# EARTH ARCHITECTURE

# EARTH ARC

Ronald Rael

HITECTURE

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*This book is dedicated to my parents, Christina Casias Rael, whose wisdom and character was shaped in a small adobe house built by her grandfather in the isolated village of La Florida, Colorado, and Miguel Arturo Rael (1945–2008), an honest and hardworking builder who left a legacy of adobe, wood, steel, and concrete in the San Luis Valley, Colorado. Anyone who has met them knows how special they were and are.*

# Contents

# Introduction—
# A New Look at the Oldest and Most Widely Used Building Material on the Planet

It is estimated that between a third and a half of the world's population—approximately three billion people on six continents—lives in buildings constructed of earth.[1] The typologies of earthen architecture, however, extend beyond buildings for living, and include structures for working and worshiping, as well as the countless forms of earthen architecture that are not inhabited by humans, such as agricultural buildings, city walls, and monuments. In India there are estimated to be as many as 80 million dwellings made of earth, and in China the number of people living in earthen homes is estimated to be 100 million.[2] In France 15 percent of rural buildings are made of rammed earth, and the United States is the leading consumer of mud bricks in the industrialized world.[3] This makes the ground we walk on and cultivate our crops in the most widely used building material on the planet—that's right, dirt. This does not include, nor should be confused with, other materials that come from the ground, such as stone, cement, or metals derived from ore. Earth, by this definition, is simply clay, gravel, sand, silt, or other friable soils, in which organic materials sometimes exist. Because of the ubiquitous availability of appropriate soil, buildings constructed of earth can also be found just about everywhere—in almost every terrestrial biome on the planet.

Earth buildings are commonly perceived to be used only by the poor or found only in "developing" countries, but there are earth buildings of almost every architectural type in use by every economic and social class in both the industrialized and nonindustrialized worlds. Airports, embassies, hospitals, museums, and factories are just a few examples of the variety of earth building types found throughout the world. For example, the Seyoun Airport in Yemen uses concrete columns and beams with mud brick infill walls. Many middle-class and wealthy residents inhabit the vast mud brick suburbs of Santa Fe, New Mexico. Ronald Reagan's Rancho del Cielo, also known as "The Western White House," in California; Saddam Hussein's childhood home in Iraq; the historic home of Paul Revere, also the oldest house in Boston; and Chairman Mao's childhood home in China were all constructed of earth.[4] Several of the buildings housing the minimalist artist Donald Judd's vast and priceless collection at the Judd Foundation in Marfa, Texas, are made of mud brick.[5] Such diversity speaks to the wide spectrum of philosophies, social strata, and cultures represented by this universal material.

Earth is often typically seen as a building material only used in rural environments; however, a wealth of earth architecture can be found in urban environments. Called "the Manhattan of the Desert," the city of Shibam, Yemen, has a population density approaching that of New York City, with thirty-two people per acre, and is home to the world's first skyscrapers: a dense cluster of five hundred tower houses rising up to nine stories high constructed entirely of mud brick.[6] Contrary to the perception of earth as a fragile, ephemeral material, earth buildings also represent the oldest extant buildings on the planet. Using approximately 7,000,000 mud bricks, the Ziggurat at Ur was constructed in 4000 B.C.E. Taos Pueblo in New Mexico, constructed between 1000 and 1450 C.E., is the oldest continuously occupied dwelling in North America, and constructed entirely from raw earth.

There are perhaps twenty different methods of employing earth to construct walls, floors, and roofs of varying dimension and form.[7] The adaptability of the material has allowed it to respond to a wide range of contexts, cultures, and epochs, including the spectrum of architectural history from antiquity to the modern era. *De Architectura*, or *Ten Books on Architecture,* as it is known today, written by the Roman architect Vitruvius, is the only treatise on architecture surviving from classical antiquity, and it continues to be an invaluable reference for architects. The primary qualities he felt architecture should represent were *firmitas, utilitas,* and *venustas*—durability, usefulness, and beauty. Inherently, earthen architecture represents this triad of values, and he wrote extensively on the topic. During Vitruvius's time, Rome was "a warren of winding streets and precarious multistory tenements (6–8 stories high), of mud brick and half-timber with cantilevered wooden balconies."[8] Vitruvius writes of the use of mud brick in the construction of city walls and devotes an entire chapter in Book II to mud brick masonry, describing with great respect the methods for making and stacking mud bricks. He speaks of lightweight waterproof mud bricks made of pumice that once dried are able to float on water.[9] Vitruvius also writes about the mud brick *cellae* of the temples of Jupiter and Hercules and the mud brick residences of Attalid kings

For thousands of years, mud bricks have been shaped by hand and allowed to dry in the sun to create a durable and long-lasting building unit.

and Croesus. He also noted that, "mud brick walls, so long as they are standing upright nothing is deducted from their assessment, but whatever it cost to make them, they will always be assessed at this value. And so in some cities, public works and private homes alike, even royal palaces, are to be seen made of mud brick."[10]

But it is the modern era that is most relevant to this book, and in the eighteenth century the questioning of Vitruvius's work had profound effects on the culture of architecture. The movement away from neoclassicism allowed architects "to establish a more objective basis on which to work," and from this emerged a new way to conceive of architecture at the dawn of modernity.[11] However, the traditions of earth were so embedded in the culture of building that within the modern movement exists a not-so-well-known history of modern architects reconsidering earth as a material in an era more famous for the use of steel, glass, and concrete. *The Four Elements of Architecture*, Gottfried Semper's "epoch-making theoretical departure" from Vitruvius, challenged neoclassical thinking, but still drew from the tradition of building with earth. His "four elements" included roof, hearth, the earthwork, and the lightweight enclosing membrane—the latter two being architectural components based upon load-bearing masonry or piled massive earth, such as mud brick or rammed earth, and the lightweight enclosure membranes being made of wattle and daub.[12]

Furthermore, not only were the traditions of earthen construction being employed at the dawn of the modern movement, it has been suggested that the evolving use of modern materials was directly influenced by traditional earthen construction techniques. For example, the origins of modern concrete can be directly linked to advancements made in *pisé* (rammed earth) in France. Advancements in this humble construction technique, such as developing efficient formwork, experimenting with appropriate aggregate sizes, and adding cement stabilizer, as Jean Baptiste Rondelet had when repairing the château in Ain, were some of the first steps toward the development of modern *béton* (concrete) traditions in France. As Peter Collins points out, "it was inevitable that sooner or later some far-sighted individuals should appreciate the revolutionary possibilities of this method of construction, and seek to extend it by improving on the material used. . . . The first of the pioneers was an ingenious but ambitious building labourer named François Cointeraux."[13]

Cointeraux, a French architect born in 1740, is considered the father of modern earthen architecture. After his "discovery" of *pisé de terre*, the rammed earth architecture of the rural French countryside, he was awarded a gold medal in a competition hosted by the Academy of Picardy for a design that used rammed earth as an inexpensive fireproof construction method. His first "incombustible house," erected in Chorges, in the commune of Hautes-Alpes, in 1786 was well received and considered advantageous for use throughout the European countryside at a time when most houses were constructed of highly flammable timber frame and wattle and daub. The early success of Cointeraux's work subsequently prompted him to devote his entire life to the study and dissemination of earthen architecture. He hoped that the use of rammed earth could contribute to improving life in France, which had suffered from the social, economic, and psychological burdens of several wars, and he believed that it could be a means by which the common man could improve the quality of his own life.[14] He developed a typology of earth architecture encompassing a complete range of housing for the poor and the wealthy in both urban and rural settings, which included four-story town houses, bourgeois country mansions, and designs for public buildings, churches, and factories—many of which were built.[15]

In the same year that Cointeraux completed his incombustible house, the Duke of Bethune-Charost, lieutenant general of Picardy, invited him to experiment with rammed earth construction in Amiens. He was not well received, however, especially by timber and stone merchants and a wide range of craftsmen who feared that if pisé became widely accepted they would lose their livelihood. Master masons and carpenters in Amiens approached the police to complain, and Cointeraux was chased out of the city.[16] His models were then destroyed by the craft guilds who were allied to the wood merchants.[17]

Despite this setback, Cointeraux persisted, and in 1788 he founded a school of rural architecture in Paris. By teaching and publishing fifty works translated into eight languages, including English, over the next three decades, he disseminated his experiments and philosophies in rammed earth. As a result of the publications, knowledge of pisé spread across Europe and to the United States, even catching the attention of President Thomas Jefferson, who visited Cointeraux in Paris to see examples of his work in rammed earth and compressed earth block. During that visit Cointeraux suggested to Jefferson that rammed earth fortifications be used to protect the frontier from attacks by Native Americans.[18] Cointeraux also influenced a new way of thinking about architecture in Europe, and he developed a number of stabilization methods that enabled rammed earth to meet the creative demands of forward-thinking architects such as Claude-Nicolas Ledoux and Étienne-Louis Boullée, whose historical impacts have overshadowed Cointeraux's contribution to architecture.[19] Nevertheless, historians increasingly consider him as a visionary equal to his contemporaries, and Cointeraux's contributions may have been influential on the work of at least one of his peers. Ledoux, best known for his grand utopian ideas, designed a series of more humble proposals for "fireproof buildings" as well as the Cours de Service, a modest farmhouse situated in the French countryside, rendered in rammed earth.

Many other well-known architects continued to experiment with earthen architecture in the nineteenth and twentieth centuries in the wake of Cointeraux's groundbreaking work. Antoni Gaudí, the Catalan architect famous for his unique style within the art nouveau movement, for example, drew from the traditions of rammed earth in Spain and constructed several projects, including the entrance pavilions and stables for the farm of Eusebi Güell in 1884.[20] Edwin Lutyens, the leading twentieth-century British architect, known for his country houses, made designs in earth in response to material and housing shortages as a result of World War I; and Luis Barragán, the most important Mexican architect of the twentieth century, utilized mud brick in his early designs.

But it was in Germany and Austria that earthen architecture was transformed by the zeitgeist of the modern movement. The German architect Hermann Muthesius, founder of the Deutscher Werkbund and influential in the creation of the Bauhaus, was a supporter of earthen architecture. As the chief architect of the Vienna Settlement Office, Adolf Loos, one of the most important architects of the modern period, designed low-cost rammed earth housing in the Heubergsiedlung settlement because of the scarcity of materials after World War I. The economic validity of building wartime housing of earth was also of interest to the German architect of Hitler's Third Reich, Albert Speer, during World War II, but he considered it a means to fuel the war machine by conserving "steel and concrete for the construction of weapons and bunkers."[21]

In the early twentieth century, Austrian-born architect Rudolph Schindler visited the Native American pueblos of New Mexico. He captured the vernacular architecture of the high-desert landscape, with its thick mud walls and protruding roof structures, in a series of sketches he made during his visit. In 1915 he was commissioned to design a country home made of mud brick in Taos, New Mexico, that explored the architectural elements he found in the vernacular. Unfortunately, the design was never realized, and Schindler moved to Los Angeles to work as the project architect for Frank Lloyd Wright on two experimental projects using a masonry system called textile block. Schindler supervised the Hollyhock House, constructed in 1921, and the Ennis-Brown House, constructed in 1924, whose forms are drawn from pre-Columbian indigenous architecture. Architectural historian Reyner Banham writes of the Hollyhock House:

> The back sloping walls of its upper parts have sources much nearer home than Mayan architecture. They look to me like the first visible influence on Wright's work of what was to be his third and truest wilderness: the high desert states and their Indian pueblos. If Wright himself had not yet seen those pueblos in 1920, and the adobe construction that give them their characteristic form, his admirer, assistant, follower and Los Angeles office manager, Rudolph Schindler, certainly had, and had recorded them in drawings.[22]

The material considerations for the Ennis-Brown House are slightly different from those of the Hollyhock House. The textile blocks for the Ennis-Brown House were produced by using soil excavated from the site that was mixed with cement, a decision that may have been based upon Wright's belief that "no house should ever be on a hill or on anything. It should be of the hill. Belonging to it. Hill and house should live together each the happier for the other."[23] However, it is more likely that the decision to use local soil in the manufacture of the textile block was influenced by project architect Schindler's appreciation of earth-building practices in the American Southwest. The blocks that clad the building can be considered a form of stabilized mud brick construction with relief, light, shadow, and the hill itself cast in to the blocks.

Wright went on to design other earth buildings. In 1942 he designed the Lloyd Burlingham House, also known as the Pottery

House, in El Paso, Texas, which was to be constructed of mud bricks and contain exposed beams similar to Schindler's design in Taos twenty-two years before. While Wright's design was not realized in his lifetime, Taliesin Associated Architects Ltd. permitted two versions of the house to be completed posthumously in accordance with Wright's original sketches.[24] Around the same time, one version, the Bendheim House, was constructed in Phoenix, Arizona, and the other, known as the Klotsche-Soiero Residence, was built in 1985 in Santa Fe, New Mexico.

Prior to his experiments in mud brick, Wright was interested in rammed earth. In 1932 he began considering the use of rammed earth in his proposal for Broadacre City, and ten years later he began to test these ideas further in the Cooperative Homesteads project.[25] The project was commissioned by a group of auto and defense plant workers, professionals, and teachers in Madison Heights, Michigan, just fifteen miles north of downtown Detroit, and was designed to house twenty-two families on 120 acres. The design consisted of a two-bedroom low-cost house that could be built by the occupants, with a built-in garden where the cooperative could grow their own food to eat or to supplement their income.[26]

To keep the cost of construction low, Wright decided to use an ingenious combination of rammed earth and earth berms. In fact, the project was to be Wright's smallest commission—the house was estimated to be built for between $1,600 and $4,000.[27] To create a garden, Wright decided to pile the earth that was excavated from the site against the rammed earth walls of the house. The areas where soil was excavated were used as retention ponds for water that was shed from the roof. The berm of soil against the walls provided additional thermal mass to the building, sheltered the building from the wind, and was to be planted with a groundcover of grass and moss. A rammed earth wall created the retaining wall for the berm, and thick rammed earth walls defined the interior spaces. To keep the berm and rammed earth walls dry, a large roof with cantilevered eaves extended over the berms. Construction on the project begin during World War II, and while Wright was able to see the walls constructed, labor shortages left him short of workers to complete the project. When Wright's project architect was drafted by the U.S. Army Air Corps, the project came to a standstill. As winter arrived, the heavy Michigan snows dissolved the unprotected walls and Wright's vision for a rammed earth utopia.

