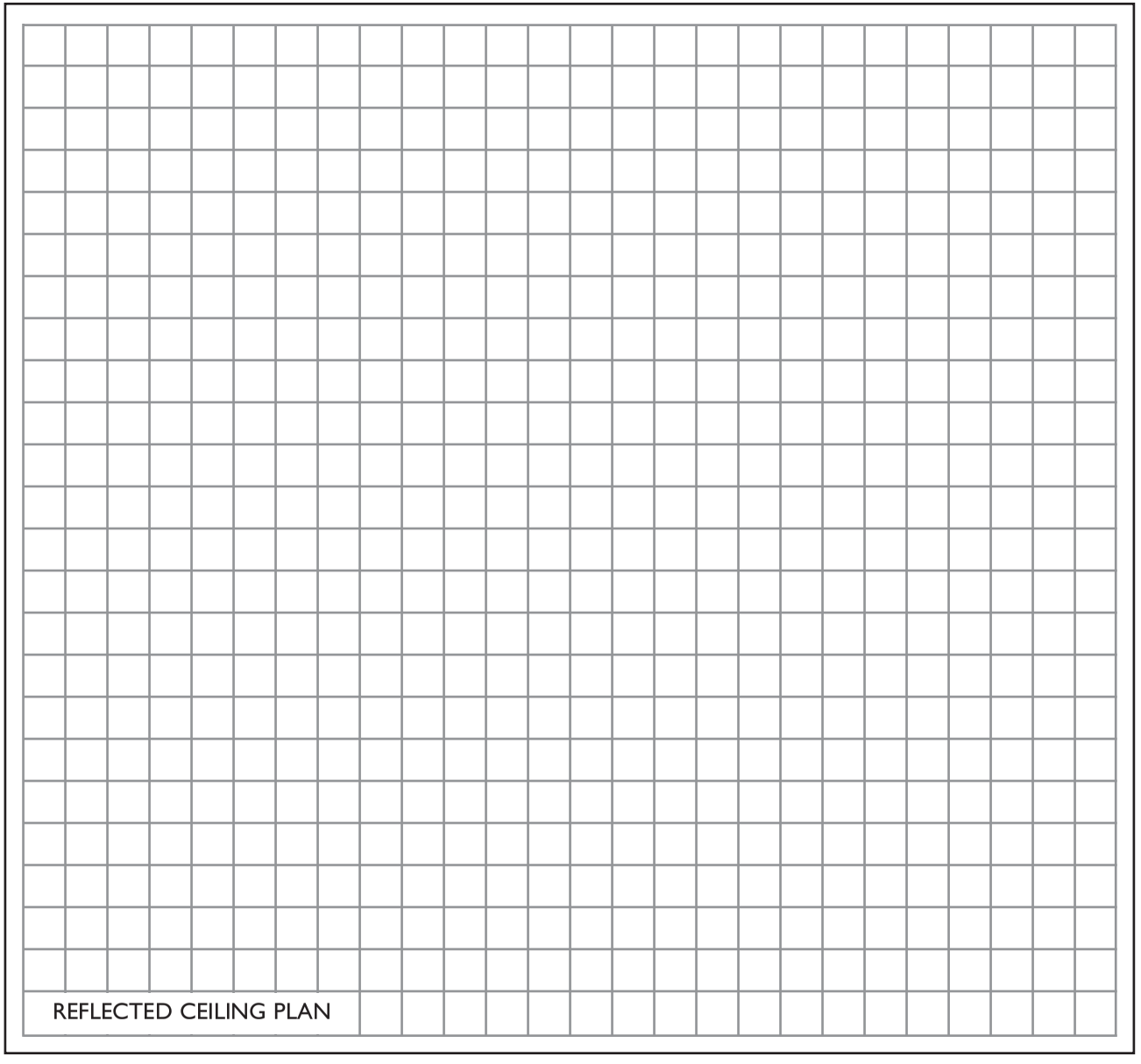


NOTE: Unseen areas of deterioration in both *vigas* and corbels may exist in the areas where they are embedded in the wall or covered by the parapet.





Examples of completed *Viga* Inspection Forms, side 1 and 2.



VIGA INSPECTION

BUILDING NAME:

DATE:

LOCATION:

SURVEYORS:

NOTES:

SHEET

VIGA END NO.___ ext. view ☐ int. view ☐

VIGA END NO.___ ext. view ☐ int. view ☐

VIGA END NO.___ ext. view ☐ int. view ☐

VIGA END NO.___ ext. view ☐ int. view ☐

VIGA INSPECTION

BUILDING NAME:

DATE:

LOCATION:

SURVEYORS:

NOTES:

NO.___

NO.___

NO.___

NO.___

SHEET

REPAIRING *VIGAS* AND CORBELS

Before beginning a *viga* or corbel repair or replacement project, be sure to read the preceding chapter, *Inspecting Vigas and Corbels*, to determine if repair and/or replacement is actually required. Please also note that emergency shoring may be needed to support the existing roof structure while repairs are carried out if there has been extensive damage to either *vigas* or corbels (see Part Two, *Emergency Shoring*).

The methods described below were developed from the experience of conducting *viga* and corbel repairs at the Socorro Mission Preservation Project. The methods described in this chapter were summarized by US/ICOMOS intern, Jacobo Herdoiza, following a workshop on *viga* repair held at Acoma Pueblo in the Summer of 2003. Jake Barrow of the National Park Service developed the "splicing" technique described here. This technique applies only to buildings with rotted projecting and/or embedded *vigas* and to corbels that have sufficient sound wood near the interior face of the wall.

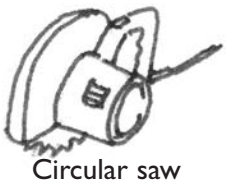
The intention of making repairs should be to restore the structural integrity of original *vigas* and corbels while preserving as much of their original fabric as possible. This is especially important if the originals are carved or pigmented. When *vigas* and corbels are repaired in place, the process is less expensive because there is no need to remove the roof. If possible, both assessment and repair should be supported by the expertise of an engineer in order to verify the structural stability of the roof system and to determine the specifications for any repair. The previous chapter on *viga* and corbel assessment provides additional information about the removal of decayed wood and determining the structural integrity of *vigas*.

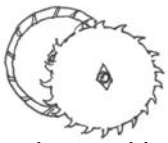
Before and after photos of deteriorated *vigas* repaired using the *viga* splicing method (Method D).

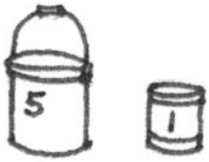
TOOLS AND MATERIALS REQUIRED

Axe

Chainsaw


Circular saw


Circular saw blade, diamond blade

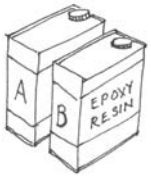


Containers

Drill

Drywall compound mixer

Dust mask



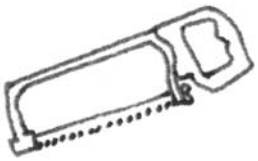
Epoxy resin

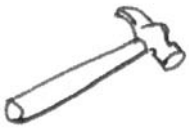
Funnel

Glass fiber rod (threaded and unthreaded) and nuts

Gloves

Goggles


Hacksaw


Hammer

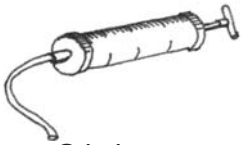
Handsaw

Hard hat

Ladder

Level

Measuring tape


Oil plunger

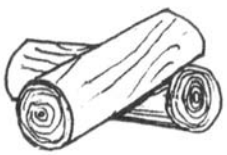
Plasterer's hawk

Plasterer's trowel

Plastic washers

Plumber's bit

Socket paring chisel


Vigas

<u>Additional materials:</u>
Bora-Care®
Modeling clay

Depending on the amount, location and characteristics of any decayed wood that is discovered, several repair options may be followed. There are four levels of decay. Each level requires a different method of repair:

METHOD A: SUPERFICIAL DECAY; APPLY BORA-CARE® TREATMENT

Bora-Care® is a chemical product used for prevention of termites, carpenter ants, wood-destroying beetles and fungi. It is preferable to many similar products because it serves as an insecticide and herbicide rather than one or the other. It is characterized by rapid, deep penetration and wide coverage. WARNING: Bora-Care® is harmful if absorbed through the skin. Avoid contact with skin, eyes or clothing. Cover plants and nearby soil to avoid contamination.

Superficial wood decay means that erosion is not affecting the structural integrity of the *viga*. This decay is noticed when the surface of a *viga* is softened wood. In such cases, the adequate repair is to apply Bora-Care® treatment:

1. Scrape down decayed wood until solid wood is revealed.
2. Clean the surface thoroughly.
3. Apply Bora-Care® (refer to Bora-Care® directions for use).
4. Allow wood to completely dry for a minimum of 48 hours.

NOTE: It is problematic to use Bora-Care® in conjunction with other repair methods involving epoxies. The presence of Bora-Care® minimizes or even prevents adequate adhesion. Apply Bora-Care® to those areas that will not be directly epoxied. Let the epoxy, once it impregnates the wood, act as the insecticide and herbicide through encapsulation and the prevention of air flow.

METHOD B: UP TO 40% OF DECAY IN REGULARLY SHAPED AREAS; APPLY A DUTCHMAN

Once all decayed wood has been removed down to solid wood, it may appear that the damaged area has a shape appropriate for the insertion of a wood dutchman. A dutchman is a solid piece of wood that matches the missing or deteriorated piece in the existing wood element or *viga*.
NOTE: Repairs are only recommended if a minimum of 60% of the original wood is retained in the *viga* after the removal of all softened wood.

The application of a wooden dutchman has the advantage of repairing the *viga* with a compatible material (wood) and reducing the volume of epoxy employed for consolidation purposes. Epoxy is a chemical compound that forms hard, strong, and chemically-resistant adhesive bonds and enamel-like coatings.

1. Scrape down decayed wood to solid wood.
2. Clean surface thoroughly.
3. Carefully remove solid wood in order to create a shaped volume that will permit clear insertion of the dutchman. Try to remove as little of the original solid wood as possible.

4. Clear and clean the surfaces again.

5. Prepare the dutchman; verify that it exactly matches with the area removed from the *viga*. Try to use the same kind of wood, and whenever possible recycle solid pieces of original wood.

6. Clear and clean the surfaces again.

7. Apply Bora-Care® (please refer to Bora-Care® directions for use) and allow wood to completely dry (at least 48 hours).

8. If the *viga* is rectangular or square in section, cut and install temporary plywood forms around the *viga*. The form will serve to cover the *viga* and the dutchman joints.

9. Apply paste wax to the inside of the plywood form to facilitate its removal when the process is complete.

10. Fill joints in the plywood forms and any cracks in the *viga* undergoing repair with moldable clay to prevent the epoxy from failing to properly infiltrate the wood.

11. Prepare epoxy (please see ConservEpoxy® or comparable brand instructions for application). Note that epoxy should be prepared and applied in a shaded place.

12. Apply epoxy to the area of the *viga* that will receive the dutchman.

13. Fix the dutchman firmly to the *viga* using diagonally driven screws. Wooden dowels installed using epoxy can also be used with a combination of screws to hold the dutchman down.

14. Remove forms when the epoxy is completely dry.

15. Repeat the same procedure if multiple dutchmen need to be applied.

METHOD C: UP TO 40% OF DECAY IN IRREGULARLY SHAPED AREAS; USE EPOXY CONSOLIDATION

Once the decayed wood has been removed down to solid wood, it may appear that damaged areas do not permit application of a dutchman. In such cases, the consolidation process will employ an epoxy resin as a structural infill to restore the stability of the *viga*.

The conditions for structural epoxy repairs are the same as those for dutchmen. Use this method if a minimum of 60% of the original wood is retained after the removal of softened wood. Take into account that applying epoxy is an expensive and very delicate procedure that may severely affect the breathability of the air in the work area.

Finally, note that epoxy consolidation should be considered a last ditch effort before proceeding to the splice method for repairing an inoperable *viga* section.