Le Corbusier, one of the most influential architects of the modern movement, shared Wright's frustration with the war. Shortly after it began, Le Corbusier closed his office and began to develop architectural solutions in earth for refugee immigration caused by the escalating war. In 1942 he wrote a small book promoting earthen construction entitled *Les Constructions Murondins*, which outlined methods and techniques for making and constructing rammed earth and compressed earth block for use in a wide range of residential, agricultural, and civic applications. Most of his earth-built designs were for refugee housing. The houses, to be built by occupants themselves, were to have "load bearing walls of concrete block and rammed earth or *pisé* on the site mixed with logs and covered with turf—a kind of prehistoric housing brought up-to-date. A reversal of all the Five Points."[28] Yet the project was not one that looked to the past and, compared to some of the radical thinking that was emerging in technology during the war, "Le Corbusier's Murondin project for installing sophisticated mechanical services in mud-huts showed a greater radicalism of approach," wrote Banham.[29] But his proposals were far more than "mud-huts." Le Corbusier's designs included proposals for temporary farm villages with houses and stables, as well as designs for youth clubs, schools, and dormitories all constructed of earth.[30] After the war, Le Corbusier returned to his ideas of building with earth and in 1947–48 proposed a housing complex in La Sainte-Baume, near Marseille, France, that was to be constructed entirely of rammed earth—an unrealized design closely related to his Unité in Marseille, whose conceptual origins grew from the ideas he developed from his explorations of the Radiant City concept.[31]

Around the same time that Wright and Le Corbusier were experimenting with earth architecture in the context of World War II, a young architect named Hassan Fathy was waging his own battles against an invasion of Western ideologies in architecture by reviving and enhancing the vernacular architecture of Egypt. In opposition to his Beaux-Arts education in a British-run university, he adopted the Nubian art of mud brick dome, wall, and vault construction, which made it possible for an entire building, including the roof, to be constructed out of earth. He also utilized principles of thermodynamics inherent to earth construction to create passive cooling systems at residential and urban scales. In addition, he developed an entire economic philosophy based on mud brick,

opposite, left: Casa Grande was constructed between 1200 and 1450 C.E. by the Native American Hohokam near Phoenix, Arizona.

opposite center: A redwood structure and an iron roof anchored to the ground by cables were constructed in 1903 to protect the ruins of Casa Grande.

training mud brick makers, masons, and vault builders. Probably not since Cointeraux had an architect so ardently advocated the use of earth architecture, and in 1945 Fathy's work caught the attention of the Egyptian Department of Antiquities, which offered him his first major commission—to design an entire city of mud brick.

The new city was to be a relocation settlement for the residents of the city of Gourna, whose livelihood was based partly upon looting the Tombs of the Nobles, which lay directly beneath their city. Unfortunately, the inhabitants of New Gourna had no economic incentives to stay in their new home other than those developed by Fathy involving the construction of the city; and instead they chose to continue looting the ancient graves. Fathy's beautiful mud brick city was soon abandoned. The construction of New Gourna came to a halt in 1948, only one-third complete, but containing a mosque, a school, arcades, a market, and numerous houses. In 1969 Fathy documented his struggles with the construction of New Gourna in his seminal book, *Construire avec le peuple* (Building with the People), a title that was later translated as *Architecture for the Poor* when published in English. The book has become an influential guide to people around the world, as it outlines the process of mud brick construction as a means for anyone to build low-cost housing that is inexpensive, sustainable, and beautiful.

In 1980, Fathy received his first North American commission, to build the Dar al Islam community in Abiquiu, New Mexico, for U.S.-born Muslims.[32] The community was to have a mosque and several houses, but the project faced a series of setbacks that were in opposition to Fathy's ideals. Fathy's work, primarily in Arabia, was based on the architecture of that region. When invited to design a mosque in the American Southwest, he originally wished to explore traditional Navajo building prototypes. Instead, he was "encouraged to transplant the Nubian vault and dome idiom he had adopted in Egypt."[33] Furthermore, to build Fathy's vaults, workers were required to use plywood supports because local building authorities were distrustful of the formless techniques that had been well established by Nubian masons for thousands of years. And although mud brick had been used in New Mexico for centuries, his design had to comply with the strict United States building codes, which required elaborate foundations and a cement plaster skin.[34]

As a result, the mosque was much more expensive than originally anticipated, leaving no budget to construct the individual homes, which were part of the original master plan.[35] Plagued by these setbacks, the construction of the mosque was ultimately a product of all that Fathy fought against through his architecture. Despite the constant struggles he faced in support of earth architecture, Fathy continues to inspire people throughout the world. James Steele, the preeminent authority on Fathy and his work, notes that he is perhaps "the earliest, clearest example of a sustainability-oriented architect we can find. Every sustainable principle you can mention or want to talk about, Fathy wrote about, thought about, built, gave us living examples of. That is why his work is important."[36]

Because of the wealth of historic earthen structures on the planet, not all earthen architecture of the modern period was conceived from the ground up. Architects have also had to interact with preexisting structures, creating interesting tensions between past and present. Perhaps nowhere is the blending of modernity and tradition more evident than at the Casa Grande Ruins National Monument. Casa Grande, a large earthen structure on the historic site, was constructed between 1200 and 1450 C.E. by the Native American Hohokam near Phoenix, Arizona. In 1892 President Benjamin Harrison designated the area a reservation to protect the massive ruin, making it the first prehistoric and cultural site to be established in the United States.[37] The significance of the ancient structure to the history of modern architecture lies in the combination of a historic past and its preservation. Many attempts were made to preserve the ruin, and in 1903 a protective cover—a large galvanized corrugated iron roof with a 6-foot overhang supported by 10-inch-square redwood posts embedded into the ground—was built over the prehistoric earth structure. The entire canopy was then anchored to the ground by cables attached to each

far right: The new roof, completed in 1932, is a singular expression of traditional and modern architecture.

corner.[38] This act radically transformed the perception of the ruin. For centuries it had remained an abandoned, hulking mass representing the power of a past civilization. Wrapped in its new protective cocoon, the historic structure became an introverted and fragile piece of history.

In 1928 the National Park Service announced a competition for a new shelter that would protect the ruin, while falling into the background so as not to take away from its impact. The Park Service suggested that a flat roof on a light steel frame be considered because the steel frame, it was thought, would be "as far a departure from the design and material of the ruin as can be obtained."[39] The winner of the competition was Frederick Law Olmsted Jr., son of the landscape architect most famous for the earthwork of Central Park in New York City, who was acting as an adviser to the Park Service.[40]

Olmsted Jr. sketched a design for a steel hip roof structure with a guy wire system, much like that used on a circus tent, to secure the structure to the ground and protect the roof from uplift due to wind. His design was chosen as the winner, and in 1932 Congress appropriated funds to construct a new shelter over the ruin. Completed on December 12, 1932, the final design was realized with the exception of the guy wires; the hip roof supported by leaning columns was consistent with Olmsted's design, and the tensile roof structure incorporated glass skylights. Angled columns, 46 feet from the ground to the eaves, were painted sage green to harmonize with the mountains and vegetation as well as to provide contrast to the ruin.[41] But the resulting combination of steel, glass, and earth was somewhat counter to the goal of creating a hierarchical relationship, with the ruin taking the foreground. Instead, the liberation of the ruin from the cocoon of preservation resulted in a singular expression and a new type of architecture—one fusing historic and modern building traditions. This hybrid form of architecture, born from the melding of the new and the old, represents the conceptual basis for the content of this book: works of architecture that employ the ancient technology of earth and are informed by the issues that affect contemporary society.

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I based the criteria for selecting the forty-seven projects featured in the book upon several important factors. First, I considered projects completed only after 1970—the year following the publication of Fathy's influential book, which shed new light on Western and non-Western architects' conceptions of earth as a building material. Also, the projects had to utilize an earthen technology that in its traditional form allowed for the finished surface of the interior or exterior to be raw, exposed earth. Throughout the world, vernacular earth building traditions are highly developed, and the level of refinement allows for finished earthen wall surfaces, so occupants have a direct connection to the material. Modern adaptations of these technologies; however, often cover the earthen surface to protect it and create a separation between the soil and the body. I do not consider earth-sheltered buildings relative to this book, because neither the structure nor the finish is necessarily earthen, and retaining walls of concrete, stone, or, more recently, tires, buffer earth from occupant.

The intention of this book is to present a survey of projects that are exemplary of contemporary and progressive earth architecture. Earth-building technologies are the oldest known construction techniques on the planet, but their use does not necessitate a historic style, nor does it reflect a retrogressive technology. Earth construction is highly refined, having been studied and improved upon for thousands of years. While several of the projects may represent a postcolonial position—a reassertion of the material culture of earth in order to break from the colonial factions that dictate the hegemony of industrial materials—none of the projects are influenced by postmodern ideals, borrowing stylistic elements from the past.

In selecting projects for this book I chose only designs that advance the state of earth architecture. Technological, economic, or aesthetic advancements in earthen construction that create a dialogue with industrial materials, or that explore form, texture, color, building techniques, or use earth to represent a political or social concern are present in some way in every project. Finally, all the included projects tackle an important contemporary issue relevant to the culture of earthen architecture. Among these issues are:

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**Industrialism** Earth is one of the few materials on the planet that has not been subject to large-scale industrialization. The heterogeneity of soil has allowed earthen building techniques to be technologically and contextually supple. While many machines have been devised to "advance" the state of the material, earthen architecture remains largely a specialized and traditional practice, unchanged for thousands of years. Yet the advancements of the industrial revolution have brought about technologies that, when appropriately coupled with earth techniques, can result in ingenious hybrid forms of construction.

**Ecology** Earth is an inherently ecological material. Earth has excellent thermal mass properties, which can maintain comfortable interior temperatures without the need for mechanical heating and cooling. The utilization of earth requires little embodied energy and structures made of it are highly recyclable. When abandoned, earthen buildings simply melt back into the ground, and their ruins can be used to grow vegetation or be reused again as a building material.

**Earthquakes** International awareness of the consequences of earthquakes on earth architecture increased in 2003 after a 6.6 earthquake hit the Iranian city of Bam, a UNESCO World Heritage Site made entirely of earth and home to the largest mud brick structure in the world, the Bam Citadel. The earthquake killed an estimated one-third of the population and destroyed 70 percent of the city.[42] While the majority of the buildings in the city had survived in the earthquake-prone region for 500 years and more, earth architecture nevertheless garnered a poor reputation for being dangerous. Thankfully, much research, particularly at the Pontificia Universidad Católica del Perú; the University of Kassel, Germany; and the University of Technology in Sydney, Australia, has advanced the technology of creating earthquake-resistant earth buildings.

**Education** There is an ever-increasing number of schools, organizations, and institutions around the world dedicated to the dissemination of earthen architecture. The construction of earth buildings is an illuminating and fun process, and often builders invite guests to construction sites to teach traditional and advanced techniques. Many international organizations offer courses and workshops on earthen construction, and the University of Grenoble in France offers a master's degree in earthen architecture.[43]

**Prejudices** The perceived hegemony of the industrialized world has for decades been directly responsible for causing an inferiority complex among earth-building cultures. Today, the most common building material on the planet is classified as "alternative" or worse—"primitive." At the dawn of every country's transition to an industrialized society, it makes a concerted effort to abandon its earth-building traditions at the risk of depleting natural resources such as wood; investing in construction projects using expensive industrially produced materials such as concrete, which often perform poorly in developing nations; and losing traditional cultural knowledge. The perception that industrial materials are better is often coupled with a society's embarrassment about its highly developed, contextually responsive, and deeply meaningful traditions.

**Politics** The makeup of soil, which differs from one place to another, makes it difficult to create material standards for earth—an important consideration in the processing and selling of building materials. This does not bode well for earth's role in a capitalist society. Increasingly, it is illegal to build with earth because of building codes that are enforced by municipalities. While these decisions are made in the name of safety, it is more likely that manufacturers of industrialized products have lobbied to prevent the use of a free and versatile material such as earth—similar to Cointeraux's experience centuries ago. In the cases where earth is part of accepted building codes, particularly in the United States, the over-building of bond beams and foundations to allow for the lack of knowledge of traditional methods results in higher building costs. These unnecessary enhancements also often require skilled labor and specialized equipment, keeping earth architecture far out of reach from anyone but the most wealthy.[44]

The issues surrounding the production of earth architecture suggest why many of the proposals by the modern masters were never realized or did not receive much acclaim. Nevertheless, the works of countless architects, builders, and laypeople who have contributed to the evolution of earthen architecture over the past several thousand years have not been in vain. As evidenced by the work in the subsequent four chapters, our planet's oldest building traditions continue to inspire and shelter us despite the complexities of a modern age.

# 1—Rammed Earth

Rammed earth is the man-made equivalent of sedimentary rock. For thousands of years builders throughout the world have compacted soil to create rock-hard structures using only simple tools and manpower, resulting in some of the most beautiful and well-known wonders of the built environment. The Alhambra in Spain, the great kasbahs of Morocco, and long stretches of China's Great Wall, begun in the fifth century B.C.E., are only a few examples of rammed earth's historic global heritage.

Some of the earliest evidence of rammed earth's origins are found in China, where archaeologists have excavated rammed earth walls built by the Longshan Culture of the Late Neolithic period (2600–1900 B.C.E.), between the Stone Age and the Bronze Age—a period that also marks the establishment of cities in China.[1] The technology later spread throughout the Middle East and was introduced to Europe via the Phoenician trading empire, which founded the rammed earth city of Carthage. Roman historian Gaius Plinius Secundus states that the Romans learned the technology from the Carthaginians and continued its dissemination throughout their territories. He also notes the survival of a rammed earth fortification built by Hannibal 250 years earlier and writes about rammed earth walls in Spain.[2] The Romans spread the technology to southern France via the Rhône River valley, where they built the capital city, Gaul, in what is present day Lyon. The substantial legacy of rammed earth country houses and agricultural buildings in the rural areas south of Lyon is still visible today.

Native Americans were practicing the technology before the arrival of Europeans in the Americas. The Pyramid of the Sun, built of 2 million tons of rammed earth faced with stone, located in Teotihuacán, Mexico, was begun in 100 C.E. and rises to an impressive height of 207 feet.[3] European traditions of rammed earth first arrived in the Americas from Spain. The oldest remnant of a European structure in the Americas is the ruin of a rammed earth house in the first formal European settlement, the city of La Isabela in the Dominican Republic, which Christopher Columbus founded on his second voyage to the Americas in 1493.[4] The technology spread with the Spanish conquest into the southern United States and South America. In the mid-nineteenth century, Chinese immigrants, arriving to participate in the California gold rush, brought the technology to the western coast of the United States. A small store built of rammed earth in 1877 by Chinese immigrants can still be found in Dutch Flat, California. While the gold rush was raging in the West, French immigrants arriving in the southern United States were building slave quarters, plantation houses, churches, and schools out of rammed earth. The historic campus of the Southwest School of Art & Craft in San Antonio, Texas, built in 1848, and the Church of the Holy Cross in Sumter, South Carolina, built in 1850, are notable examples of this legacy. While rammed earth was taking hold in the United States, Australians, caught up in gold rush fever, were beginning to establish towns by compacting the soil of the Central Australian desert.

The rammed earth process begins with soil selection. Soil used to make rammed earth must have an appropriate ratio of sand, gravel, and clay to give cohesion, stability, and strength to the wall. Commonly, soil used in the construction of rammed earth buildings is taken directly from the site, moistened, and compacted with little thought as to its precise composition. In regions where rammed earth building has existed for hundreds, if not thousands, of years, appropriate soil is selected by location, visual inspection, smell, feel, and even taste. Traditional builders also found many ways to adapt their material to local conditions by inserting branches, water, blood, or lime to prevent cracking or to increase cohesion and durability. Occasionally, long branches or bamboo are placed in the wall between compaction layers and parallel to the ground, to act as a reinforcement and reduce shrinkage as the wall dries. However, because rammed earth is now being used in places where the tradition has been lost, in places where the tradition never existed, or where it must comply with building codes that demand specific performance values, experts have determined the appropriate amount of silt, sand, gravel, clay, moisture, and stabilizing agent necessary to build structures compatible with the demands of today's rigorous standards. Yet the variability in soil composition makes standardization difficult, and there are many differing opinions regarding the best formula for making a rammed earth structure. The ideal mixture is 15 to 18 percent clay mixed with 23 percent coarse aggregate, 30 percent sand, and 32 percent silt; but because clay provides good cohesion, mixes with up to 30 percent clay are possible.[5]

An aggregate composition of several different-size particles is necessary to increase wall density and strength, and the amount of moisture in the mix is critical for good soil compaction. Appropriate moisture content cause particles to become increasingly dense as the soil is compressed, and moisture levels are good if there is no dust being emitted by the pounding of the earth. But if the soil is too muddy, it will stick to the formwork or the tamping device.

In modern rammed earth construction, portland cement, emulsified asphalt, or hydrated lime is commonly mixed with the soil to increase its compressive strength and water resistance and to reduce the soil's expansion due to ambient moisture or precipitation. Some question these additives, especially the addition of cement, since adding this stabilizing agent in the mixture can be seen as unnecessary, redundant, or producing an admixture that is not rammed earth at all, but rather concrete or soil-cement. In most instances, however, as in the projects in this chapter, the added cement is negligible. While asphalt is known to have been used in earth construction thousands of years ago—Sumerians, for example, set mud bricks in a mortar of bitumen—today its use might raise eyebrows, considering rammed earth's ecological reputation.[6]

The formwork used in the construction of rammed earth structures is designed to resist the outward forces created by the compaction of the soil. It also defines the structure's shape and allows for the creation of windows, doors, or impressions in the earth structure. While traditional formwork may vary slightly around the world, it is generally constructed of wood, is portable, and is typically light enough to be manageable by one or two people. Portable formwork requires a builder to construct only small sections of the wall at a time, moving the form along the length of the wall and lifting it as the wall grows taller. Because this system creates joints between the areas of a completed section and a section in process, ramming is coursed like brickwork, with each subsequent layer overlapping the next, especially at the corners. Tying one section to the previous one may entail quoining the two sections together by ramming earth at an incline to create a lap joint.

In contemporary Western construction practices, the formwork used in rammed earth has become very advanced, primarily through the appropriation of the steel-lined slip forms used in building concrete structures. Like traditional forms, slip forms can be lifted as the wall grows. In some cases, however, many people or specialized equipment and machinery are required to lift and maneuver these forms. In other instances, the formwork that represents the entire finished product is erected at once, and workers compact soil within the completed shuttering.

The advancement of formwork has allowed architects to escape from the rectilinear geometries of traditional rammed earth and use curves and obtuse angles, as seen in the projects by Loco Architects, Reitermann and Sassenroth, and Cox Architects. The process of compacting soil and the plasticity of earth capture the texture and size of the formwork in the wall surface. In Rick Joy's Palmer-Rose House, joints left by the formwork speak to the memory of the rammed earth process. The thin layers of cement found between compaction layers in the Rammed Earth Houses by Jourda & Perraudin Partenaires express the architects' attention to the process of assembling and removing the formwork in the facade.

The ramming process begins by filling a formwork with a small amount of soil and compacting it with a tamping device. Soil is typically added 4 to 8 inches at a time and compressed to 50 percent of its uncompacted height. Traditionally, this was achieved by tamping the earth by hand. Manual tampers constructed of wood or steel with a thick, heavy base are common tools. To compact the earth, the soil is pounded with these tools until the appropriate level of density is achieved. In industrialized construction, pneumatic tampers are more commonly used. These air-powered tools are operated by hand and can compact large volumes of soil at impact levels much greater than human strength can achieve, increasing the durability, longevity, and strength of the wall.[7] In the case of large rammed earth works, gasoline-powered earth tampers are sometimes employed, as long as the machine fits within the formwork.

The labor-intensive process of adding and compacting soil continues until the desired height of the structure is achieved. Depending on how the soil is added, different aesthetic results are possible. Soil compacted incrementally will result in stratification, a subtle detail visible in the walls of the Chapel of Rest by Marte.Marte. The articulation of earthen layers can be further accentuated by adding different colors of soil or by increasing and decreasing the height of the uncompacted layer. The facade of Hotson Bakker Boniface Haden's Nk'Mip Desert Interpretive Centre is an excellent example of this effect taken to its full potential. A more even and homogenous wall surface can be achieved by adding soil continuously while it is being compacted. The walls of Gary Marinko's Margaret River House are richly varied rather than layered, exploiting the warmth created by the material's hue. The size and nature of the aggregate is also a factor in the resulting structure. Erosion by wind, water, and time will reveal the particles of earth, exposing stones or creating a variegated texture, which is expressed beautifully in the Storage Sheds and Chronometry Tower by Roger Boltshauser Architekten and the Chapel of Reconciliation by Reitermann and Sassenroth.

Increasingly, architects are using rammed earth as a modern material that is durable, adaptable, and responds to growing environmental concerns. A reemergence of rammed earth is occurring in France, China, Australia, and Germany, and it is being introduced to areas where it has little or no history, such as Canada and Japan. In other parts of the world, rammed earth has been introduced in environments where other earth-building technologies, such as mud brick, were already common. Arizona, where many earth-building traditions have been practiced for thousands of years, is now home to rammed earth projects of international prominence that display a high level of technical precision and sophistication. As evidenced by the number and variety of projects in this chapter, from housing to religious and cultural buildings, rammed earth has emerged as the most popular earth-building technique in contemporary architecture culture.

ARCHITECTURE FIRM

**Jourda & Perraudin Partenaires**

LOCATION

**l'Isle-d'Abeau, France**

DATE

**1984**

In 1980 the Centre Pompidou in Paris sponsored an exhibition to showcase both traditional and modern earth-construction techniques. The exhibition's success prompted the Centre Pompidou's Industrial Creation Centre to host a competition for the creation of a new town constructed entirely of earth. A partnership was formed between the center and the mayor of L'Isle-d'Abeau, an adjacent town that would incorporate the urban village, and together they established a site for the construction of seventy-two earthen homes in an experimental housing complex called Domaine de la Terre—the Earthen Estates.

The site for the new complex was divided into eleven blocks, each designed by a team of architects. Ten teams of architects and builders, selected in a national design competition aimed at utilizing raw earth technologies, worked directly with technical consultants from the Grenoble-based Center for Research and Application of Earth Architecture (CRATerre) to develop the technological, aesthetic, and environmental objectives of their designs. The final proposals explored an eclectic range of spatial, material, and formal attitudes toward rammed earth construction. While some reflect the traditional vernacular of the region, others challenge tradition by exploring innovative approaches.

Although there are many interesting schemes in the complex, some of the projects employ a postmodern pastiche to reference the traditional earthen architecture of the region. Françoise Jourda and Gilles Perraudin's design, however, demonstrates a uniquely progressive use of rammed earth. The project comprises two semidetached duplex housing units. The three-story apartments contain two bedrooms, a kitchen, two bathrooms, a living area, and a garage. All apartments also have access to the outdoors via balconies, private terraces, greenhouses, and private gardens.

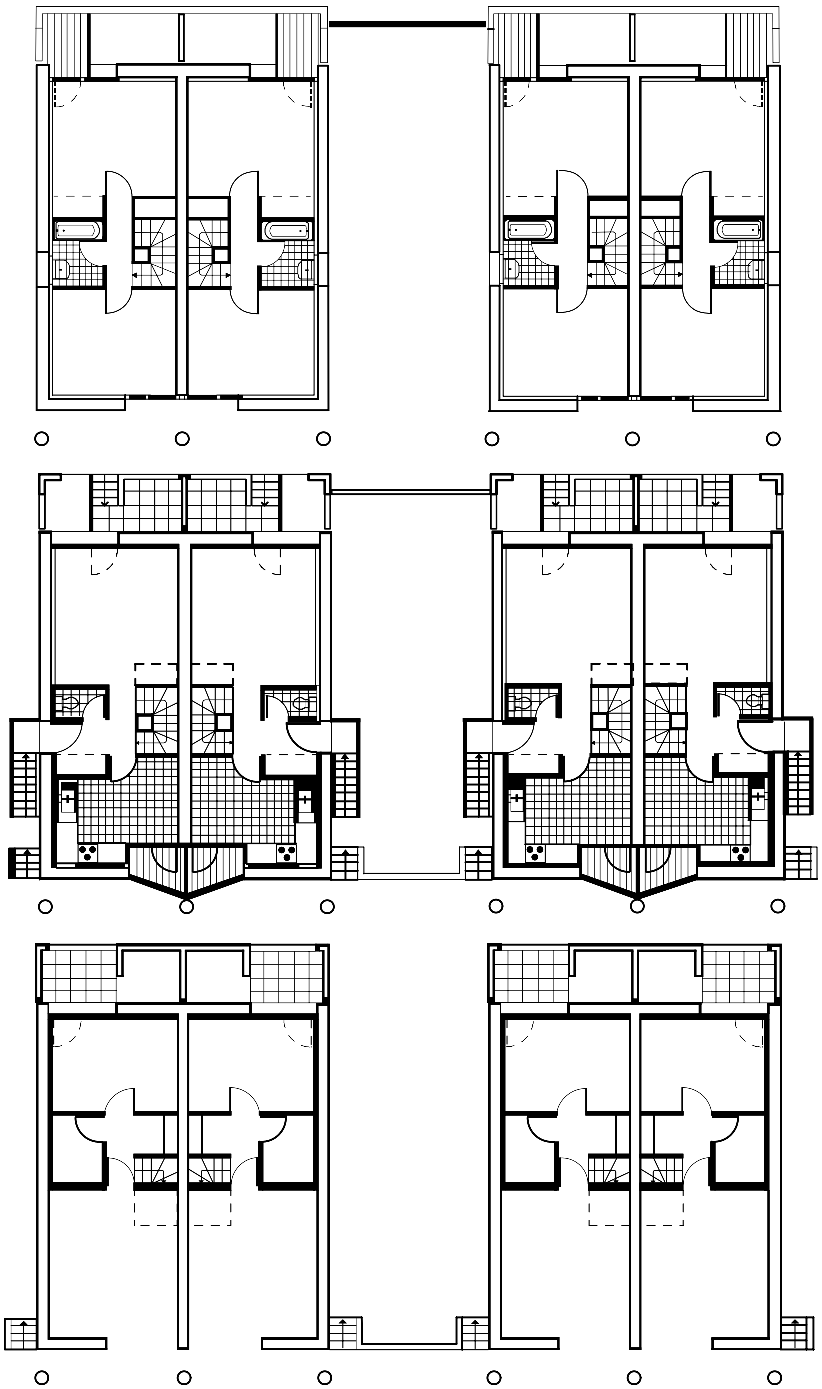
The walls were constructed of stabilized rammed earth compacted in wooden formwork with a pneumatic tamper. In order to articulate the process, the architects laid a thin layer of concrete between each lift of the formwork. This layering of concrete and earth gives an aesthetic rhythm to the facade while providing lateral reinforcement to the tall earthen walls, and the thin horizontal layer also helps prevent erosion of the layers of earth below. Conceptually, framing the traditional material in a modern material is a reflection of the original aims of the Centre Pompidou's exhibition.

The juxtaposition of traditional and modern is also present in the design of the roof. Unlike traditional rammed earth buildings, whose walls carry the load of the roof, here the roof, constructed of translucent polycarbonate supported by a lightweight steel truss, is rendered almost invisible next to the massive walls. To emphasize this condition, the rammed earth walls do not hold up the truss, which is supported instead by concrete columns that stand apart from the walls, creating an eave that protects the earthen walls from rain. The translucent roof also produces a greenhouse effect, and the heat is used to warm the building via ventilators that are controlled by a thermostat. At the rear of the apartments, a concrete-block wall defines private terraces on the first and second floors of the complex, providing a transition between the interior and the private garden.

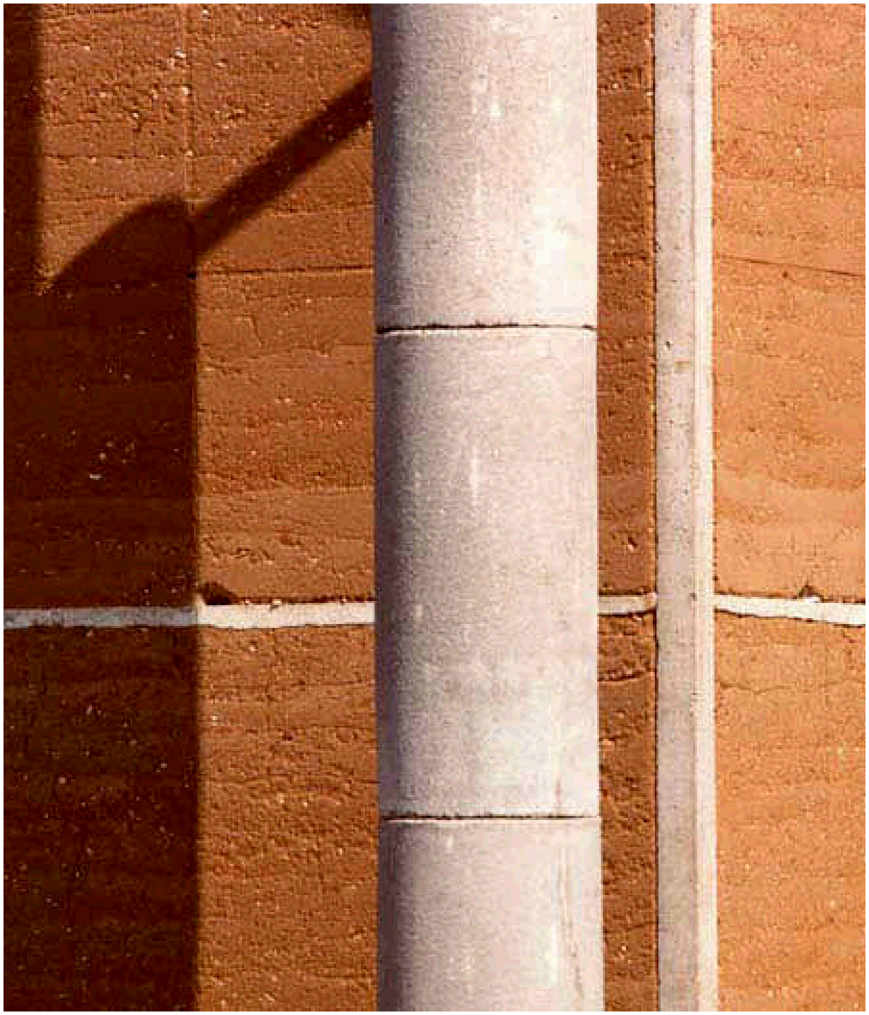
opposite, top: Each pairing of semidetached units contains two three-story rammed earth apartments.

opposite, bottom: In back, each apartment has its own private garden that can be seen from the concrete-block terrace connected to the third-story bedrooms.