1. Scrape down decayed wood to solid wood.

2. Clean the surface thoroughly.

3. Apply Bora-Care® (please refer to Bora-Care® directions for use) and allow wood to completely dry (at least 48 hours). Apply Bora-Care® only to those areas that will not be epoxied. The epoxy itself will

minimize threats from insects or fungus by blocking airflow once it cures.

4. Prepare a wood form to contain the epoxy, preferably with plywood, if the *viga* undergoing repair is square or rectangular.

5. Check the plywood form for fit and then remove it from the *viga*.

6. Coat the inside of the form with paste wax for ease of removal later.

7. Fill cracks in the form and its corners with moldable clay and fix the wood form firmly to the viga with screws.

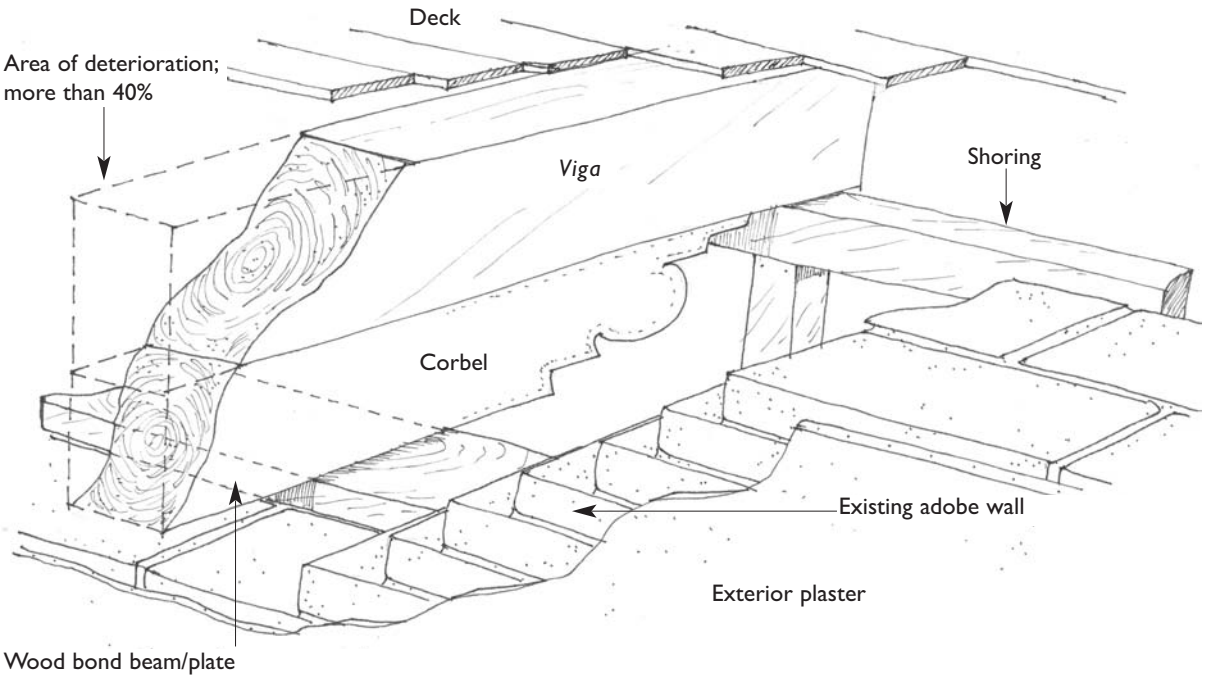
8. Prepare the epoxy according to the manufacturer's directions (see ConservEpoxy® or comparable product instructions) and augment it with a consolidation recipe of two parts sand and one part fine aggregate. NOTE: Epoxy should be prepared and applied in a shaded place to obtain optimum results.

9. Apply epoxy mix carefully and slowly to avoid any risk of damage (fire) to the *viga*. (The chemical reaction of epoxy creates intense heat and could cause wood to catch fire.)

10. Let the *viga* completely dry before removing the forms and reinstalling it in the building.

METHOD D: MORE THAN 40% OF DECAY; USE *VIGA* SPLICING AND GLASS FIBER ROD REPAIR

If more than 40% of the original section of the *viga* appears to be decayed after the softened wood has been scraped away, consider complete removal of the decayed section and splicing new wood to the original *viga*. The possibility of reusing most of the original *viga* justifies this type of intervention. NOTE: Splicing should only occur at the *viga* end for best structural stability. The good end of the original *viga* must extend at least four inches into the wall, and rest, preferably, on the existing or new wood bond beam or plate.



Splicing the *viga* and introducing glass fiber rods and epoxy repair is a non-reversible process. Before proceeding, be sure that the preservation team unanimously agrees to this type of intervention and that all other possible repair procedures have been investigated.

This method is recommended when decay is noticed in load-bearing sections that rest on adobe walls. If vertical cracks or deep deterioration is noticed in the middle of the load-bearing areas of a *viga*, consider complete removal of the *viga* and replacement in kind.

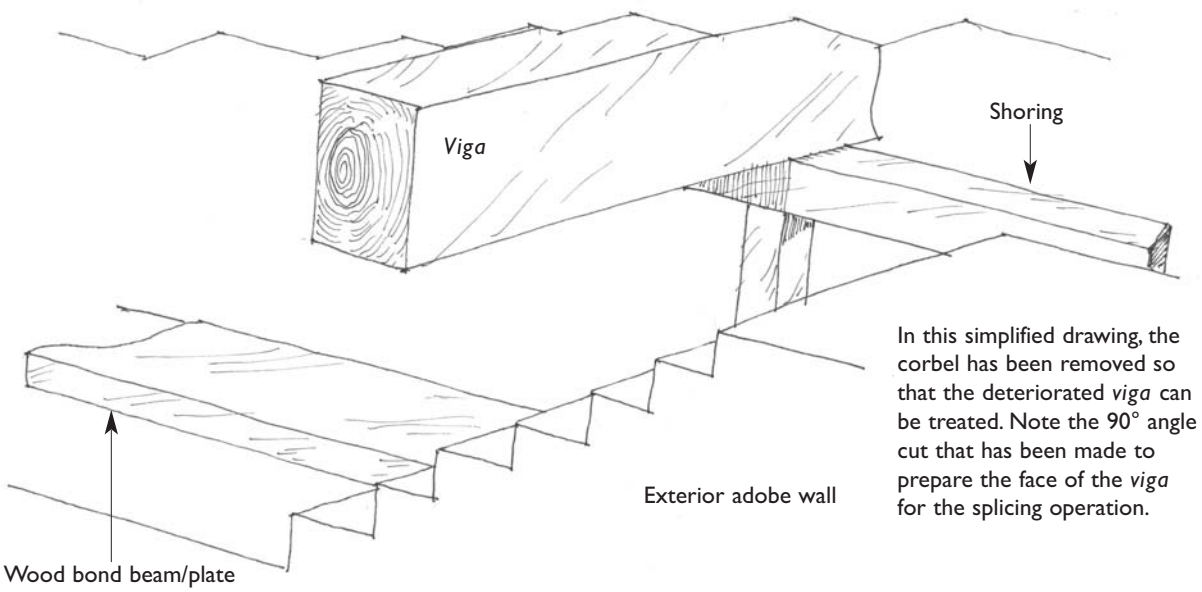
NOTE: Cornerstones has had success obtaining threaded glass fiber rods from:
Harrington Industrial Plastics
5312 Pan American Freeway NE
Albuquerque, NM 87109 Phone: 505-884-0295 Fax: 505-881-2464

1. Scrape down decayed wood to solid wood.

2. Estimate the volume of decay within the *viga*. If the remaining solid section of the *viga* is less than 60% of its original volume, proceed to repair, using glass fiber rods and epoxy.

3. Document the *viga* (especially the area to be spliced) with drawings and photos.

4. Measure the length and the section of the portion to be spliced, but verify that the remaining solid *viga* is long enough to cover the bearing distance between the adobe walls, as mentioned above. Note that glass fiber rods will operate as part of the main structural component and need to be located in the load bearing portion of the *viga* that rests on the adobe walls or the wood bond beam or plate.



In this simplified drawing, the corbel has been removed so that the deteriorated *viga* can be treated. Note the 90° angle cut that has been made to prepare the face of the *viga* for the splicing operation.

5. Mark the edges of the section to be spliced. NOTE: For the best results cuts should always be made at a clean 90° angle.

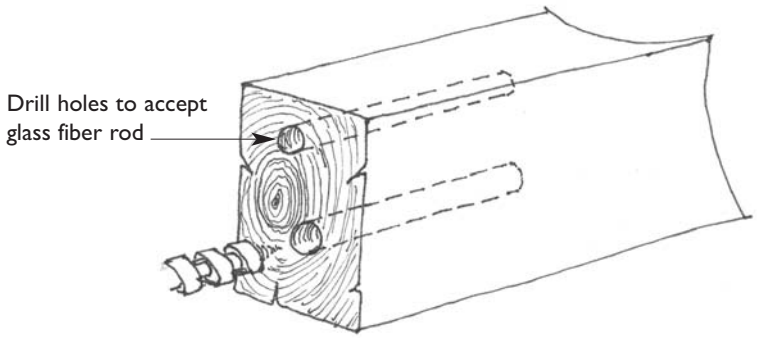
6. Select the piece of wood for the splice. Choose a piece of wood that has similar characteristics as the section being removed; i.e. same type of wood and equal dimensions. Whenever possible, try to use a splice that is created from a solid fragment of a recycled original *viga*. The splice should be cut at a 90° angle to match the cut in the face of the existing *viga*.

7. Match as precisely as possible the facing side of the replacement piece with the existing *viga*. Level and fix the splice to the existing *viga* using screws driven diagonally into both pieces. Verify that there is full contact between both pieces.

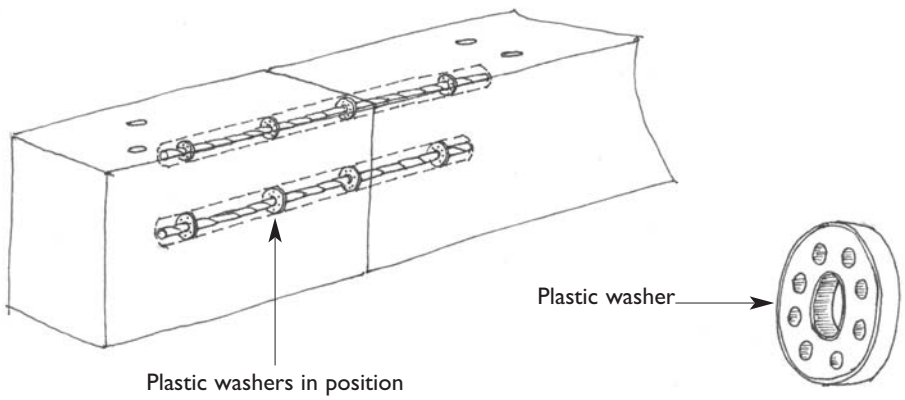
8. Analyze the sectioned *viga* and identify adequate locations on the cut end where holes for the glass fiber rods can be drilled. Note that each glass fiber rod must be located at least one and a half inches away from any crack or from the edges of the *viga* face.

9. Mark the locations of the holes on the *viga* ends and transfer the locations accurately to the section of the replacement piece.

10. Select the diameter of the glass fiber rods (1/2 or 3/4 inches in diameter) based upon the structural stress to be loaded and the area available in the section of the *viga* that is to be drilled. You may need an engineer to verify the amount of weight each glass fiber rod can hold.



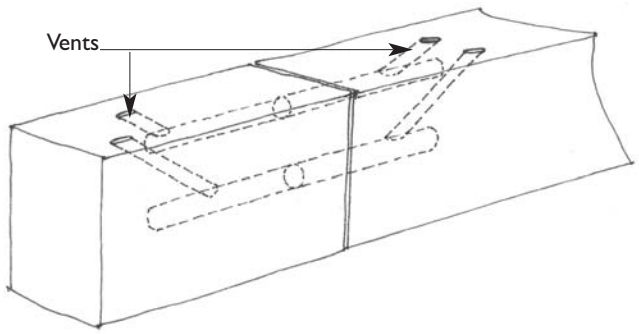
11. Drill holes 12-inches deep (long) into the marked locations in each section of the existing *viga* and the replacement splice. Make sure that the holes are drilled level and are thoroughly cleaned of sawdust and debris.



12. Purchase or fabricate plastic washers to slip the rod through. The washers will slide over the rod, and should fit snugly into the drilled portion of the *viga* and the tail splice. Place two washers in the original *viga*, and place two in the new tail. The washers serve to center the rod. They keep the rod from floating to the bottom of the drilled channel once the epoxy is introduced. Small holes will be drilled in the washers to permit epoxy to flow through and around the rods and the washers. Always do a dry run before pouring the epoxy to make sure everything fits properly.

13. Firmly and precisely match the replacement splice with the *viga*, making sure that there is full contact between all facing cuts. If the faces of the cuts do not precisely align, clean and level them again.

14. After successfully performing a dry run (no epoxy), separate the tail and *viga* and remove the glass fiber rods and washers.



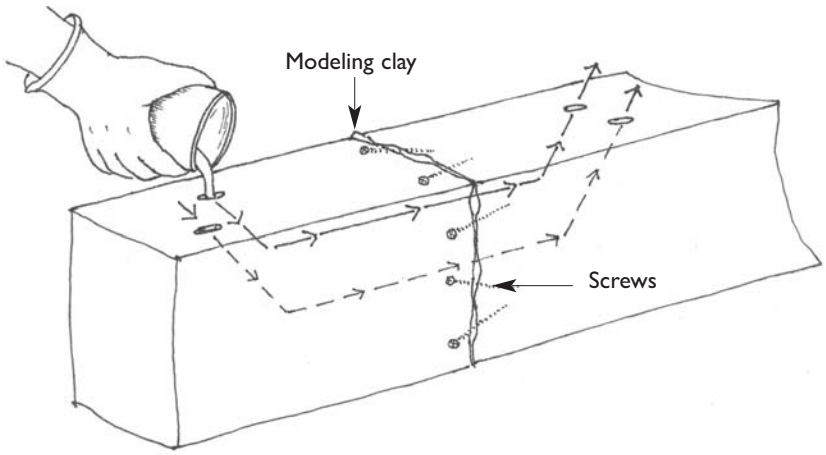
15. Drill several 7/8-inch-wide holes at a 45° angle down from the top of the *viga* and down from the top of the replacement splice until they intersect with the rod holes. These will be used as air vents and as conduits for the fluid epoxy.

16. Place the 45° vent and application holes so that each is within one and a half inches of the end of the rod holes.

17. Reinsert the glass fiber rods and washers and then rematch the *viga* with the replacement splice. Fix them firmly together using screws.

18. Prepare the epoxy (see ConservEpoxy® or comparable product instructions). NOTE: Epoxy should be prepared and applied in a shaded place to obtain optimum results.

19. Cover all the joints between the *viga* and the replacement splice with modeling clay. Be sure to also cover any possible conduits for leaks, such as cracks in the wood, at least three feet in each direction.



20. Slowly pour the epoxy into the vent holes in the top of the replacement splice. It is important to do this slowly to avoid loss or damage to the *viga*. Ensure that the epoxy penetrates adequately into the *viga*. Epoxy application is complete when the epoxy appears level in the vent and application holes that are in both the replacement splice and in the original portion of the *viga*.

21. Let the epoxy dry completely before reinstalling the *viga* in the roof. Make sure that you always follow the epoxy manufacturer's specific instructions.

METHOD E: AN ALTERNATE SPLICING METHOD FOR *VIGA* TAILS

The following method may be used for splicing *vigas* in place. If using this method for *vigas* that are square or rectangular in section, accuracy is extremely important.

1. With a 1/4x16-inch auger bit, drill into the *viga* at a 30° to 45° angle to check it for rot (see instructions above).

2. If the *viga* tail is deteriorated, one remedy is to splice a new tail onto the body of the original *viga* without removing it.

3. Remove six to eight inches of plaster and adobe around the *viga* to expose the rotted wood.

4. Accurately measure the rotted *viga* tail to determine the correct dimensions of the replacement tail.

5. Using a chain saw and other tools, remove all the rotted wood and leave the exposed cut as smooth and as close to 90° as possible.

6. Match the replacement tail with the existing *viga*. Take note of the square, flat faces of both pieces.

7. Determine the location and size of the drill hole based upon overall dimensionsof the *viga*, cracking in the timber, and ease of access. Always try to minimize the amount of original material that is removed, and seek to maximize structural strength. The hole will need to accomodate the glass fiber nut to be used. Make sure the hole and the nut match in size as closely as possible.

8. With a socket-paring chisel, transform the round circumference of the drilled hole in the *viga* into a square. This will allow a square glass fiber nut to be inserted.

9. Attach the square glass fiber nut with epoxy resin into the square hole in the *viga*.

10. Once the replacement tail has been cut to match the diameter of the existing *viga* and length of the section being removed, measure and cut a threaded glass fiber rod to a length of two feet. Drill the appropriately sized hole to match the first hole. Fit the rod with plastic washers to help center the rod in the hole. Drill small holes in the plastic washer to allow the epoxy to squeeze in and around the washer.

11. Mix epoxy according to the manufacturer's specific instructions.

12. Stand the replacement piece vertically. Fill the hole in the tail half full of epoxy resin and insert the glass fiber rod.

13. Before the epoxy sets, adjust the rod so that it projects accurately from the face of the tail at a 90° angle. Then allow the epoxy to set.

14. Drill two 7/8-inch holes at a 45° angle a couple of inches above the center hole of the *viga* so that they intersect with the rod hole. One hole will serve to pour in the epoxy resin and the other will serve as a vent.

15. Coat the threaded glass fiber rod with heavy motor oil or Vaseline®. Screw it into the square nut in the face of the *viga* the entire depth of the hole. Pour the epoxy resin into one of the 3/4-inch holes using a funnel or an oil plunger. The center hole will be full when the epoxy runs out the vent. Allow the resin to settle by tapping the *viga* with a mallet and make sure the threaded rod remains at a 90° angle to the face of the *viga*. Before the resin completely hardens, completely unscrew the threaded glass fiber rod from the hole and the nut. The rod will have formed a threaded shaft. In order to calculate how fast the epoxy resin dries, test by using a sample of the epoxy resin before inserting the rod back into the *viga*. Make sure the timing is correct so that the threaded shaft maintains its integrity.

16. Allow the epoxy to harden completely. Screw the new *viga* tail that has the threaded glass fiber rod protruding from it into the square glass fiber nut in the existing *viga* and tighten securely.

17. After the new *viga* tail is in place, fill the cavities between the wall and the *viga* with adobes laid in mud mortar. Infill any crevice or hole with mud mortar and it to dry. Apply a plaster on the outside that matches the existing plaster.

GENERAL RECOMMENDATIONS

Systematically document each *viga* before repairing. Make drawings, take photos, and collect samples of rotted wood for lab analysis if necessary.

Bora-Care® and epoxy are extremely toxic materials. Follow all the safety procedures before preparing and applying.

Bora-Care® and epoxy have specific directions for use. Carefully read the instructions before using. Especially consider the conditions needed to apply each material and to let them dry.

Do not hesitate to consult technical experts to assess *vigas* and to determine the appropriate repair procedure.

FIELD NOTES

REPAIRING, REMOVING AND INSTALLING WOOD FLOORS

Milled wooden floors were introduced in New Mexico in the mid 1800s. In many of the early Spanish adobe structures, the traditional packed earth floors were replaced with wooden floors by the late territorial period. Improved metal tools, manufactured nails and milled lumber made wood floors more readily available.

By the early 1850s, saw mills were introduced in New Mexico to serve army forts. A crude sawmill was operating near Glorieta Pass in the mid 1850s, and the Wilfred Witt sawmill near Taos followed in the late 1850s. Planing mills established in Las Vegas in 1879 provided the finished lumber for floors. Finished flooring was usually pine. Hardwood flooring was eventually utilized but not until arrival of the railroad in New Mexico made delivery of these non-indigenous materials possible.

Many wood floors built in the mid- to late-1800s were set over traditional earth floors, usually for structures built during the Spanish Colonial or the Mexican periods. Joists were true 2x with 1x rough-sawn planks used to finish the floor. In some cases, *vigas* were used instead of milled lumber for the joists. Tongue-and-groove floors were introduced later. Some wood floors were vented, usually to the outside.

This section describes common deterioration factors found in historic wooden floors and will describe methods of installing new wood floors to match the existing fabric. It also discusses the installation of appropriate new wood floors if no evidence remains of the historic floor.

What **not** to do when replacing a wood floor: *Do not replace a wooden floor with a concrete slab!*

The wooden floor is a distinctive feature of San José de Gracia in Las Trampas, NM. (Jim Gautier)

TOOLS AND MATERIALS REQUIRED

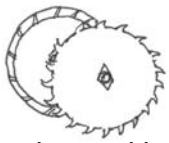
Anchor bolts

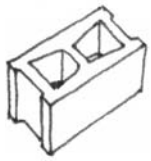
Broom

Cement

Chalk line

Circular saw


Circular saw blade, diamond blade


CMU's

Gloves

Goggles

Gravel

Hammer

Handsaw

Level

Lumber

Measuring tape

Nails

Plywood

Rebar

Sand

Shovel

String

Surveyor's level

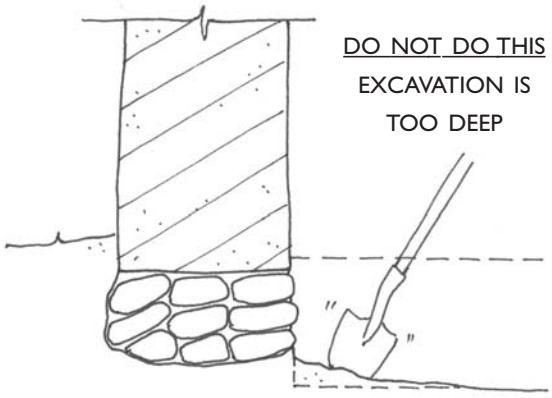
Water (potable)

Wheel barrow

ADVICE REGARDING CONCRETE SLABS

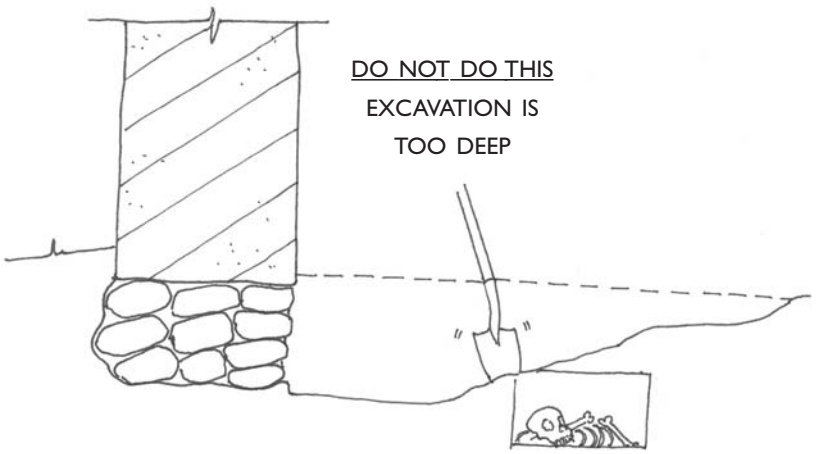
If removing a concrete slab floor to install a wood floor, Betonomite®, the expansive clay used for breaking *contra paredes*, may not work well for slabs that are less than five inches thick. For a thin slab, we advise cutting it into pieces with a masonry saw and then removing the pieces by hand. Another possibility is to create a breathing space along the walls of the building by cutting out a few inches of the slab around its perimeter. You can then install a wood floor directly over the slab and the breathing space. A radiant heating system may be used with this type of floor application.