# Rammed Earth Houses



top to bottom: Third-floor plan; second-floor plan; first-floor plan



left: Private terraces made of steel and concrete block offer a view of the private garden.

right: The architects articulated the process of lifting the formwork by inserting a thin layer of concrete between each layer of earth.

# Bowali Visitor Information Centre

ARCHITECTURE FIRM
**Glenn Murcutt & Associates and Troppo Architects**
LOCATION
**Kakadu National Park, Northern Territory, Australia**
DATE
**1994**

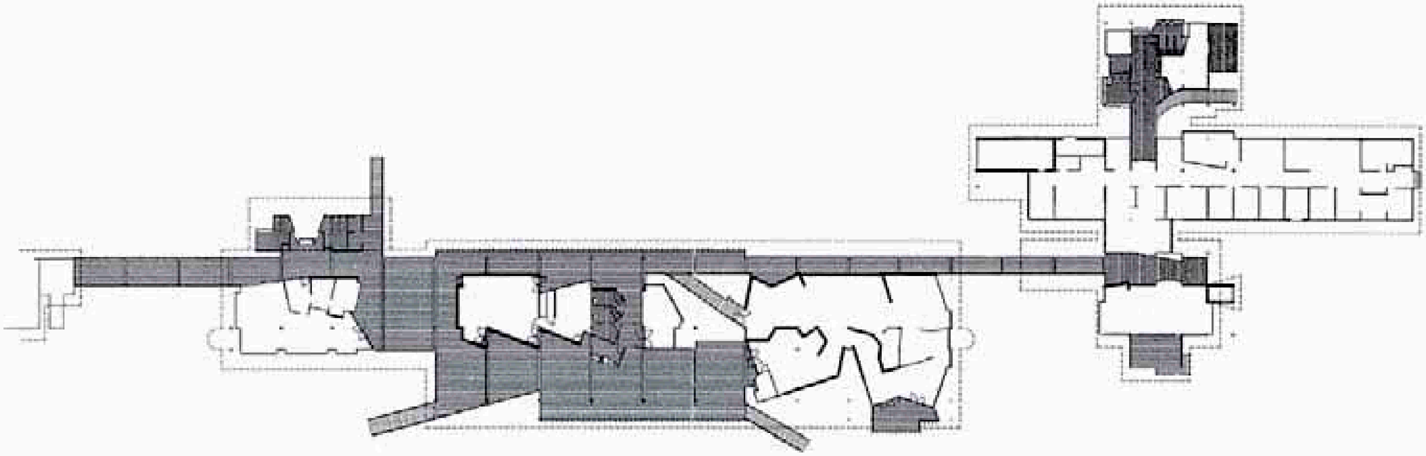
The Kakadu National Park is an enormous wildlife and nature preserve covering almost 7,700 square miles located in Australia's Northern Territory. Vast amounts of land with caves and escarpments—home to crocodiles, wallabies, dingos, goannas, and a myriad of bird species—define this World Heritage Site. In the early 1990s, the park became an increasingly popular destination for tourists: visits to the park were four times as numerous as in previous years, and the number of park staff had increased 33 percent. To accommodate this increased traffic the Australian Nature Conservation Agency and the park's board sponsored a competition for a new visitor center. A team composed of internationally renowned architect Glenn Murcutt and Troppo Architects, whose work has received numerous Royal Institute of Australian Architecture awards for their climate- and context-sensitive work, won the competition. Their submission for the center seemed to grow from the landscape—using natural materials and making formal and spatial references inspired by the culture and experience of visiting the savannah bush site.

The primary inspirations for the Bowali Visitor Information Centre were the caves and escarpments of the Kakadu National Park. Named *Bowali*, after the Mirarr Gundjeihmi clan's name for a nearby creek, the center has a long, reflective roof that becomes an actual creek. During monsoon season, rain collects in the long central gutter and is channeled to spouts, forming waterfalls like those that leap from the park's cliffs and shedding water away from protected spaces beneath the roof that are like the caves found in the cliff walls. As it does in the park, the water then flows to a billabong, or pond, that cools the spaces below the continuous shelter of the roof. It is here in the shade that the entire building program is located. The complex includes an environmental interpretation center, a bird information center, gallery, library, cafe, audio/visual area, park headquarters, and reception area. Each space opens up to shaded outdoor areas that are organized along a long central spine made of rammed earth. The soil used to construct the wall, sourced locally with help from the Aboriginal Djabulukgu Association and the Gagudju people (who are well known for their distinctive rock art painted with clay pigments) has a distinctive red color. This color and the wall's height make it reminiscent of the termite mounds, which sometimes reach up to ten feet in height, that are visible on the approach to the building.

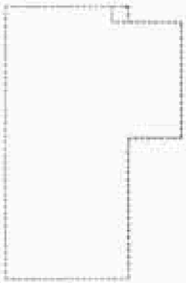
Aboriginal sacred sites are always approached at an angle, and the architects took this into consideration in the design. The oblique pathway to the building also allows one to see the entire length of the building, with the qualities of light and shadow beneath the corrugated metal roof, as it extends into the landscape. The light that filters through transparent corrugated fiberglass and perforated metal, coupled with shadows formed by the vertical slats that conceal parts of the building, create a dynamic experience, similar to that of walking through the bush.

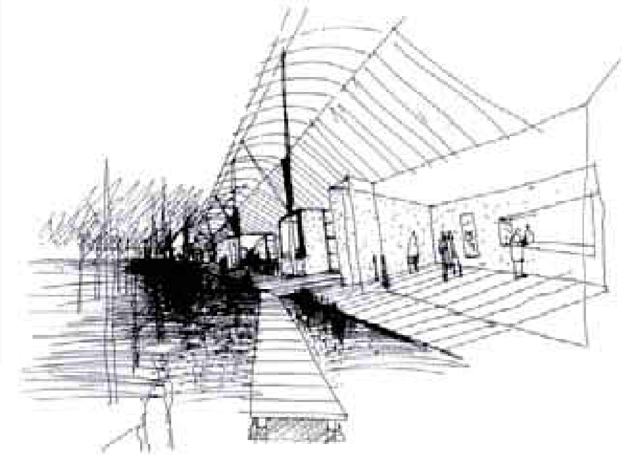
opposite, top: The Bowali Visitors Centre meanders through the bush like the creek after which it is named.

opposite, bottom: Walking along the continuous wooden deck that connects all the Centre's facilities is like a trek through the bush.

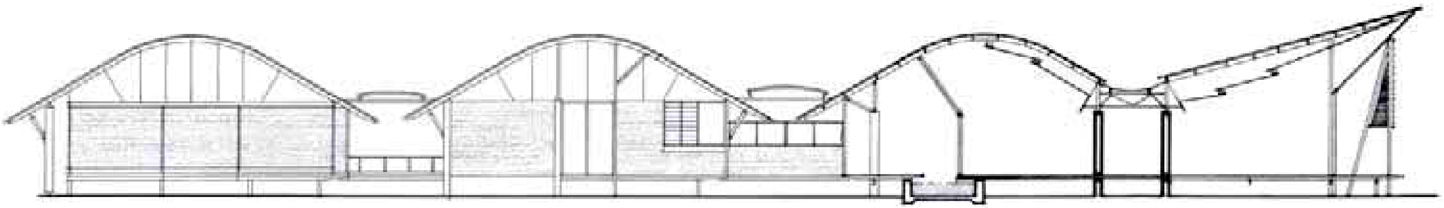


Floor plan





Early sketch illustrating the airy roof canopy over the continuous wood deck



Section

top: Vegetation, ponds, and shade make the center a continuous part of the landscape.

bottom left: Long gutters channel water and create waterfalls during the monsoon season.

bottom right: Termite mounds, tree trunks, the canopy, and water are all embodied in the building's forms and materials.

ARCHITECTURE FIRM

**Jones Studio**

LOCATION

**Scottsdale, Arizona**

DATE

**1997**

Called "The Dirt House" by neighbors, the Low Compound is a single-family private residence whose functions are housed in several buildings, making the 7,800 feet of space feel more intimate. The scheme comprises a garage, guesthouse, main wing, bedroom wing, and study; each part has its own identity and is situated within the ten-acre parcel of land so that the large footprint does not overwhelm the site. Every component of the compound respects the natural drainage patterns of the site, and they are clustered together, unobtrusive and somewhat hidden by the surrounding paloverde trees and saguaro cacti. A rich palette of materials that reference the landscape also helps situate the building within its context. Although it is easy to imagine that a large, sheltered compound tucked into the landscape would be an introverted, enclosed environment, the interiors of the Low residence are bathed with light, and the cluster of buildings creates surprising outdoor spaces that connect the occupants to the virtually untouched desert landscape.

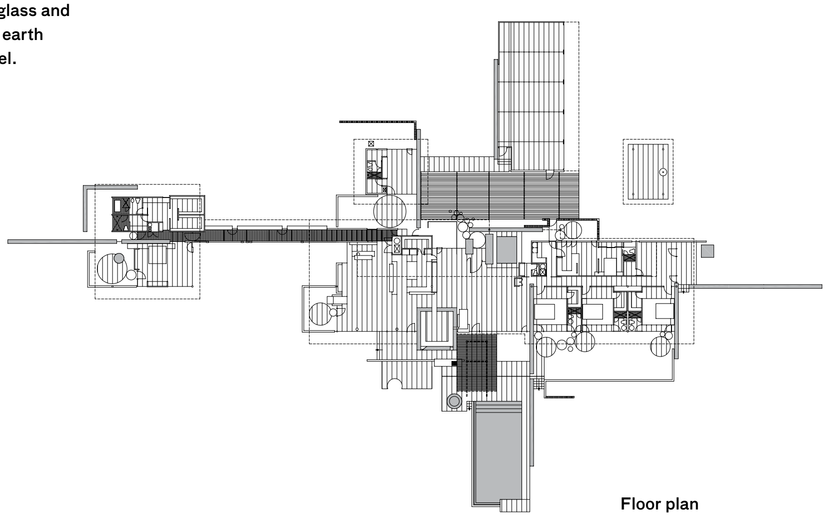
The rammed earth walls—18 to 24 inches thick—were constructed from soil taken directly from the site and mixed with 5 percent portland cement. This admixture was loaded in 8-inch layers into formwork typically used in the construction of concrete walls and was compacted to 6 inches using hand-held pneumatic tampers. Both interior and exterior walls expose the countless layers of compacted soil, but the interior walls are coated with a clear sealer to prevent small particles of the rammed earth surface from dislodging. The study, the only room where rammed earth walls completely enclose a space on all four sides, is constructed as a free-standing object between the family and living rooms. Its walls are punctured with small, deep-set panes of colored glass, giving the space the quality of a small chapel.

Both the family room and the living room have long transparent walls that open up the interior to light and views to the south. Through triangular clerestory windows at the east and west gable ends of the building, indirect light enters the house, except during the morning and evening hours when the interior is bathed in direct desert mountain sunlight. Light transcends the spatial boundaries of the interior divisions through clear glass panels above the rammed earth walls that separate the living room from the guest bedrooms. A slit in the roof spanning almost the entire length of the main building is perhaps the subtlest means by which light enters the building. Light from this long, narrow opening is reflected off the metal leaf panels, canted to illuminate the interior with diffuse light; and the fir ceiling oriented along the lengthwise axis of the building reinforces the incision. Sandblasted glass, coupled with galvanized and oxidized metals, the polished concrete floor, and a large reflecting pool add further to the diffusion, reflection, and buffering of light that occurs within the house.

opposite, top: Adjacent to a massive rammed earth wall, the pool helps cool the air around the house.

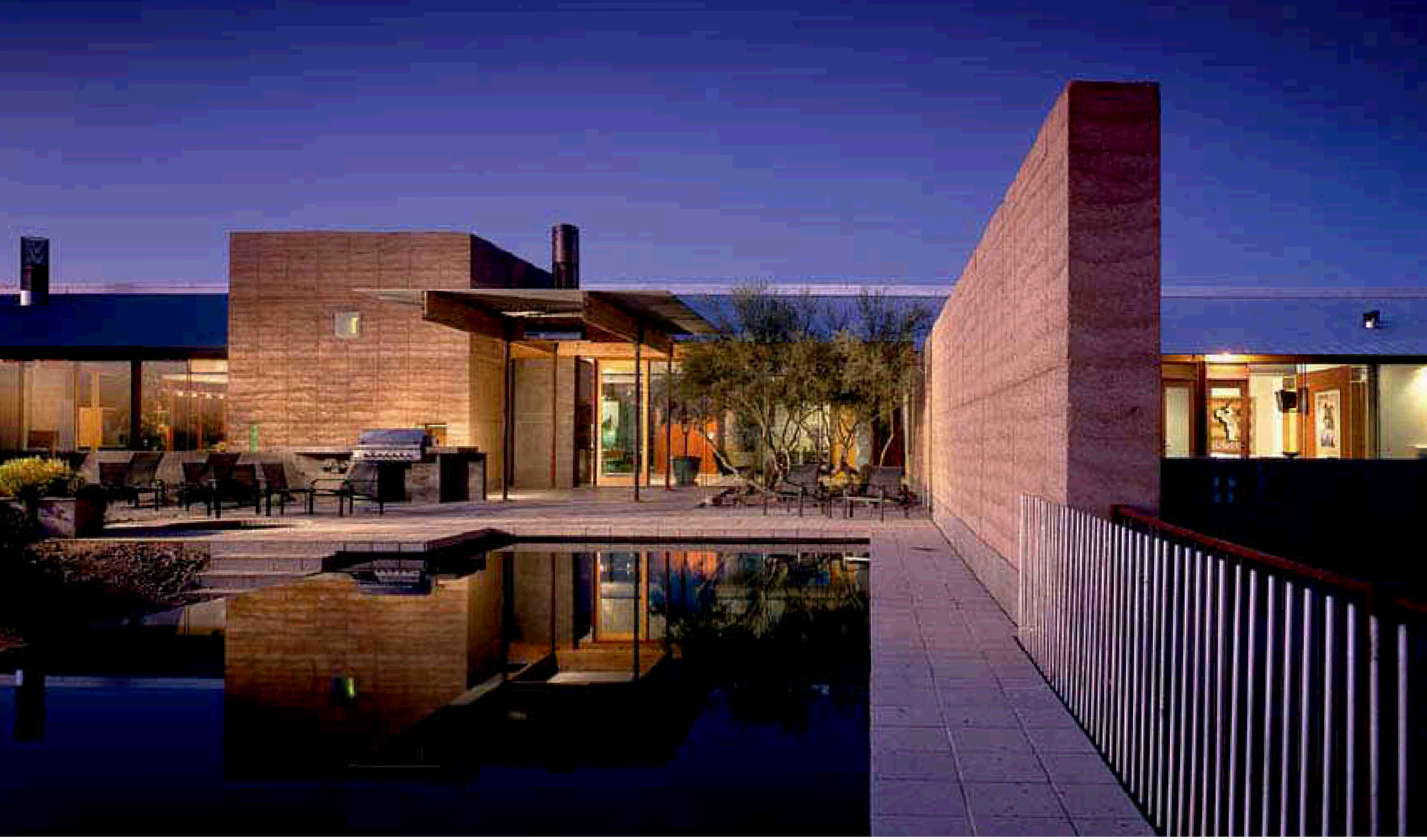
opposite, bottom left: Fir, metal leaf, polished concrete, rammed earth, and acid-etched glass make up the rich material palette.

opposite, bottom right: Colored glass and small openings give the rammed earth study the quality of a small chapel.