A slab can also be removed by using sledgehammers and large wrecking bars. This process works better when the slab does not contain rebar or lathe. The concrete is broken into small pieces and pried apart with a wrecking bar. When a large piece of slab is lifted slightly off the ground, break it into smaller pieces with a sledgehammer prior to prying it out. Pneumatic equipment is not practical because the vibration produced can damage the structural integrity of adobe walls. Use wood blocks with the pry bars to minimize vibration and maximize leverage.

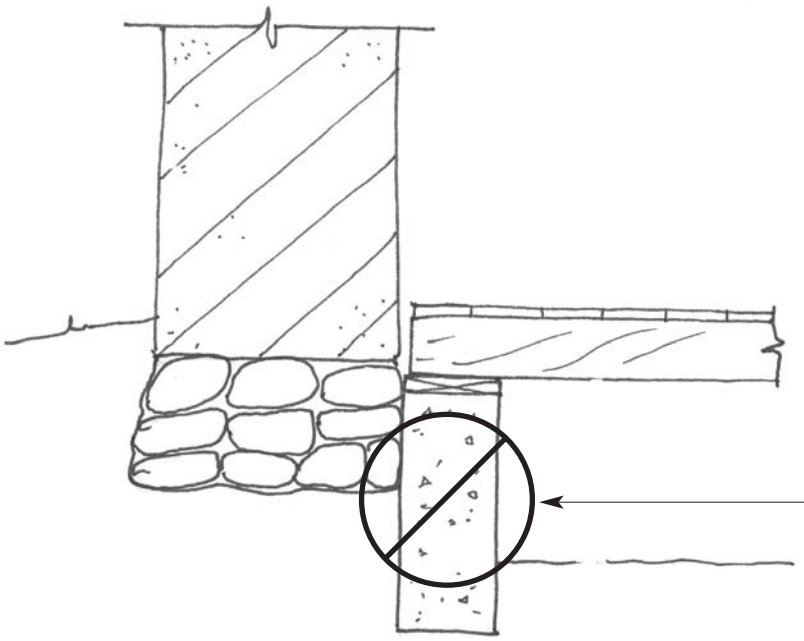


1. When removing a deteriorated wood floor, the dirt underneath the floor should not be removed in order to meet building code. Installing a wood floor according to code can damage the integrity of the adobe wall because the depth of the crawl space specified by code is too great. Instead, consult the International Building Code to determine the variance that is permissible for historic buildings.

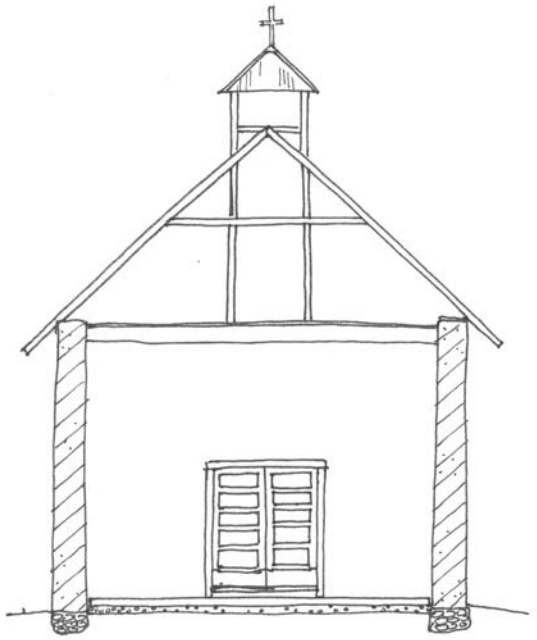
2. Many historic adobe buildings are constructed over stone footings or with no footings. If the dirt adjacent to the stone footing in the interior is removed, the stones may shift, especially if the mortar is wet. If the stones shift, the wall could collapse or settle.



3. Many historic adobe churches in New Mexico and elsewhere contain burial sites under the existing dirt and wood floors. Because of this possibility, digging and the removal of dirt should be minimal. See Part One, *Archeological Sites and Burial Grounds* for details on what to do if a burial is uncovered. In some cases, wood floors have collapsed due to the presence of burials beneath the floor.



4. Deteriorated wood floors in historic buildings should be replaced with minimal impact to the original adobe wall and foundation. Do not use a concrete girder or *contra pared* adjacent to the interior stone footing; it will lead to moisture retention.



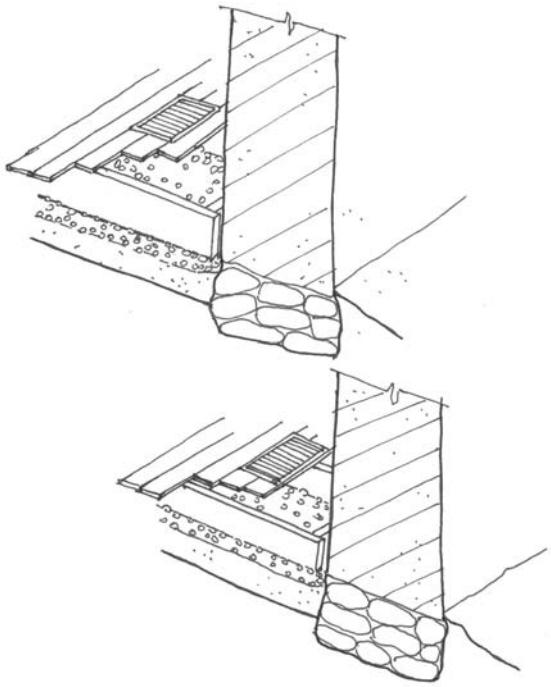
5. If deteriorated wood sleepers are removed and a minimal working space below the level of the entry door threshold exists, the design should be restricted. New floor systems should always be designed to minimize the removal of interior dirt.

When the deteriorated wood sleepers are removed and a good working space below the entry door threshold exists, a crawl space should be included in the design. If a crawl space is not possible and an existing historic dirt floor exists, burials and/or the foundation may be jeopardized. Therefore, a minimal impact flooring system should be utilized.

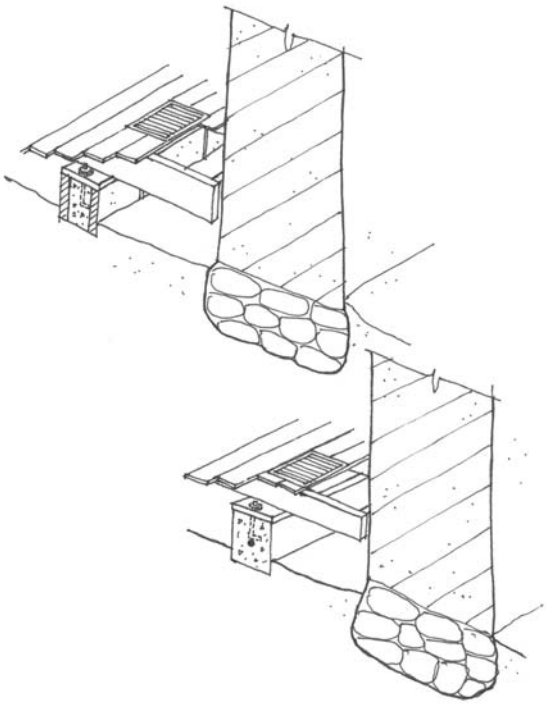
When the cause of deterioration has been identified and eliminated, and the existing historic floor has been repaired with new lumber to match the existing floor, the exposed historic wood should be treated, if possible, with Bora-Care®. See information on Bora-Care® in Part Three, *Repairing Vigas and Corbels*.

Pressure-treated joists should be used whenever possible. Cornerstones has had success ordering borate preservatives from:

Preservation Resource Group
PO Box 1768
Rockville, MD 20849-1768
Phone 301-309-2222, Fax 301-279-7885
www.PRGinc.com

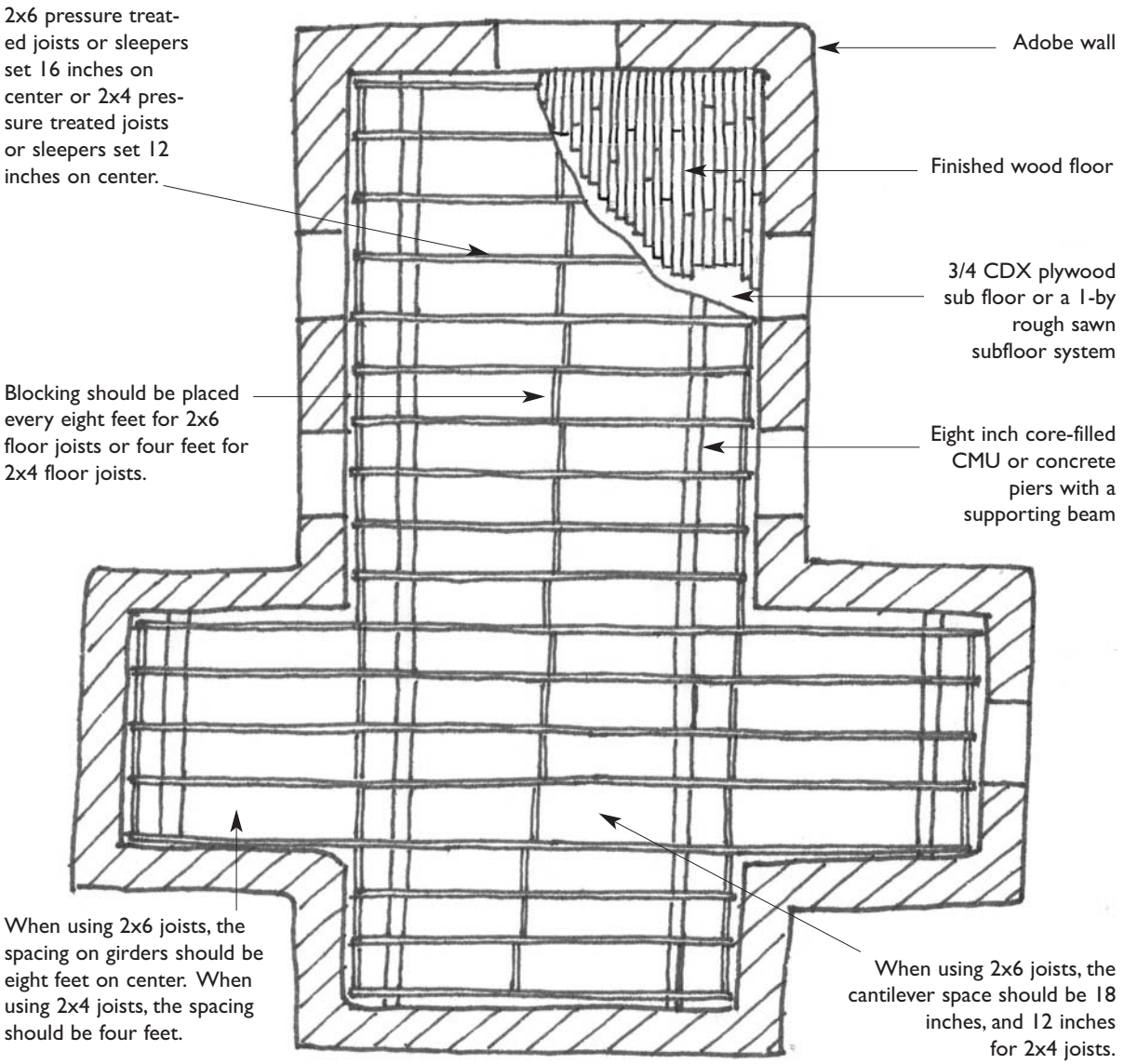


6. If a limited crawl space or no crawl space is present, then a two- to six-inch layer of leveled gravel should be laid over the existing dirt. This will prevent capillary action from pulling moisture from the ground into the foundation. The sleepers should be pressure-treated when possible. 2x6 sleepers should be laid 16 inches on center and 12 inches on center when using 2x4s. Blocking should be installed every 12 feet (see illustration on following page). A subfloor should be installed using 3/4 CDX plywood or other subflooring material to match the historic floor. If there are no remnants of the historic floor present, then the new floor should be patterned after the time period in which the structure was built. Douglas fir, hardwood, tongue-and-groove, and 1x pine planks were the most popular materials for finished wood floors. The use of 2x tongue and groove pine flooring is also an option. In this case, no subfloor is needed. Do not use laminated or vinyl wood products to finish the floor; they will result in moisture retention.