Floor plan

# Low Compound



ARCHITECTURE FIRM

**Kerry Hill Architects**

LOCATION

**Prevelly, Western Australia**

DATE

**1998**

Situated on a sloping site in the semirural landscape of Prevelly amid vineyards, rolling hills, the wind and surf of the Indian Ocean, and the vast landscape of the Leeuwin-Naturaliste National Park, a small house asserts itself among these varied environments by responding to the particulars of each one. Called the Ooi House, the three-bedroom, 3,400-square-foot vacation retreat is divided into two zones—a more public living space that exposes one to the qualities of the natural environment and a private sleeping area that is sheltered and protected.

The living area is the most prominent part of the house. It is composed of a thin metal roof and elevated platform supported by a lightweight steel frame and enclosed by glass, which joins the living spaces with the landscape. Because the two outdoor decks at each end of this hovering transparent box and its interior spaces use tallowwood flooring, which is naturally resistant to the elements, there is a seamless visual connection between the interior and exterior. The kitchen, dining, and living areas have an unsurpassed view of the national park and take full advantage of the warmth of the winter sun. Reinforcing the relationship between inside and outside, the entire space is adjacent to an outdoor courtyard separated from the interior only by glass walls. This outdoor room contains a reflecting pool and is enclosed on one side by a massive stabilized rammed earth wall that anchors the living spaces to the hillside and alludes to the more protected component of the house that contains the sheltered bedroom spaces behind.

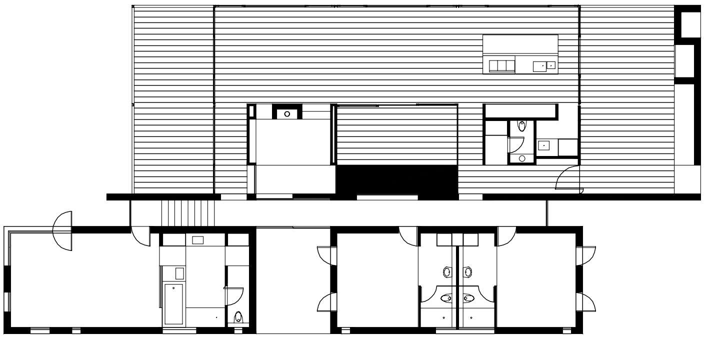
The sleeping area is designed to provide protection from the elements, particularly the cold southwesterly winds, and to give a sense of quiet enclosure to the master bedroom and two guest rooms housed within this zone. Unlike the living area, which is primarily defined by steel and glass, here meticulously detailed rammed earth walls and tallowwood siding create a zone of warmth and comfort. Only small openings penetrate this protected space, defined by wood brise-soleil screens. In contrast with the exposed glass-enclosed courtyard in the living area, a small earth-sheltered courtyard provides privacy for the guest bedroom.

opposite, top: The open views toward the front and dense forest at the rear make up the *parti* of the Ooi House.

opposite, center left: Tallowood floors extend past glass walls to outdoor spaces, blurring the inside and outside.

opposite, center right: Meticulously detailed rammed earth walls, tallowood siding, and bris-soleil screens enclose the sleeping zone.

opposite, bottom: A glass wall separates the living space from an exterior courtyard that segues between the two zones of the house.



Floor plan

# Ooi House




# Palmer-Rose House

ARCHITECTURE FIRM

**Rick Joy Architects**

LOCATION

**Tucson, Arizona**

DATE

**1998**

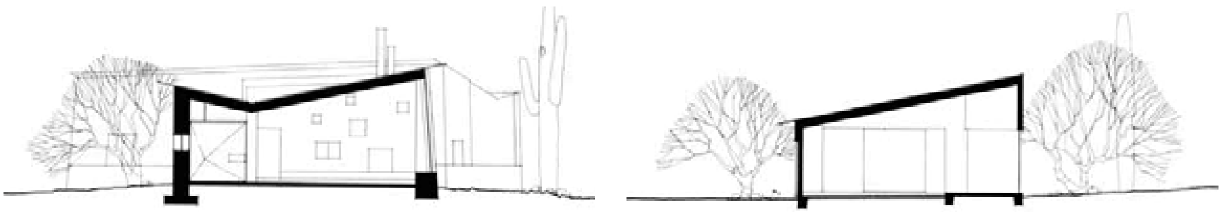
Good desert architecture often blends seamlessly with its context while possessing expressive and responsive form. For example, the ruins at Mesa Verde in Colorado can be seen as a series of individual structures and as a seamless extension of the cliff itself. Taos Pueblo in New Mexico, well known for its multistory earthen building rising from the landscape, blends seamlessly with the surroundings because of its materiality, while shade and shadow articulate the building's massing. The influence of these buildings on Tucson architect Rick Joy's work is evident in the Palmer-Rose House, which blends with and is almost hidden in the landscape while simultaneously leaping forward from its desert environment—a dynamic expression of architectural form. These qualities of the house make it particularly exemplary as a modern building, but the contrasting relationships between interior and exterior, exquisite details, its contextual responsiveness, and the juxtaposition of modern and traditional materials result in an architectural tour de force.

The house is situated on a 4-acre site surrounded by native vegetation at the edge of a large arroyo. As a response to the native vegetation and the grandeur of the nearby 7,000-foot-tall Santa Catalina Mountains, the architect nestled the house 25 feet below the elevation of the road, allowing the house to maintain a low profile, and carefully sited it so that no trees or cacti were destroyed in the construction process. The combination of these two factors makes the house almost completely hidden from view.

The 2,800-square-foot private residence comprises two rectangular rammed earth volumes that define the public and private spaces. The two segments join at a point, creating a hinge that emphasizes the main entrance to the house. From here the more public section of the house is revealed, which contains an open living room connected to the kitchen and adjacent prep kitchen. The space, shaped by an inverted gable roof, gestures towards a panoramic view of the Santa Catalina Mountains only a few miles away, framed by a floor-to-ceiling wall of structural glass along the entire north facade. The interior also extends outdoors to a 500-square-foot covered patio enclosed by rammed earth walls; a fireplace is embedded in one of them.

The more private wing of the house, which houses the bedroom, study, bathrooms, and storage, is slightly askew to the living wing, aligned with the morning sun to bring eastern light into the bedroom. Like the living room, the bedroom opens up to views through an uninterrupted structural glass wall. This glass wall system is a two-layer system custom-designed specifically for the harsh desert environment. On the exterior, the 1-inch-thick insulated glass has a tinted coating to reflect direct and indirect sunlight; and on the interior, ¼-inch clear tempered low-emissivity glass controls heat transfer.

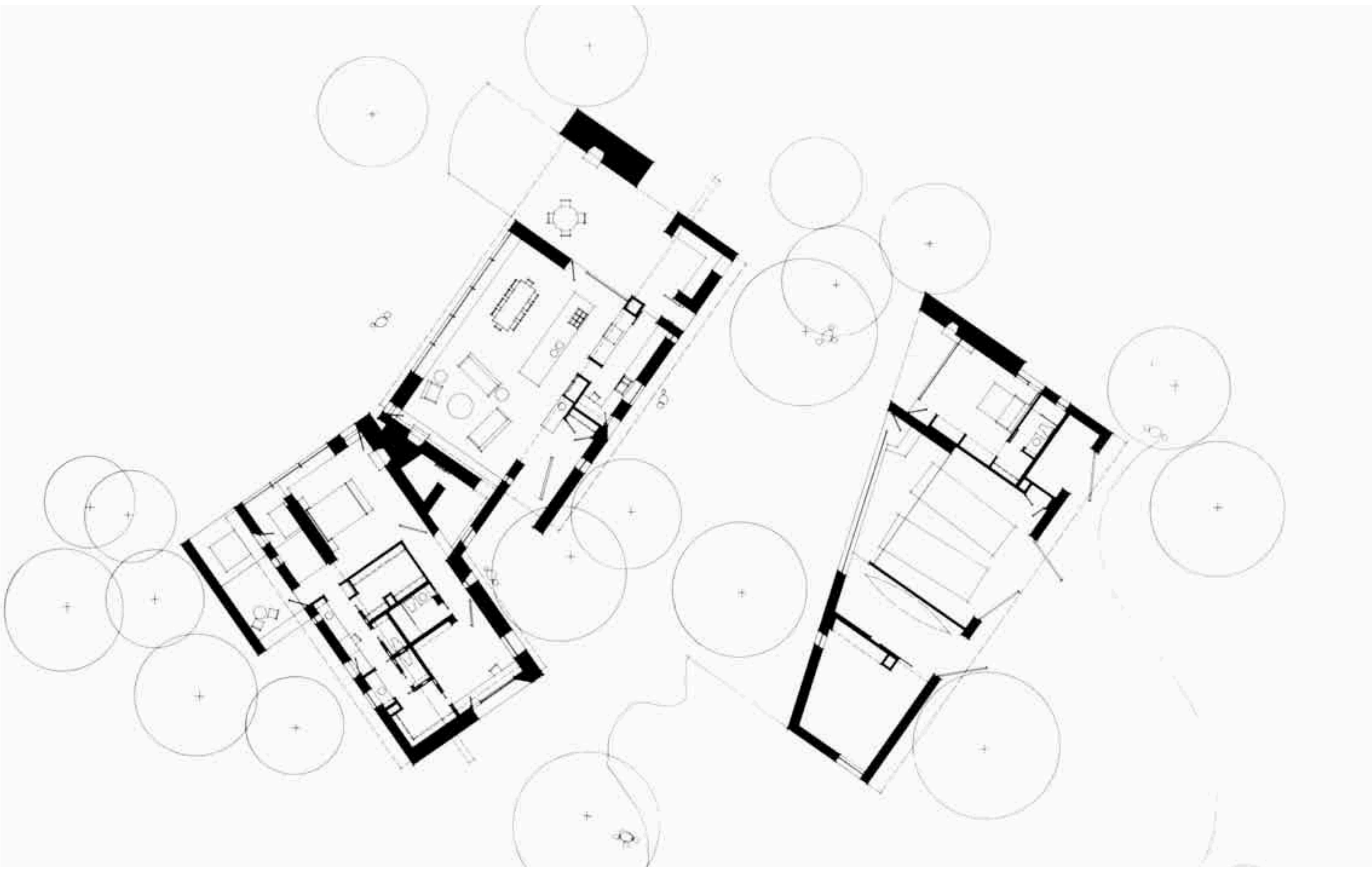
opposite: Large expanses of tinted insulated glass buffer direct sunlight and keep out heat.



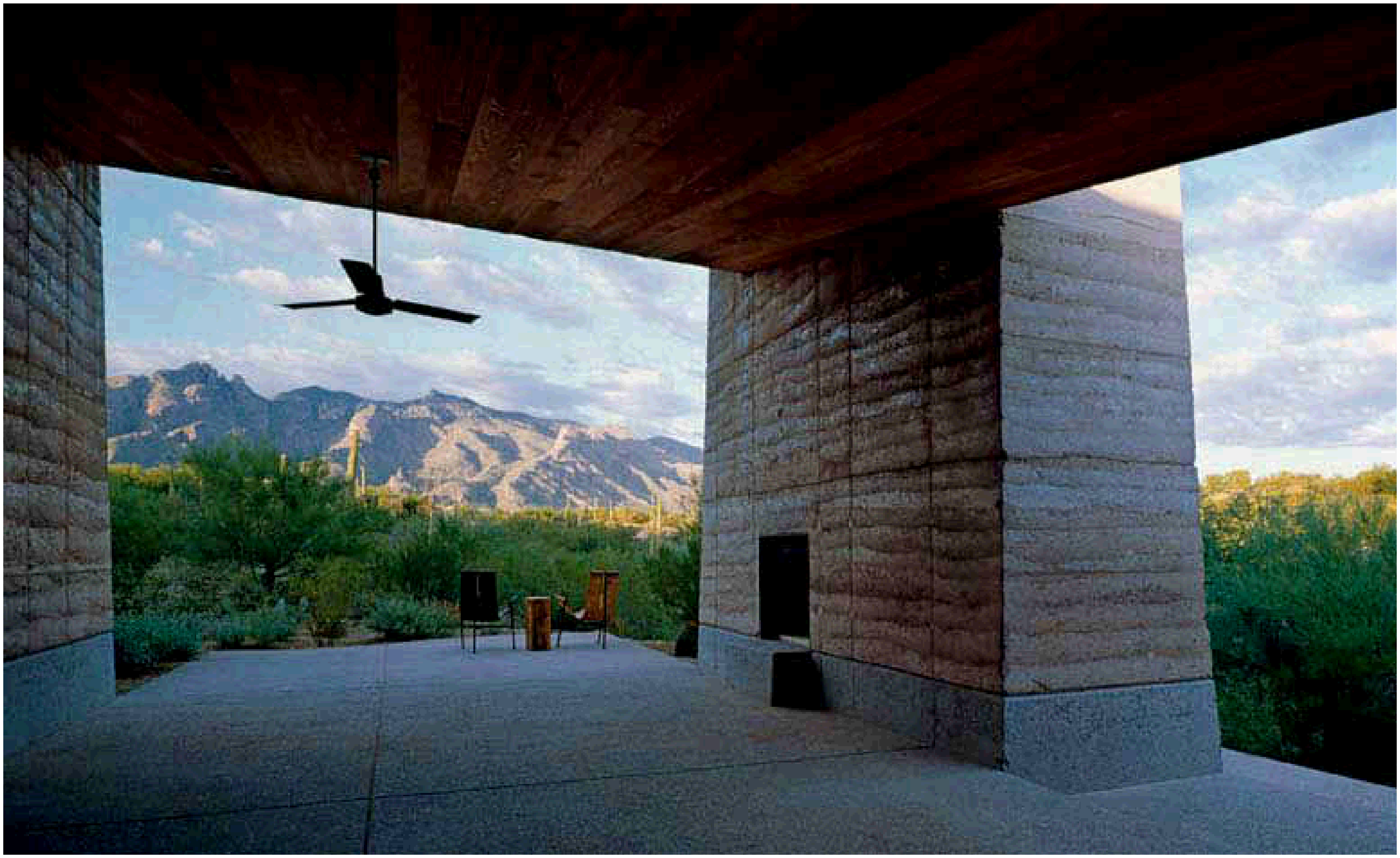
Sections

In contrast to the delicate, almost invisible quality of the glass, the rammed earth walls are massive elements that shield the rooms from the psychological and physical effects of the desert sun. So massive are the walls that their weight, including the foundation, is estimated to be 500 tons. Three different local soils were used in the rammed earth mixture, each with different amounts of clay, sand, and gravel, and mixed with portland cement and the pigment iron oxide to achieve the desired erosion resistance, structural integrity, and color. The soil was compacted atop a reinforced concrete foundation in reusable formwork that imparted the memory of the individual panels and the layering process in the wall. Quarter-inch-thick plate steel welded to steel tubing and gusset plates was used to create lintels for doors, windows, and niches in the thick walls, giving the effect of clean and precise incisions into the earth. To help lower the temperature of the walls during periods of extreme heat, an evaporative cooling system blows humid air over them, preventing heat gain and further cooling the interior of the house.

In strategic locations, structural steel columns embedded in the rammed earth walls support long spanning steel beams that comprise the inverted roof. Consistent with Joy's desire to contrast the heavy earth with other materials used in the house, the rusting corrugated metal roof reads as thin, structureless leaves floating above the earthen walls, extending at times up to 4 feet beyond the top of the wall. Not only does this create a dynamic relationship between the ground and the sky, it is also a necessary condition to protect the battered earthen walls. The shape of the roofline drains the water toward a single gutter that cantilevers far past the house to create a waterfall announcing the desert rain during the rainy season.



Site plan



top left: A skylight washes down the rammed earth wall, revealing the texture and layers left by the formwork that are part of the process of construction.

top right: The house, carefully sited so that no trees or cacti were destroyed in the construction process, is surrounded by native flora at the edge of a large arroyo.

bottom: A fireplace is embedded into one of the massive rammed earth walls that enclose the outdoor terrace and frame views of the Santa Catalina Mountains.

# Poll House, Margaret River

ARCHITECTURE FIRM

**Gary Marinko Architects**

LOCATION

**Perth, Western Australia, Australia**

DATE

**1998**

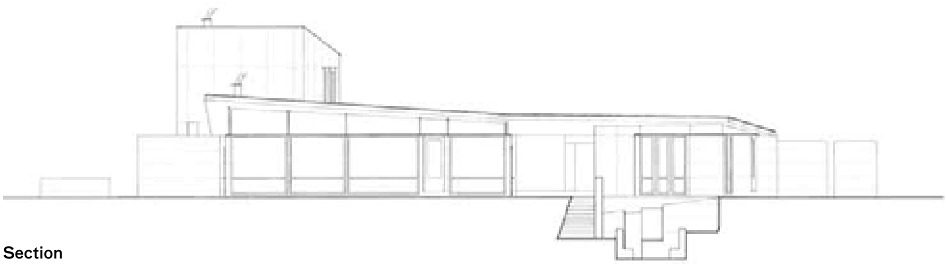
The Margaret River wine-growing region of Western Australia is known for its beaches, vineyards, farmland, and forests. Home to the Leeuwin-Naturaliste National Park, which stretches for 75 miles along the hilly coast of the Indian Ocean, the landscape is filled with tall trees whose canopies dissolve into patterns of light. Gary Marinko Architects took advantage of this unique landscape, creating a house defined by terraces and walls that grow from the soil and weave through the dense tree-stands, guiding the eye from spaces shaped by earth, wood, and light toward breath-taking views.

The house comprises a series of paved terraces, enclosed exterior areas, and retaining walls that define spaces with various qualities of light, scale, and material on the sloped site. The south courtyard, an outdoor room located at the rear of the house, is the first space that visitors enter when they arrive at the complex. This textural outdoor space is paved with river rocks and stone and is surrounded on all sides by the main house, guesthouse, carport, and a retaining wall. The marri tree canopy 197 feet overhead creates a natural ceiling above the tall perimeter walls. From this courtyard, the entry to the house is perpendicular to a long stabilized and reinforced rammed earth wall that creates a datum along which the entrance, bathrooms, bedrooms, and storage are organized, each space separated by earthen walls. The cement-stabilized walls contain a unique mixture of soils that differs from the typical use of Australian red earth for rammed earth in the region. Limestone, yellow sand, and white cement give the walls a bright, reflective color. Finely crushed granite added to this mix makes the wall sparkle in the sunlight. Inside each room plywood furniture unfolds from the walls, reminiscent of the retaining walls and courtyards that seem to unfold from the landscape outside. A continuous skylight along the length of the corrugated metal roof illuminates these spaces with diffuse light softened by the tree canopy. A secondary earthen wall perpendicular to the long exterior wall, punctured with openings for light and views, separates the more private spaces of the house from the main living room and kitchen.

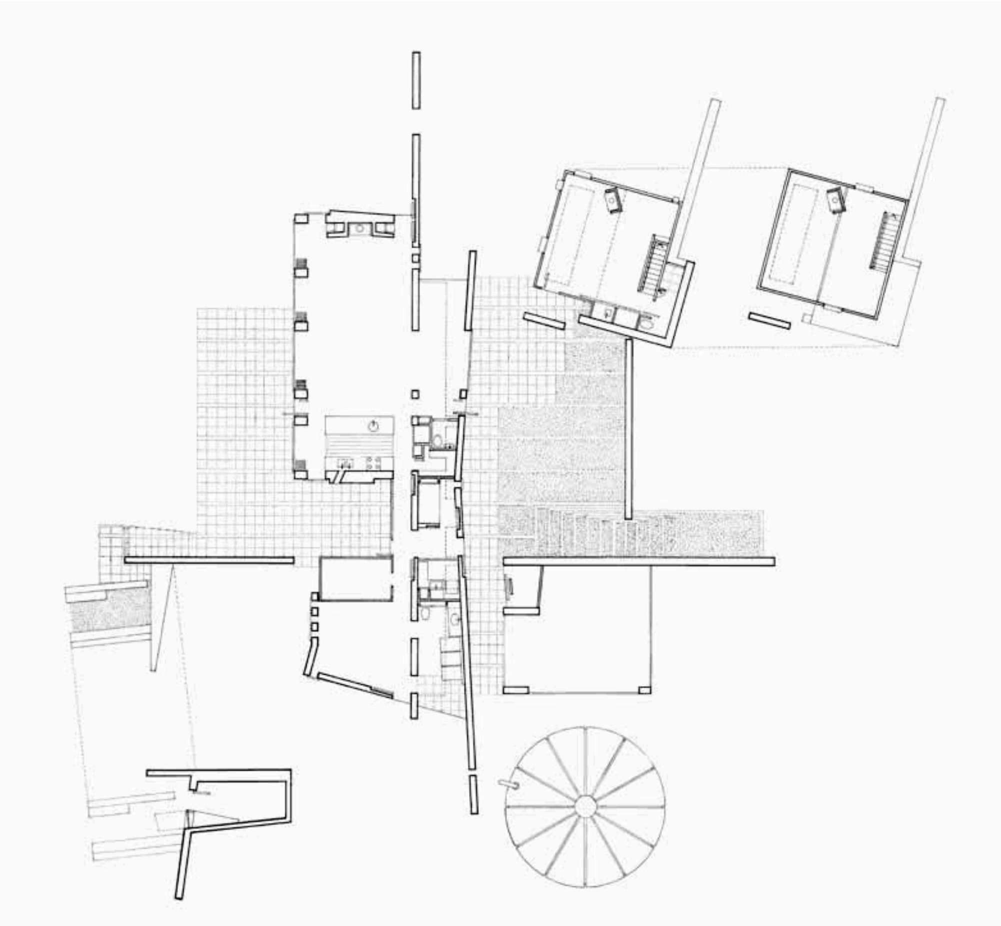
The living room is more akin to an interior courtyard with a concrete floor and a plywood ceiling, enclosed on three sides by earthen walls. A kitchen and a massive earthen fire-place flank each end of the room, and the north-facing wall is defined by a rhythm of earthen columns. Like the plywood furniture found elsewhere in the house, the entire wall can be opened or closed with folding shutters that allow residents to moderate the amount and quality of light that enters the room. When open, the space expands past a sundeck toward framed views of the Boodjidup Brook at the base of the site and the distant untouched landscape beyond.

opposite, top: Rammed earth walls of varying heights climb the hillside to define outdoor and indoor spaces.

opposite, bottom: The entire north wall can be opened or closed with folding plywood shutters that moderate the amount and quality of light and heat entering the space.



Section



Floor plan

Section

top: With its expansive glass walls, the living room is like an indoor courtyard with a large fireplace at one end.

bottom: Wood furniture and partitions complement the rammed earth walls and separate the more private spaces of the house.

ARCHITECTURE FIRM
**Marci Webster-Mannison**
LOCATION
**Thurgoona, New South Wales, Australia**
DATE
**1996–2003**

In 1996, the faculty and staff of the Thurgoona Campus of Charles Sturt University in New South Wales, Australia, set out to create a new kind of university environment—one that employs some of the most innovative ecological strategies ever used in campus architecture and planning. This new university branch was built near the city of Albury on a 215-acre site that had suffered generations of land clearing and farming, resulting in poor soils, erosion, and invasive vegetation growth. The hot, dry summers, freezing winters, and fragile site demanded additional consideration as the scheme was developed. Marci Webster-Mannison, the Campus Director of Design at the time, led a design team that brought together traditional and up-to-date technologies through careful planning, architecture, and landscape design to create a series of award-winning structures. Ranging from housing to research facilities, they are some of the most environmentally sensitive public buildings in Australia today. The combination of rammed earth and advanced computer-controlled environmental systems that engage both passive and active technologies had never been used before in a university environment. Even more unique, most buildings on the Thurgoona Campus were designed and constructed by the CSU staff.

The master plan for the campus took into account many important considerations, including the local context, the condition of the site, and the potential to harness wind, sun, and rain. All of the buildings employ a similar set of ecological systems and use ecological materials. Rainwater from the roof collects in steel tanks and is circulated into an array of solar collector panels mounted on the roof, where it is heated with the sun's energy. This water is stored in insulated tanks where the temperature can be increased by a gas boiler; it can then be used for domestic purposes or circulated via a computer-controlled system through a radiant heating system within the concrete floors during the cooler months.

The same roof-mounted panels that heat water also perform the opposite task, taking advantage of the cool night air during the temperate seasons. An ingenious air-conditioning system is created by circulating this water, using solar-powered pumps, to an evaporative cooling system where a mist spray waterfall located in the air circulation system substantially lowers the air temperature by increasing its humidity. Storm- and gray water from the buildings is treated in man-made wetlands that are part of the campus's landscaping. Because the recycled water is ultimately cleaner than the local drinking water and all of the buildings use dry-compost toilets, the campus is not connected to the main sewer system, and all water is eventually cycled into retaining ponds, promoting the natural ecology of the site.

All of the buildings on the campus are sited to take advantage of seasonal and daily solar conditions by allowing the sun's warmth to penetrate the building during the colder months and reducing heat gain from the rising and setting sun in the warm season. South-facing clerestory windows admit light to the buildings' interiors, and in the winter, the warmth of direct sunlight enters through north-facing windows and is collected in the concrete floors and the unstabilized rammed earth walls used throughout the campus. The thermal mass provided by the 12- to 24-inch-thick rammed earth walls also helps maintain comfortable temperatures within the buildings. Natural wool insulates secondary

opposite, top: The teaching wing of the C. D. Blake Theatre Complex is defined by galvanized metal water tanks, solar collector panels, and rammed earth.

opposite, bottom: Technologies replace architectural motifs: a solar collector panel articulates the entrance to the auditorium.

# Thurgoona Campus of Charles Sturt University


walls and roofs, which are also clad with corrugated steel to reflect the sun's rays. Thermal chimneys that punctuate the roofline help keep temperatures comfortable by drawing hot air out of the building. Large eaves and sun shading devices are also common features; they protect the buildings from the high angle of the summer sun while allowing for the penetration of low winter sun.