7. A different type of flooring using concrete or block guides requires the use of eight inch core-filled CMUs (concrete blocks) or concrete girders spaced every 8 feet on center with anchor bolts set at plus or minus four feet on center, when using 2x6 floor joists. The blocks or girders should be set four to six inches below the grade level and set over a compacted, leveled surface depending on the type of joist, subflooring and finished wood flooring. The joists should be laid no more than 16 inches on center when using 2x6s and nailed to a 2x8 pressure treated plate, anchored on the concrete or block girder. If using 2x4 floor joists, the concrete or block girders should be spaced four feet on center and the joists spaced 12 inches on center and nailed to the top plate similar to the 2x6 floor joists. Use pressure treated lumber when possible and install blocking every eight feet when using 2x6, or blocking every four feet when using 2x4 joists (see illustration on following page).

NOTE: If desired, the concrete girder can be higher and in different proportions as specified by an engineer or architect to best match the interior crawl space to the threshold level.



If the finished floor is less than one and a half inches thick, a 3/4-inch plywood subfloor should be installed.

Other possibilities of floor installation are possible. The use of piers with wood girders is another way to install wood floors. The sketches in this section are schematic designs that should be sized and calculated by an engineer or architect.

NOTE: The cantilever span between the adobe wall and girder may vary according to floor joist material. If using a 2x4 floor joist, the member should not cantilever more than 12 inches. If a 2x6 floor joist is used, then it may cantilever a maximum of 18 inches. An engineer or architect should be consulted for floor design expertise when possible.

All floors should be vented when possible. Vents should be at least eight feet apart along the interior walls. Some floors may be vented to the outside; however, when groundwater levels fluctuate heavily, maintaining a dry crawlspace may become a problem. In such cases, a mechanized system with moisture sensors may be installed to monitor water levels in the crawl space and ventilate the area.

INSTALLING WOOD SHINGLES AND SHAKES

In New Mexico, roofs with wood shingles were introduced after 1848. Wood shingles were costly and, therefore, were only used on important buildings such as churches and officers' quarters.

Many historic structures have lost their wood shingle roofs. In some cases they have been replaced with metal roofs. However, some historic churches in New Mexico still retain wood shingles, while others have only remnants of wood shingles on belfries and gable ends.

Cedar shingles are widely available, but only the highest grade should be installed. As with any roof, flashing at joints, valleys and points of penetration are the keys to its ultimate success.

This section explains the restoration or replacement of a wood shingle roof on an historic structure. This method can also be applied to wood shingle gable ends and belfries.

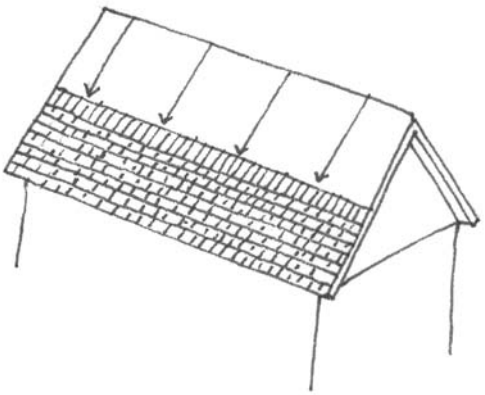
Considering the cost of cedar shingles, great care should be taken in installing them. When possible avoid using a pneumatic roofing stapler; instead, hand nail with 3d or 4d hot-dipped galvanized nails. Do not use electro-galvanized nails. Use only two nails per shingle. Make two shingles out of any shingle wider than 12 inches.

Shingles that are pre-dipped in a preservative stain are recommended. Cornerstones has had success obtaining them from the Cedar Shake and Shingle Bureau and recommends its installation guide:

Cedar Shake and Shingle Bureau
515 116th Ave. NE, Suite 275
Bellevue, WA 98004-529
Phone 425-453-1323

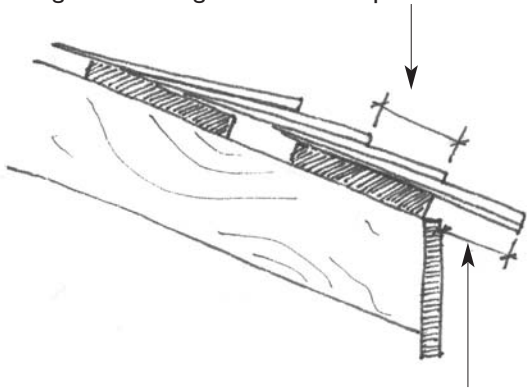
INSTALLATION PRINCIPLES

The following drawings and directions serve as a guide for installation of wood shingles on adobe structures. NOTE: Shingles are sawn, shakes are split. Four bundles equals 25 square feet. Cedar is a natural insect repellent and does not rot.



Measure from ridge to check alignment of shingles. Strike a line with chalk.

All bundles of shingles contain a graph that indicates the appropriate overlap for the shingles according to the roof slope.



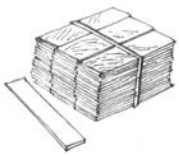
Double or triple the first course at the overhang.

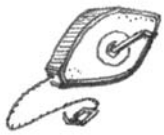
Shingle and shake roofs are very durable when installed correctly and maintained properly. Though somewhat costly, they are an important part of the history of New Mexico and the Southwest; they were the first non-native roofing materials to be introduced. Next to the rapidly disappearing earthen roofs, they are perhaps the most endangered element of historic New Mexican architecture.

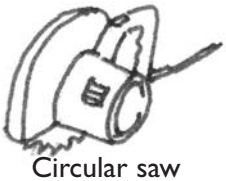
TOOLS AND MATERIALS REQUIRED

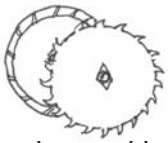
Air compressor

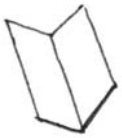
Broom


Cedar shingles


Chalk line


Circular saw


Circular saw blade, diamond blade


Flashing

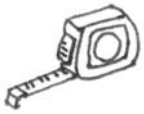
Gloves

Goggles

Hammer

Ice and water shield

Ladder

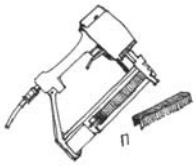

Measuring tape

Nails

Scaffolding

Sheet metal shears

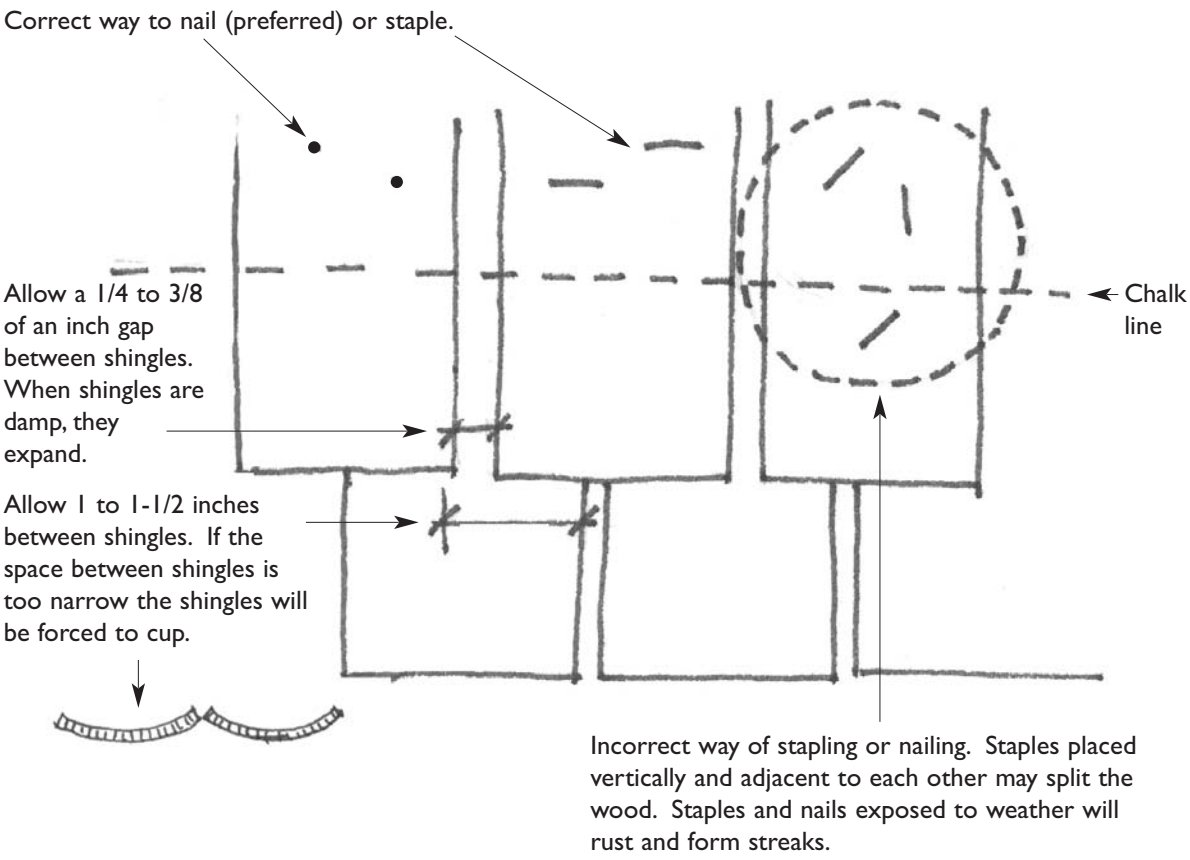
Shovel

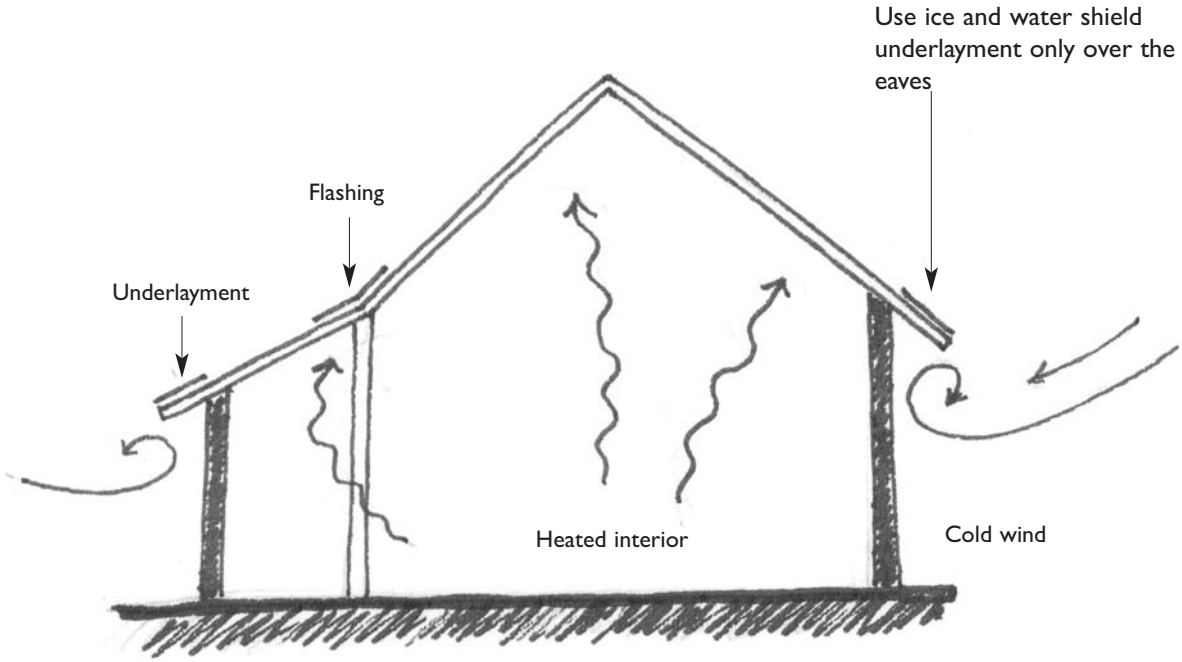

Staple gun

Staples

String

Utility knife


Correct way to nail (preferred) or staple.
Allow a 1/4 to 3/8 of an inch gap between shingles. When shingles are damp, they expand.
Chalk line
Allow 1 to 1-1/2 inches between shingles. If the space between shingles is too narrow the shingles will be forced to cup.
Incorrect way of stapling or nailing. Staples placed vertically and adjacent to each other may split the wood. Staples and nails exposed to weather will rust and form streaks.