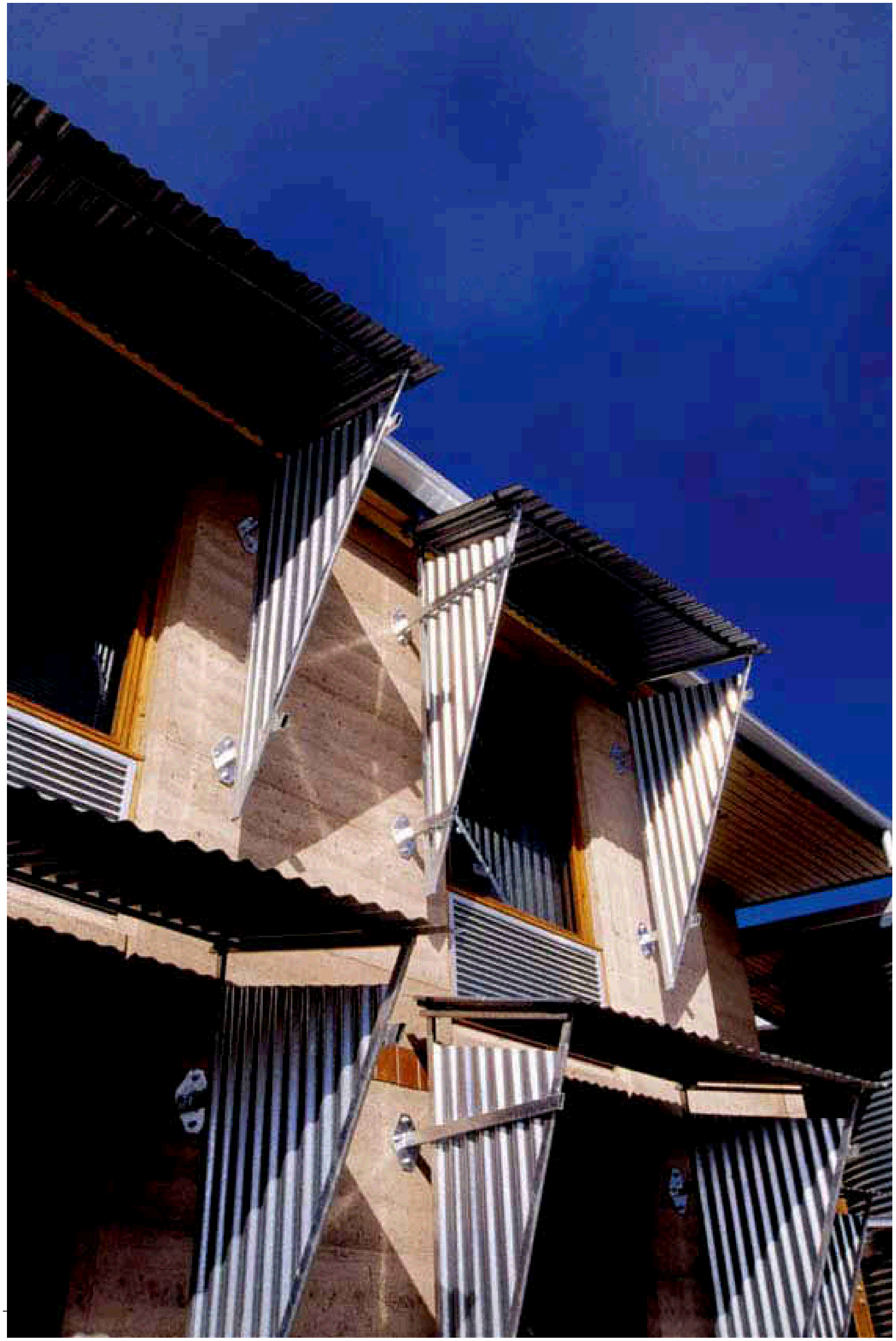
The first building constructed using these principles was a student pavilion, completed in 1996. In addition to demonstrating the ideals set forth by the campus staff, it laid the groundwork for the series of ambitious buildings that was to come next. Next built was the School of Environmental and Information Sciences. With two stories and 31,958 square feet of space, it accommodates one hundred staff members and postgraduate students, a Mapping and Teaching Room, an Information Technology Hub, and a Herbarium, which contains living examples of regional fauna. Because of the use of alternative materials, the cost of the building is estimated to be between 4 and 14 percent less than a conventional structure of this type.

The C. D. Blake Theatre Complex was completed next. Its program includes a two-story teaching complex that contains two thirty-seat tutorial rooms and two theaters—one that accommodates one hundred occupants and a larger two-hundred-seat lecture theater that has an earth-covered roof to help maintain the thermal quality of the space. The expanding university's next project was a series of rammed earth student cottages named the Rothwells. Between 2000 and 2002, six buildings accommodating forty-six beds with laundry facilities were constructed; and in 2003, another rammed earth building, the Student Association, the center for students living and working on the campus, was completed.

Plans for additional buildings following the ecological concepts set forth by the campus's first buildings are ongoing, and the projects have had an influence that has extended beyond its grounds. The success of Thurgoona has also prompted other local groups, including a church and a local college, to construct their new buildings in rammed earth.

left: Thermal chimneys, which draw out rising hot air, punctuate the roofline of the School of Environmental and Information Sciences.

right: Clerestory windows admit light into the auditorium foyer.



Corrugated metal sun-shading devices around the windows protect the interior from the high angle of the summer sun but allow the low winter sun to penetrate.

ARCHITECTURE FIRM

**Reitermann and Sassenroth**

LOCATION

**Berlin, Germany**

DATE

**2000**

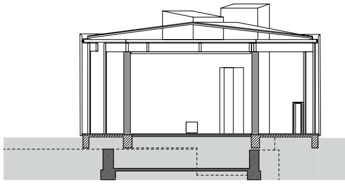
In 1985 the Church of Reconciliation was destroyed by German Democratic Republic (GDR) border troops. The historic neo-Gothic Evangelical brick church, consecrated on August 28, 1894, had an unfortunate location. With the swift construction of the Berlin wall in 1961, the church, located in the prohibited no-man's-land between East and West Berlin, was closed off from the city literally overnight. Caught within this zone, the building remained inaccessible to anyone for more than twenty years. Because of its awkward position in what was called the "death strip," the building created a problem for the GDR, who patrolled the wall to prevent any crossing to the west: the long detour around the church made patrol routes difficult, and the steeple was an obstruction to their line of fire. Subsequently, in January 1985 the GDR razed the nave and steeple using explosives. The images of the destruction were televised internationally.

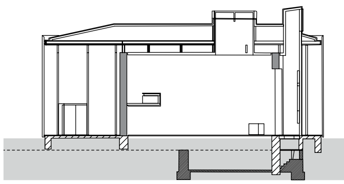
Less than five years after the destruction of the church, the Berlin wall was removed, uniting Germany once again. The grounds of the former church, then marked by tall grass, two concrete patrol paths, and the remains of the church foundation, were given back to the community, and the congregation quickly began to consider what should be done with the property. While many wanted to erase the history of the city's division as soon as possible, the community instead conceived of a plan for a new chapel to commemorate the tenth anniversary of the fall of the Berlin wall.

Rudolf Reitermann and Peter Sassenroth, two young Berlin architects, were offered the commission to design the new Chapel of Reconciliation on the site of the previous church. Their initial proposal called for concrete and glass, but the community considered these materials representative of the oppressive wall that had divided their cities and alternatively selected wood and clay to construct the building—significant because a historic clay mine once existed adjacent to the church property. The chapel was the first load-bearing earthen religious building in Germany and the first public rammed earth structure there in 150 years. The clay used to construct the walls was brought from the nearby town of Herzfelde, on the outskirts of Berlin, and mixed with the ground remains of the demolished church. Crushed brick, tile, and nails, all remnants of the previous church, are embedded in the walls and visible on their surface, preserving the tumultuous history of the site.

The heart of this small, oval building is an ovoid room constructed of rammed earth, enclosing the worship space. While the shape of the space designates the traditional east-west axis of Christian churches by aligning the entrance of the room to the altar, a secondary axis is created by an alcove where the recovered altar section of the previous church is stored. It marks the center of the preexisting nave and faces the direction of the original aisle and entrance. The new rammed earth altar, which

opposite: Wood louvers surround the rammed earth chapel.





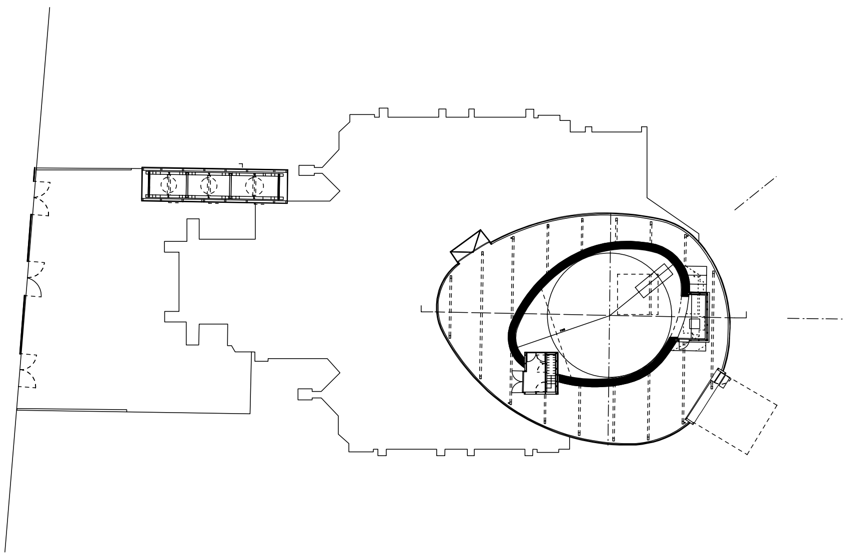
Sections

# Chapel of Reconciliation

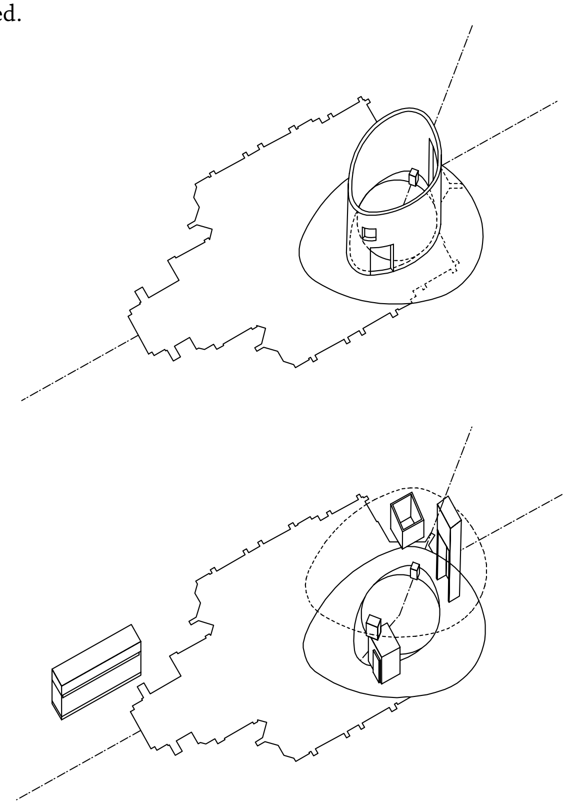
houses the baptism and communion vessels, rests atop the original church's stone refectory and is embedded in the floor, creating another connection to the buried remains of the previous church. Steps that at one time went down to the basement are now visible through a window placed in the earthen floor. Upon the steps rests an unexploded bomb from World War II that was discovered during the excavation process.

An enclosure of vertical wood louvers encapsulates the entire rammed earth structure. While this screen allows for the passage of light and air, it is a perceptible threshold between exterior and interior and marks the beginning of a series of experiences that distance the outside from the inner sanctuary. The thick rammed earth walls add a second layer of separation: silence created by the massive noise-absorbing walls and floor creates a space for contemplation separated from the busy urban streets of Berlin. Only the constantly changing light that enters from the large skylight at the center of the roof offers a connection to the outside. At night, the building's screen is illuminated from inside as a beacon that symbolizes unification

The building was constructed without any heating or air-conditioning system. While this was considered risky at the time, it has proved to be one of the most celebrated features of the church. Though the wall's thermal mass has the ability to temper radical shifts in temperature, the building is not entirely weathertight. Thus, various seasonal and religious events are heightened by the experience of a living building where heat and cold and dark and light can be celebrated.



Site plan showing location of previous church



Axonometric drawings

top left: An impression in the thick rammed earth wall of the chapel houses an altar section recovered from the previous church.

top right: A wood screen and rammed earth wall offer a sense of isolation from the city.

bottom: At night the chapel is illuminated to become a glowing symbol of unification.

ORGANIZATION

**Rural Studio**

LOCATION

**Mason's Bend, Alabama**

DATE

**2000**

During the Great Depression, the U.S. government widely promoted rammed earth building to provide low-cost housing for the poor. In Gardendale, Alabama, in the 1930s, the Gardendale Homesteads project funded by the U.S. Resettlement Administration built 68 single-story homes on 512 acres; several of them were prototype houses constructed of rammed earth. The success of these experimental houses, some of which are still used today, was inspirational to students designing a community center in 1999 in one of the poorest counties in the United States.

Mason's Bend, not so far from Gardendale and deep within the Black Belt of rural Alabama, is nestled in an oxbow on Hale County's Black Warrior River. Four extended families have lived there in poverty for generations, occupying ramshackle trailers and shacks. For many years, Rural Studio, part of the architecture program at Auburn University, has built innovative homes for Mason's Bend residents, and to thank them one of the recipients presented the studio with a gift of land at the intersection of properties owned by three different families. Because the property symbolized a meeting point in the community, Rural Studio students chose to construct on it a multifunction civic building made of a shrewd combination of recycled materials and Hale County red earth.

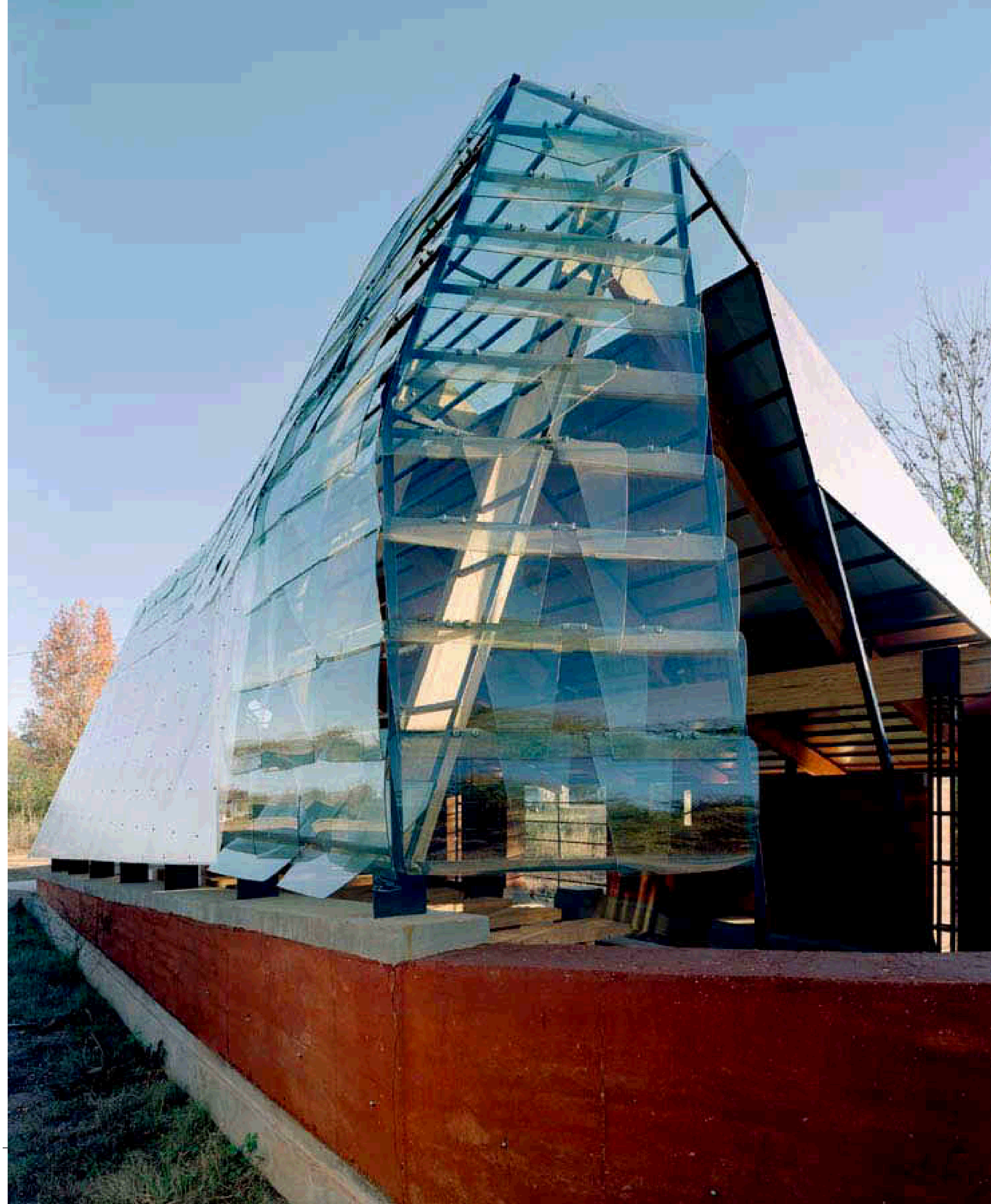
Because the property lies on the intersection of two roads, it provided the perfect opportunity to create an architectural landmark that was visible to anyone coming to the community. The open-air structure, whose form was inspired by vernacular architecture of the region, allows the community to meet in a cool, shaded space. Informal and formal events take place here: it is the stopping point for a regional book mobile as well as the county's mobile health clinic, and it is a meeting place for a local prayer group. The humble yet sublime quality of light created by the partially glazed roof—which gives the building its alternative name, the Glass Chapel—creates an exhilarating space of reflection inside.