Use ice and water shield underlayment only over the eaves
Flashing
Underlayment
Heated interior
Cold wind

1. Remove existing shingles if any.

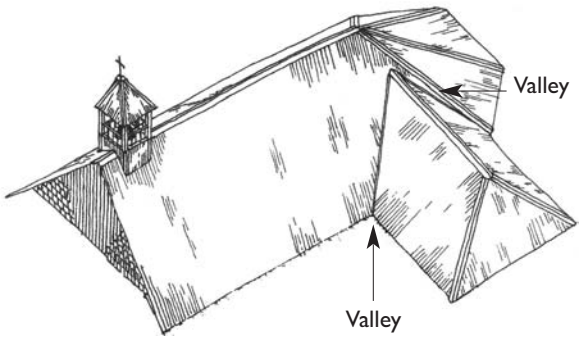
2. Sweep and clean the roof surface.

3. Drive in or pull out existing nails and repair or replace damaged purlins.

4. Ice and water shield should be installed on all overhangs. Roll out shield, cut to a workable length, and cut to fit at the hip if a hip exists.

5. Carefully remove kraft paper from underside of the shield. Work from one end to the other. Carefully place the shield on roof surface.

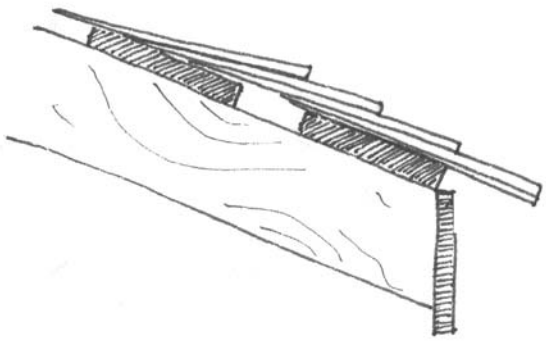
WARNING: When shield glue touches any surface, it will stick and stay!



6. When the roof structure contains valleys, place galvanized, stainless steel or copper sheet metal flashing in the valley. Cut to length. Nail flashing in place.

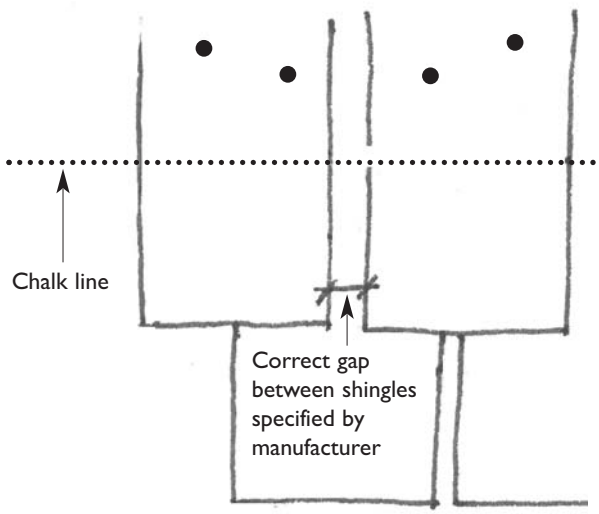
7. After shield and flashing installation has begun, determine the eave overhang and nail a guide shingle at one end. Leave a three inch overhang.

8. Nail a shingle at the other end of the span. Pull a string as a guide at the outside edge of the shingle.



9. Nail two or three overlapped shingles. Illustration shows the bottom layer of shingles with three laps and a single layer above.

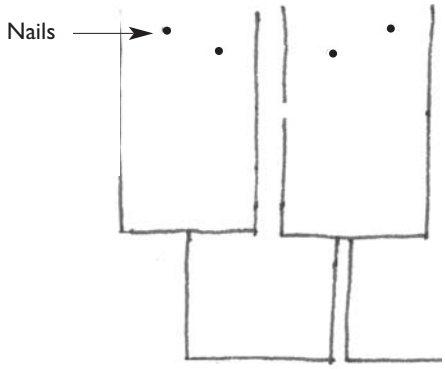
10. Hand place shingles with the right spacing.



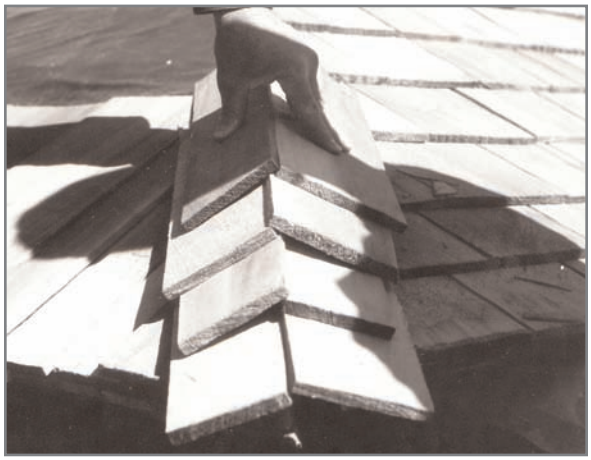
11. Break shingles by hand to obtain the correct spacing of the gap between shingles.

12. Make sure to use a chalk line to strike a line as a guide. The shingle manufacturer specifies the correct distance for the spacing between shingles.

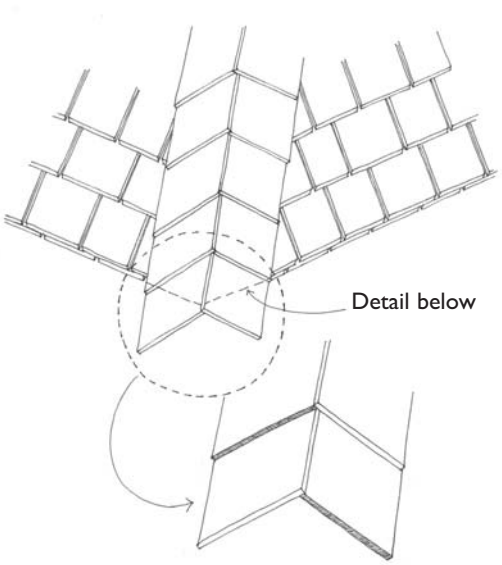
13. Continue the process of placing shingles.



14. Once the row of shingles has been put in place, anchor each shingle with two nails as shown above.



15. At the hip each side of the shingle overlaps in an alternating fashion.



16. Using a circular saw cut the extending shingles at the hip in order to place ridge cap.

NOTE: When installing wood cedar shakes, the process is similar except a 15-pound roofing felt is installed on every course. The roll of roofing felt is cut in half in order to install it over each layer of shakes. The first course should always begin with shingles and then continue with shakes. Shakes are nailed in similar fashion and since a shake is split not sawn, there is always a rough or textured side. This side should always face up. The felt, when installed, should be completely hidden under the layers of shakes and not exposed to sunlight.

GLOSSARY OF TERMS

The following glossary is intended only as a handy reference for the terms used in this handbook. It is by no means complete. A more complete compilation of general building terms can be found in the International Building Code.

Acequia – a word derived from Arabic referring to an irrigation canal.

Adobe – sun dried, earthen brick; *amixtl* is the Nahuatl word for adobe.

Adobera – wooden mold used for making adobe.

Adobero – one who works with adobe.

Adzed – the process of stripping or smoothing a log with a stone or metal blade, usually into a rectangular shape.

Aggregate – sand and gravel in plasters, mortars and mud.

Alum (alumbre) – chemical composition commonly referred to as aluminum sulfate, though the actual composition is most commonly potash alum (potassium aluminum sulfate).

Araña – literally 'spider' in Spanish, but here refers to a wooden candleholder suspended from the ceiling.

Belfry – the small, tower-like structure sheltering the bell on a church with a pitched roof.

Betonomite – brand name of an expansive clay used to break boulders and concrete.

Bird's mouth cut – refers to a notched rafter that sits snuggly on the top plate of a wall.

Bond beam (tie beam) – beam, historically made of wood, that runs along the top of the wall and supports *vigas*.

Brown coat – term used in the United States for the plaster layer over the 'scratch' coat and under the 'color' or finish coat.

Bruñido – polished lime plaster burnished with river rocks or smooth stones; usually used for roofs and domes finished with lime plaster.

Bulto – a three-dimensional carved image of a saint or holy figure.

Canal – New Mexican term referring to roof drain spouts projecting through parapet walls.

Capillarity – the process wherein moisture rises through plaster, mortar and/or wall material; also referred to as rising damp.

Cedro – literally cedar; wood usually split in half or used whole as decking spanning from *viga* to *viga*.

Cement – refers to Portland cement in this handbook; produced from limestone at a very high temperature; a durable and non-permeable material used commercially for mortars and plasters.

Chamfer – decorative, finished edges of a square beam or post, obtained by carving down its sharp corners.

Clay – sticky soil used as a binder in earthen blocks, mortars and plasters, defined by particle size that swells when wet and shrinks when dry.

CMU – abbreviation for a concrete masonry unit, or cinder block.

Collar tie (whythe) – board attached to two rafters about two-thirds of the distance below the peak to create a truss and increase structural stability of the rafters.

Contra fuerte – the Spanish equivalent of a buttress, a massive piece of masonry or concrete, usually used to keep walls from moving.

Contra pared – literally 'against the wall'; refers to concrete grade beams often installed at the base of adobe walls in an attempt to stop basal erosion; thought to give structural stability to walls without foundations or with stone/rubble foundations.

Coping – decorative element on the top of a parapet wall, usually made of brick or stone.

Corbel – decorative, carved wooden element, usually with a scroll-like profile; often used to support *vigas* in a wall.

Course – term used to describe one row of masonry units, such as adobes, in a wall.

Dado – painted or colored band around the interior wall, typically just above the floor.

Dentil – decorative motif of alternately projecting elements.

Drip-line – a line below the eave of a roof where water dripping from it makes contact with the ground.

Drywell – hole filled with gravel that acts as a drain pit for runoff from a roof or site.

Earthen – in this handbook refers to the predominant use of local soils in construction or repair.

Eave – the overhang of a pitched roof.

Estípite – pyramid-shaped pillar or baluster; decorative element making up a portion of a column or pillar.

Flashing – system, typically of metal, that directs water away from vulnerable areas on roofs and from around doors and windows.

Filter fabric (geo-textile/landscape fabric) – non-woven polyester fabric that separates soil from water, preventing drainage systems from clogging and prevents unwanted vegetation from taking root.

Finish coat – final 'set' or 'color' coat of plaster.

Fogón – fireplace located in the corner of a room.

Footing – base of the foundation or subsurface system, beneath the stem wall.

Gable end – triangular-shaped end wall supporting a pitched roof.

Glazing – pane of glass in a window.

Gravel – term used to describe aggregates that are larger than sand but smaller than cobbles.

Half-lapped joint – joint between two boards in which one-half the thickness of each board is removed and the two pieces overlap.

Head trim – decorative element over a window or door.

Horno – Spanish term for a beehive-shaped earthen oven.

ICOMOS – International Council on Monuments and Sites

INAH – Instituto Nacional de Antropología e Historia (México)

Jacál – method of building walls using upright posts chinked with mud and stone.

Jamb – wooden mountings around windows and doors.

Jaspe – Spanish word for gypsum; refers specifically to a gypsum-based whitewash.

Joist – board in a floor or ceiling that stands on edge and to which the decking is attached.

Kiva – ceremonial chamber used by Native Americans.

Lap joints – half-lapped joints; see definition for half-lapped joints above.

Lath – mechanism used to mechanically bond plasters to walls; can be wire mesh, wood strips, *rajuelas* or other material.

Latillas – small wooden poles laid horizontally over the *vigas* or beams that provide a deck for the roof; also called *sabinos*.

Lime – calcium carbonate used as a permeable mortar and plaster in earthen buildings.

LINTEL – beam or log over an opening, such as a door.

MANTA – cloth attached to the bottoms of the *vigas* or beams to create a ceiling and to catch dirt filtering down from the roof.

MAYORDOMO – lay caretaker of a church.

MONITOR – in this handbook refers to a device or method used to keep track of movements in cracks.

MORTAR – binder used to join two masonry units such as bricks or adobes.

MUCILAGE – juice extracted from plants and used as a binder in traditional plasters.

MUD – the primary component in earthen buildings, a combination of clays, silts, aggregates, water and sometimes straw.

MUDSILL – plate at the top of the foundation system, placed to accept framing.

MUNTIN BARS – the grid in a window used to hold glazing in place.

NAGPRA – Native American Graves Protection and Repatriation Act.

NICHO – Spanish word for niche; a small recess in a wall.

PARAPET – low wall on a flat-roofed building that extends above the roof; also called *pretil*.

PIER – small concrete, stone or block that supports a floor joist as a vertical support column.

PEDIMENT – decorative element, often triangular, above a window or door.

PINTLE HINGE – rudimentary hinge that mates a peg on the ends of a door with corresponding holes in the jamb.

PLANE – action of smoothing a board with a blade.

PORTÁL – porch or partially enclosed area attached to an elevation of a building.

POINT – action of filling the joints between bricks with new mortar material.

PUDDLED MUD – method of building walls in which the mud is stacked free form into courses.

PURLINS – boards spanning the tops of the rafters, usually with several inches of open space in between and to which roofing material is attached.

RAFTER – board installed on the edge of a pitched roof to which purlins or decking are attached.

RAJAS (*CEDROS*) – similar to *latillas*; split poles used as decking atop *vigas*.

RAJUELA – stones embedded in masonry joints that serve as laths for lime plaster.

REREDO – altar screen.

RETABLO – two-dimensional representation of a saint or saints; a painting on panel.

RIDGE – peak of a pitched roof, supported by the ridge board and sealed with the ridge cap.

SALA – large 'living' room.

SAND – small aggregate used in the making of mud.

SASH – the part of a window containing mutins and glazing.

SCRATCH COAT – first or leveling coat of plaster.

SCREED BAR – straight edge installed temporarily as a guide in leveling material for walks and floors; part of a comprehensive system of chalk lines, stakes and screed bars.

SELENITE – translucent mineral of the gypsum family used as glazing in windows before glass was available; similar to sheet mica.

SHAKE – roofing shingle that is split not sawn.

SHEAR – in this handbook refers to the downward movement of part of a wall resulting in a structural crack.

SHIM – thin wedge used as a spacer to help hold door and window jambs, scaffolding, adobes undergoing repair and *vigas* and beams in place.

SHINGLE – thin roofing element, usually made of cedar that is sawn not split.

SHORING – process or system of installing supports to take the load off a failing wall or to hold it in place.

SHORING JACK – adjustable pole used to temporarily support a roof

SILL – also called a plate; structural wooden element that runs continuously around a building at floor level and at roof level.

SILT – finest soil found in mud; defined by its particle size.

SLEEPERS – ties or grade beams that rest directly on the ground and provide a point of support for a floor or other structural element.

SLUMP – In this handbook refers to the movement of an earthen material that is too wet and cannot support its own weight.

STANDING SEAM – metal roofing material that is joined at the edges by the overlap of one break or fold over another.

STRAW – dried stalk of any of a number of grasses that are used in some adobe mud.

TERNEPLATE – corrugated steel roofing.

TOP PLATE – horizontal member at the top of a frame or masonry wall placed to accept roof-framing system; see definition for sill above.

TORREON – round tower, used for defensive purposes.

TORTA – Spanish for the dried mud membrane over the *latillas* or *cedros*; one component of an earthen roof.

VALLEY – low line of the junction of two pitched roofs.

VALLEY FLASHING – material, usually sheet metal, that prevents water running down the valley from getting underneath the roofing.

VERNACULAR – in this handbook refers to buildings that were not designed by an architect.

VIGA – a log stripped of bark and used as the principal support in the roof system of an earthen building.

WAINSCOTING – a functional and/or decorative element installed around the interior walls of a building. A functional wainscoting is typically made of wood, but a decorative one, like a dado, may be painted on the surface of the wall.

WATTLE AND DAUB – method of building with earth in which mud is applied to an upright wood or wicker frame.

WHEAT PASTE – compound of wheat flour and water used for decorative purposes on interior adobe walls.

ZAGUÁN – covered vestibule that connects the exterior of a house to an inner patio; typically large enough to permit animals and wagons to pass.

ZAMBULLO – Spanish term for the pintle hinge of a door.

ZAPATA – similar in appearance to a corbel, but used at the top of a post to provide support where two horizontal beams are joined.

ZOQUETE – leftover piece of wood.

CORNERSTONES' ASSESSMENT, EDUCATION, PRESERVATION AND MAINTENANCE SITES 1986-2006

Cornerstones Community Partnerships has helped preserve adobe buildings across the Southwest. This list, organized by state and town, provides the name and, if known, the construction date of the buildings where Cornerstones has performed assessment, education, preservation and/or maintenance programs. If you would like to request a site visit or need technical assistance with an historic adobe building, please call us at 505-982-9521 or email **info@cstones.org**

ARIZONA

Ganado
- Sage Memorial Hospital, 1911 (Navajo)
- Mission church, 1906

Oraibe
- 7 ruins, c. 12th century

COLORADO

Antonito
- Society for the Mutual Protection of United Workers (SPMDTU) Fraternal Lodge, 1925

Arboles
- St. Francis Mission, 1917

Garcia
- Morada, late 1800's

Gardner
- Sacred Heart Church, 1871

Ft. Collins
- Romero House, 1927

Los Sauces
- San Antonio Church, 1923

Mogote
- San Rafael Presbyterian Church, 1895

Redwing
- Señora de Guadalupe, 1883, addition 1929

Trinidad (Long's Canyon)
- Nuestra Señora Del Carmen, c. 1900

NEW MEXICO

Abeytas, Socorro County
- San Antonio de Padua, 1800's

Abiquiu, Rio Arriba County
- Morada, 1820 – 1850
- Santo Tomas, 1935 (John Gaw Meem)

Acoma Pueblo, Cibola County
- San Esteban del Rey, 1629 – 1634
- Meeting House

Alamogordo, Otero County
- St. John's Episcopal Church, 1905

Albuquerque, Bernalillo County
- Hubbell House, prior to 1868
- Woodward House, 1938
- Our Lady of Lourdes, c. 1933

Alcalde, Rio Arriba County
- San Antonio, 1878

Alto Talco, Mora County
- Santiago de Talco, c. 1900

Amelia, Taos County
- Santa Niño

Anthony, Doña Ana County
- St. Anthony's Church

Anton Chico, Guadalupe County
- San Jose, 1930

Arroyo Hondo, Taos County
- Nuestra Señora de Los Delores, c. 1820

Arroyo Seco, Taos County
- Santisima Trinidad, c.1845
- Schoolhouse

Aurora, San Miguel County
- San Antonio Church, 1930

Aztec, San Juan County
- Aztec Presbyterian, 1889

Bernalillo, Sandoval County
- San Lorenzo, 1875
- Mortuary (future Wine Museum)

Bibo, Cibola County
- Our Lady of Loretto, early 1900's

Borica, Guadalupe County
- San Isidro, 1910's

Buena Vista, Mora County
- Santo Niño de Atocha, 1876

Bueyeros, Harding County
Sacred Heart, 1910
Cañada de Los Alamos, Sante Fe County
Our Lady of Guadalupe, 1921
Canjilon, Rio Arriba County
Morada de San Lazaro, late 1800's
San Juan Nepomuceno, 1878
Cañones, Rio Arriba County
San Miguel, pre-1889
Cañoncito del Apache, Santa Fe County
Nuestra Señora de la Luz, 1869
Cañon Plaza, Rio Arriba County
Nuestra Señora de Carmel, 1916 (on ruins of earlier church built in 1880)
Cañoncito de la Cueva, Mora County
Capilla de San José 1900
Capulín, Rio Arriba, County
Santo Niño, 1941
Casa Colorado, Valencia County
Immaculate Conception, 1920's
Cebolla, Rio Arriba County
Santo Niño, 1948
Chacón, Mora, County
Capilla de San Antonio, 1865
El Rito Presbyterian, 1880
Chimayo, Rio Arriba County
Santuario, 1816
Plaza del Oro Oratorio, late 1700's
Clayton, Union County
D.D. Monroe Building., WPA 1939
Cleveland, Mora County
Morada de San Pedro
San Antonio, 1865
Colonias, Guadalupe County
San Jose Church, pre-1896
Concepcion, San Miguel County
Immaculate Conception Church, c. 1886
Corrales, Sandoval County
San Ysidro church, 1860
Costilla, Taos County
Sacred Heart, 1895
Coyote, Rio Arriba County
Coyote Morada
Cuervo, Guadalupe County
Santo Niño Church, 1915
Dilia, Guadalupe County
Sacred Heart Church, 1900
Dixon, Rio Arriba County
Convento, 1930's
Dixon Presbyterian , 1910-20
Doña Ana, Doña Ana County
Nuestra Señora de la Candelaria, 1860
Amador Hotel, 1866
Dulce, Rio Arriba County
Applied Learning Program 2004-2006
Duran, Torrance County
San Juan Bautista, 1616
El Carmel, Mora County
Morada
Nuestra Señora del Carmel, c. 1900
El Cerrito, San Miguel County
Nuestra Señora de los Despanparados, 1888
El Guique, Rio Arriba County
San Rafael, pre-1910
El Guache, Rio Arriba County
La Capilla de San Antonio, 1900
El Llano, Taos County
El Llano Presbyterian, 1929
El Macho, San Miguel County
Our Lady of Guadalupe, 1875
El Porvenir, San Miguel County
San Antonio, 1895
El Pueblo, San Miguel County
San Antonio de Padua, 1900
El Valle, Taos County
Schoolhouse
Ensenada, Rio Arriba County
San Joaquin, 1916
Española, Rio Arriba County
St. Stephen's Episcopal
Estaca, Rio Arriba County
Capilla de San Francisco, 1930
Estancia, Torrance County
United Methodist Church, 1908
Fierro, Grant County
St. Anthony's, 1910's
Folsom, Union County
St. Joseph's, 1870
Ft. Stanton, Lincoln County
Ft. Stanton Chapel, 1870
Stables, 1855
Ft. Sumner, Baca County
St. Anthony's, 1880's
Galisteo, Santa Fe County
Sala de San José, early 1900's

Gallinas, San Miguel County
- La Capilla de Santo Niño, 1936

Gallup, McKinley County
- Cotton warehouse

Glencoe, Lincoln County
- St. Anne Episcopal, 1906

Glorietta, Santa Fe County
- Nuestra Señora de Guadalupe, 1950

Golden, Santa Fe County
- Capilla de San Fancisco, 1828

Golondrinas, Mora County
- San Acacio, 1862

Guachupangue, Rio Arriba County
- Nuestra Señora de Guadalupe, 1804

Guadalupita, Mora County
- Nuestra Señora de Guadalupe, 1957

Hanover, Grant County
- Holy Family, 1925

Hayden, Union County
- Holy Trinity, 1912

Hernandez, Rio Arriba County
- San José del Chama, c. 1870

Holman, Mora County
- Morada de San Isidro, 1868
- Immaculate Heart of Mary, 1950's

Isleta Pueblo, Bernalillo County
- St. Augustine, 1613

Jemez Pueblo, Sandoval County
- San Diego, 1880's

La Bajada, Santa Fe County
- San Miguel, 1831

La Cienega, Santa Fe County
- San José

La Cieneguila, Santa Fe County
- Capilla de San Antonio, 1875

La Cueva, Mora County
- San Rafael, 1862

La Jara, Sandoval County
- Oratorio de Jesus Nazareño, 1932

La Manga, San Miguel County
- Santo Niño de Atocha, 1932

La Mesa, Doña Ana County
- San José, 1868

La Mesilla, Doña Ana County
- Fountain Theater, mid-1800's

La Mesilla Park, Doña Ana County
- St. James Episcopal Church, 1911

La Mesilla, Rio Arriba County
- La Iglesia de San Isidro Labrador, 1918

La Puebla, Santa Fe County
- La Capilla de Nacimiento Del Niño Dios, 1880

La Puente, Rio Arriba County
- Capilla de San Miguel, 1914

Laguna Pueblo, Cibola County
- San Jose Mission, 1706

Lamy, Santa Fe County
- Our Lady of Light, 1927

Las Colonias, Taos County
- Santo Niño de Atocha, 1930's

Las Cruces, Doña Ana County
- Christian Methodist Episcopal Church

Las Nutrias, Socorro County
- San Isidro, 1930's

Las Trampas, Taos County
- San Jose de Gracia, 1760 –1766
- Morada

Las Vegas, San Miguel County
- St. Paul's Episcopal, 1886
- Kings Stadium, WPA, 1930's
- Sala de San José, 1886
- Las Vegas Presbyterian, 1871
- Winternitz Building

Ledoux, Mora County
- San José, 1906

Lemitar, Socorro County
- Sagrada Familia, 1831 – 1837

Llano Quemado, Taos County
- Nuestra Señora del Carmen, prior to 1945

Los Alamos
- San Miguel
- Santo Niño, 1945

Los Brazos, Rio Arriba County
- Schoolhouse, 1896

Los Hueros, Mora County
- San Juan Bautista, 1895
- Morada, approx. 1850

Los Lefebres, Mora County
- Nuestro Señor de Esquipula, 1886

Los Luceros, Rio Arriba County
- Capilla de la Sagrada Familia, 1860

Los Lunas (Los Lentes), Valencia County
- San Antonio de Los Lentes, 1790s

Lower Colonias (Pecos), San Miguel County
- Santo Niño, 1867

Lower Rociada, San Miguel County
- Santo Niño, 1861

Lucero, Mora County
- Morada, mid-1800's
- Santa Rita, 1886

Lumberton, Rio Arriba County
- San Francisco de Assisi, 1913

Maes, San Miguel County
- Iglesia de San Santiago, 1900

Manuelitas, San Miguel County
San Isisro Chapel, c. 1900
McCartys, Cibola County
San Fidel, c. 1933
Medanales, Rio Arriba County
Capilla de San Antonio, 1950
Mescalero, Otero County
St. Josephs Apache Mission, 1920 – 1939
Monte Aplanado, Mora County
Santo Niño de Atocha, 1830's
Montezuma, San Miguel County
Nuestra Señora de Santana Morada, 1893
Mora, Mora County
Santa Gertrudis, 1800
Santa Gertrudis Morada
St. Vincent de Paul Schoolhouse
Mosquero, Harding County
St. Josephs, 1900
Mountainaire, Torrance County
United Methodist Church, 1908
Nambe, Santa Fe County
Sagrado Corazon, 1947
North San Isidro, San Miguel County
San Isidro Labrador, 1930
Ocate, Mora County
Our Lady of Guadalupe, 1900
Ojitos Frios, San Miguel County
Our Lady of Guadalupe, 1904
Ojo Caliente, Taos County
St. Mary's, 1939
Santa Cruz Church, 1860
Ojo Feliz, Mora County
San Isidro Church, 1900
Ojo Sarco, Rio Arriba County
Santo Tomas, 1886
Pajarito, Santa Fe County
La Sagrada Familia, 1920
Pastura, Guadalupe County
Chapel of St. Helen, 1926
Peñasco, Taos County
San Antonio de Padua School, 1962
Peñas Negras, Taos County
Peñas Negras Oratorio, 1800's
Peralta, Valencia County
Nuestra Señora de Guadalupe, 1879 – 1888
Picuris Pueblo, Taos County
San Lorenzo Mission, Oct. 1776
Pilar, Taos County
Nuestra Señora de Las Dolores, 1892
Pintada, Guadalupe County
La Sagrada Familia, 1880's
Placita Plaza, Taos County
Nuestra Señora de Asuncion, 1869
Questa, Taos County
Iglesia de San Antonio, 1860
Rainsville, Mora County
Sacred Heart Church, 1910
Ranchos de Taos, Taos County
St. Francisco de Asissi, 1810
Rehoboth, McKinley County
Christian Reform Church, 1920's
Reserve, Catron County
Apache Creek Church, 1935
Ribera, San Miguel County
Schoolhouse
Rincon, Doña Ana County
Our Lady of Nations, 1914 –1917
Rio en Medio, Santa Fe County
Nuestra Señora de Los Dolores, 1883
Rodarte, Taos County
Morada de Santa Barbara
Sabinal, Socorro County
San Antonio, 1830's
Sabinosa, San Miguel County
Nuestra Señora de Guadalupe, 1900
San Acacia (aka San Acacio), Socorro County
San Acacia Church, 1929
San Agustin, San Miguel County
San Agustin Church, early 1800's
San Antonito, Bernalillo County
San Antonito Mission, 1921
San Cristobal, Taos County
San Cristobal Mission, 1942
Sandia Pueblo, Sandoval County
San Antonio de Padua, early 1800's
San Fidel, Cibola County
St. Joseph, 1920
San Geronimo, San Miguel County
St. Jerome, 1846
San Ignacio, San Miguel County
San Ignacio Church, 1862
San Isidro Del Sur, San Miguel County
Our Lady of Guadalupe, 1800's
San Isidro, San Miguel County
Morada
San Jose, Taos County
San Jose de Gracia, 1760 – 1776
San Juan, San Miguel County
San Juan Nepomuceno, 1900

San Juan Pueblo, Rio Arriba County
- Our Lady of Lourdes, 1889 – 1990

San Lorenzo, Grant County
- Father Aull House & Chapel, 1930's

San Miguel, San Miguel County
- Capilla de San Miguel, 1927 –1928
- San Miguel del Vado, 1805

San Patricio, Lincoln County
- San Patricio Church, 1885

San Pedro, Rio Arriba County
- San Pedro Church, rebuilt 1939

San Rafael, Cibola County
- Morada de San Rafael

Santa Ana Pueblo, Sandoval County
- Santa Ana Church, 1730-1750

Santa Clara Pueblo, Rio Arriba County
- Santa Clara Church, 1758, rebuilt 1918

Santa Clara, Grants County
- Santa Clara Church, 1950's

Santa Cruz, Santa Fe County
- Santo Niño de Atocha, 1880

Santa Cruz, Santa Fe County
- Santa Cruz de La Cañada, 1733

Santa Fe, Santa Fe County
- Friends Meeting House, Pre-1900
- Cristo Rey Church, 1939
- Oldest House, pre -1500's
- Rosario Chapel, 1807
- San Miguel Chapel, 1710
- Santuario de Guadalupe, 1776 – 1795
- St. Catherine's Indian School, mid-1800's

Santa Rosa, Guadalupe County
- Santa Rosa de Lima, 1879

Santiago, Mora County
- Santiago del Talco, 1900

Sapello, San Miguel County
- Nuestra Señora de Guadalupe, 1940's

Sena, San Miguel County
- Iglesia de Nuestro Señor de Esquipula, 1908

Socorro, Socorro County
- San Miguel Church, 1815

So. San Isidro, San Miguel County
- Nuestra Señora de Guadalupe, c. 1930's

Tajique, Torrance County
- San Antonio, 1915

Talpa, Taos County
- Nuestra Señora de San Juan de Los Lagos, 1907

Taos, Taos County
- Millicent Rodgers Museum, 1930's-40's

Taos Pueblo, Taos County
- San Geronimo de Taos, 1850
- Village structures, c. 1500-1600

Tecolote, San Miguel County
- Our Lady of Sorrows, 1852

Tecolotito, San Miguel County
- Nuestra Señora de Guadalupe, 1945

Tesuque Pueblo, Santa Fe County
- San Isidro Mission, 1641 (destroyed by arson 2002)

Tohatchi, McKinley County
- St. Mary's, 1920

Tomé, Valencia County
- Immaculate Conception, 1750's

Trementina, San Miguel County
- San Rafael Church, 1925

Truchas, Rio Arriba County
- Virgen Rosario Church, 1760

Trujillo, San Miguel County
- San Isidro Convent, 1930

Tucumcari, Quay County
- Bathhouse, 1930's

Turquillo, Mora County
- Santa Teresita del Niño Jesus, 1920

Tularosa, Otero County
- St. Francis de Paula, 1869
- Rectory, St. Francis de Paula, 1920-1921

Upper Rociada, San Miguel County
- San José Church, 1900

Valdez, Taos County
- San Antonio de Padua, 1840

Vaughn, Guadalupe County
- St. Mary's, c. 1937

Vallecitos, Rio Arriba County
- United Methodist Church, 1932

Velarde, Rio Arriba County
- Nuestra Señora de Guadalupe, 1817

Villanueva, San Miguel County
- Nuestra Señora de Guadalupe, c. 1790

Wagon Mound, Mora County
- Santa Clara Church, 1911

Watrous, Mora County
- School, 1919 – 1920

White Rock, Los Alamos County
- Baptist Church, 1983

Willard, Torrance County
Our Lady of Sorrows, 1912
Youngsville, Rio Arriba County
San Pedro Church, 1910
Zia Pueblo, Sandoval County
Nuestra Señora de la Asunción de Zia, prior to 1613
Zuni Pueblo, McKinley County
Middle Village, 14th century
Nuestra Señora de Guadalupe, 1700's
Rock Quarry, youth training and re-opened profitable quarry, 1994-95
Hapadina Building (formerly Kelsey Trading Post) approx. 1879

TEXAS

Los Portales
San Elizario, c. 1790
Ruidosa
Sacred Heart of Christ, 1914
San Elizario
Historic Adobe Jail, 1860s
San Elizario Presidio Chapel, 1882
Socorro
Nuestra Señora de la Limpia Concepción, 1843 (nave)

INTERNATIONAL WORKSHOPS AND SEMINARS ON LIME TECHNOLOGIES, AND THE CONSERVATION AND RESTORATION OF EARTHEN ARCHITECTURE

2000
Casas Grandes, Chihuahua, México

2001
Pueblo of Acoma, New Mexcio
Chalchihuites, Zacatecas, México
Hidalgo del Parral, Chihuahua, México
Mata Ortiz, Chihuahua, México

2002
Pueblo of Acoma, New Mexico
Chihuahua,Chihuahua, México

2003
Lincoln, New Mexico
Jano, Chihuahua, México
Nombre de Dios, Durango, México

2004
Chihuahua, Chihuahua, México
Pabellón de Hidalgo, Aguascalientes, México

2005
Chihuahua, Chihuahua, México
La Mesilla, New Mexico

2006
Bernalillo and Coronado State Monument, New Mexico
Carrizal, Chihuahua, México
Guerrero, Chihuahua, México

ABOUT CORNERSTONES COMMUNITY PARTNERSHIPS

Since 1986, Cornerstones Community Partnerships has worked to preserve architectural heritage and community traditions at more than 300 locations in New Mexico and the Southwest. Cornerstones has built a national reputation for the creative use of historic preservation as a tool for community revitalization and as a method for engaging both youths and adults in the conservation of historic buildings, the maintenance of traditional building skills and the affirmation of culture.

Cornerstones is a 505(c)3 not-for-profit organization located in Santa Fe, New Mexico, 87501. The organization has no religious affiliation. For more information visit the Cornerstones web site at **www.cstones.org**. Tax-deductible contributions to support our efforts can be sent to Cornerstones Community Partnerships, P.O. Box 2341, Santa Fe, New Mexico, 87501-2341

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