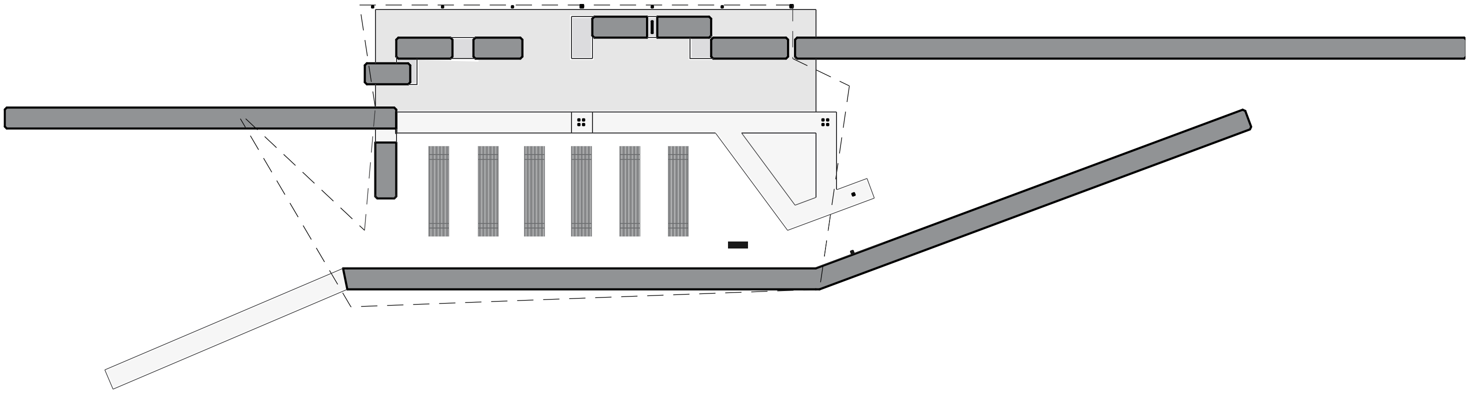
The glass portion of the roof is made up of eighty 1985 Chevrolet Caprice side-door windows, purchased by the students for $120 from a scrap yard in Chicago, Illinois. The students ingeniously used the ready-made holes in the glass, by which the mechanism that raised and lowered the window was attached, to secure the panes to a steel structure in a fish-scale pattern. The lightweight steel frame also supports the aluminum roof that reflects the colors of the earthen walls and the surrounding landscape, further adding to the ethereal quality of the space.

The entire roof system is supported by laminated cypress beams harvested from nearby Akron. These heavy beams are attached to steel supports embedded in a concrete bond beam that sits on the thick rammed earth walls. The locally sourced walls are made of 30 percent clay, 70 percent sand, and a small amount of portland cement to help protect the walls from the heavy Alabama rains. Long arms of rammed earth reaching out to the community from entrances on opposing sides of the building guide approaching visitors into the structure. Outside, these extensions are protected with rusted steel caps that have taken on a hue similar to the iron-rich soil used to construct the walls. On the interior, the steel cap is replaced by a concrete bond beam that follows the various heights of the rammed earth wall, taking on various architectural and programmatic functions: giving the walls structural stability, supporting the roof, or serving as a bench while complementing the cypress benches and tables that rest upon the humble gravel floor inside.

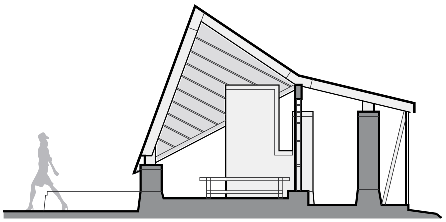
opposite: The glass for the roof is partially constructed of eighty 1985 Chevrolet Caprice side-door windows, which hang from a delicate steel structure.

# Mason's Bend Community Center





Floor plan



Section

top left: The iron-rich Alabama soil gives the rammed earth walls that reach out to the community a vibrant red color.

top right: Located at the intersection of two main roads, the center is a community landmark.

The community gathers in the celebratory
space beneath the airy roof structure.

ARCHITECTURE FIRM

**Grieve Gillette and Cox Architects**

LOCATION

**Adelaide, South Australia**

DATE

**2001**

South Australia, Australia's leading wine-producing region, has embraced a modern, scientific approach to viticulture, making it the global leader in production research and education. Grieve Gillette and Cox Architects adopted this progressive approach in their design of a building conceived from the materials and forms found in ancient and modern wine-making traditions. By connecting visitors to the landscape of the modern vineyard and giving them the experience of several aspects of the cultural and production process, the National Wine Centre in Adelaide promotes an understanding of an experience that goes from the soil to the glass.

This flagship of Australian wine making was built to promote the growing industry and to serve as an educational and cultural center, as well as a major tourist attraction. Run by the University of Adelaide, the center offers courses in oenology, mounts exhibits in wine making, and hosts tastings of wine from various regions in Australia. An extension of Adelaide's 125-acre Botanical Garden, the Wine Centre preserves two and a half acres for a vineyard containing 500 grapevines that display seven of the most important varieties of grapes used in making red and white wine. Visitors can walk among the rows of vines, which are organized in a semicircular pattern that mirrors the plan of the buildings.

The building emerges from the earth much like a vine from the soil. In fact, soil taken from all the leading wine districts in Australia was brought to the site and compacted to form the largest rammed earth wall in the Southern Hemisphere. The main entrance to the building is alongside this massive wall, which serves as a central spine off of which the architecture grows. The great height and slenderness of the wall is achieved by a reinforcing steel structure that—just as modern technology bolsters wine-making traditions—allows rammed earth to achieve such proportions.

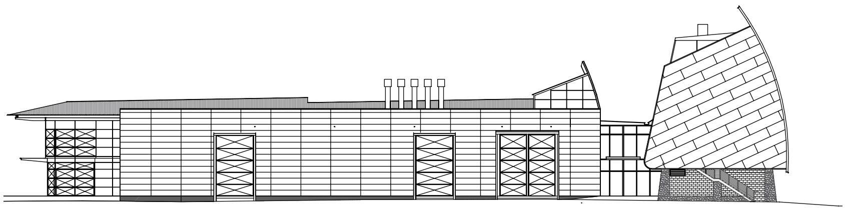
From this central spine of the vertical *terroir* emerges a structure of laminated hoop pine and transverse steel tension cables that is inspired by the grape vines and their supporting trellis. The use of wood also reflects the traditional role of barrels, which give wine its complexity; they are referenced in the shape of the structure, which forms a half-arc to suggest the shape of the casks that house wine beneath the earth in traditional cellars.

As visitors move through sequentially organized spaces—exhibits, educational facilities, and restaurants—the materials and experience of the building become progressively refined, a parallel to how grapes are refined into wine. Glass and stainless steel, commonly found in the fermentation vats in modern wineries, are used in the final stop on the tour, a wine-tasting room. Here, at the terminus of the grand arced promenade, visitors view the vineyard through large windows, contemplating the beauty of architecture and wine with glass in hand.

**opposite, top: The Wine Centre is sited at the edge of Adelaide's 125-acre Botanical Garden, where 500 grapevines in a semicircular pattern reflect the plan of the building.**

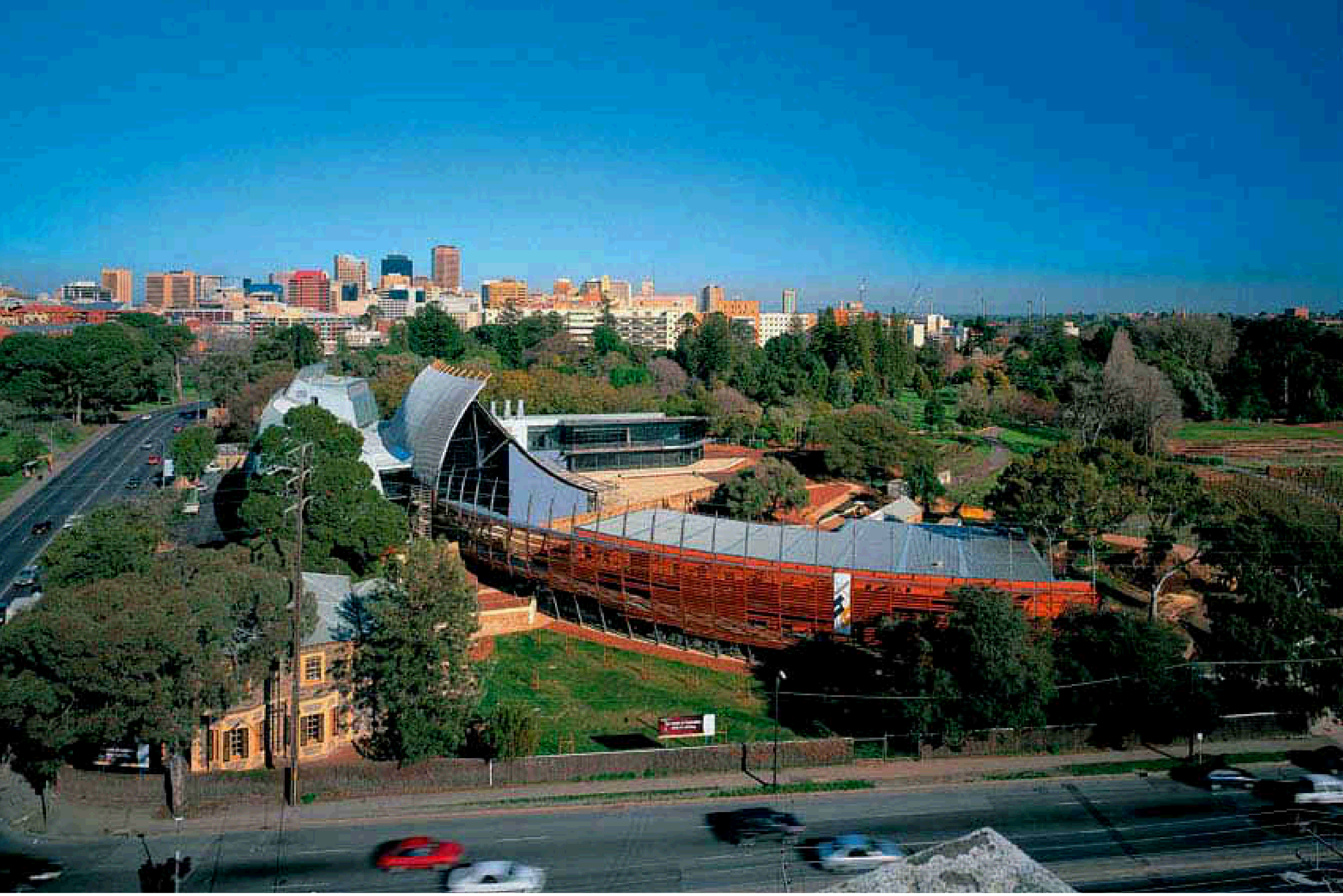
**opposite, bottom left: Earth, steel, wood, and glass used in the construction of the National Wine Centre parallel the terroir, trellis, barrels, and bottles of wine present in the wine-making process.**

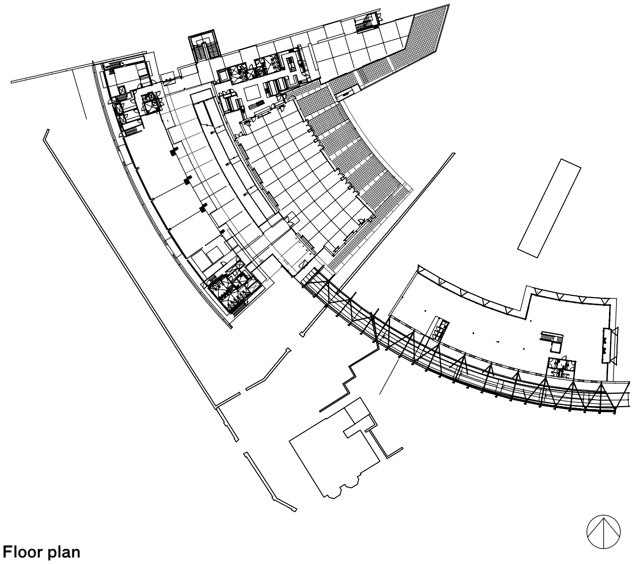
**opposite, bottom right: The multi-layered space is enclosed by a grand roof structure supported by laminated hoop pine beams.**



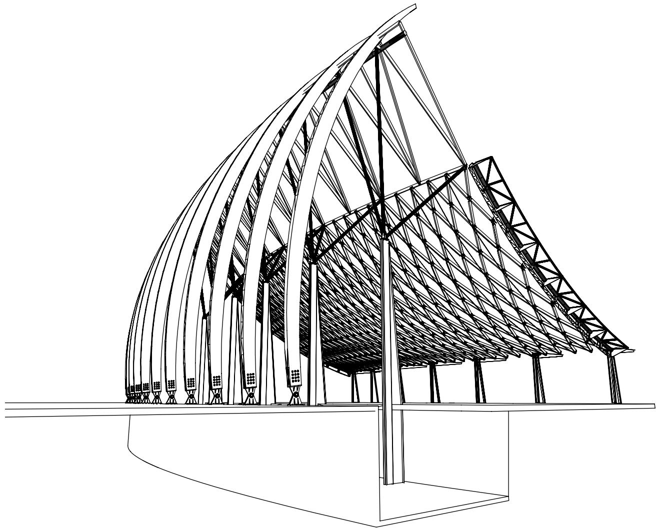
**West elevation**

# National Wine Centre

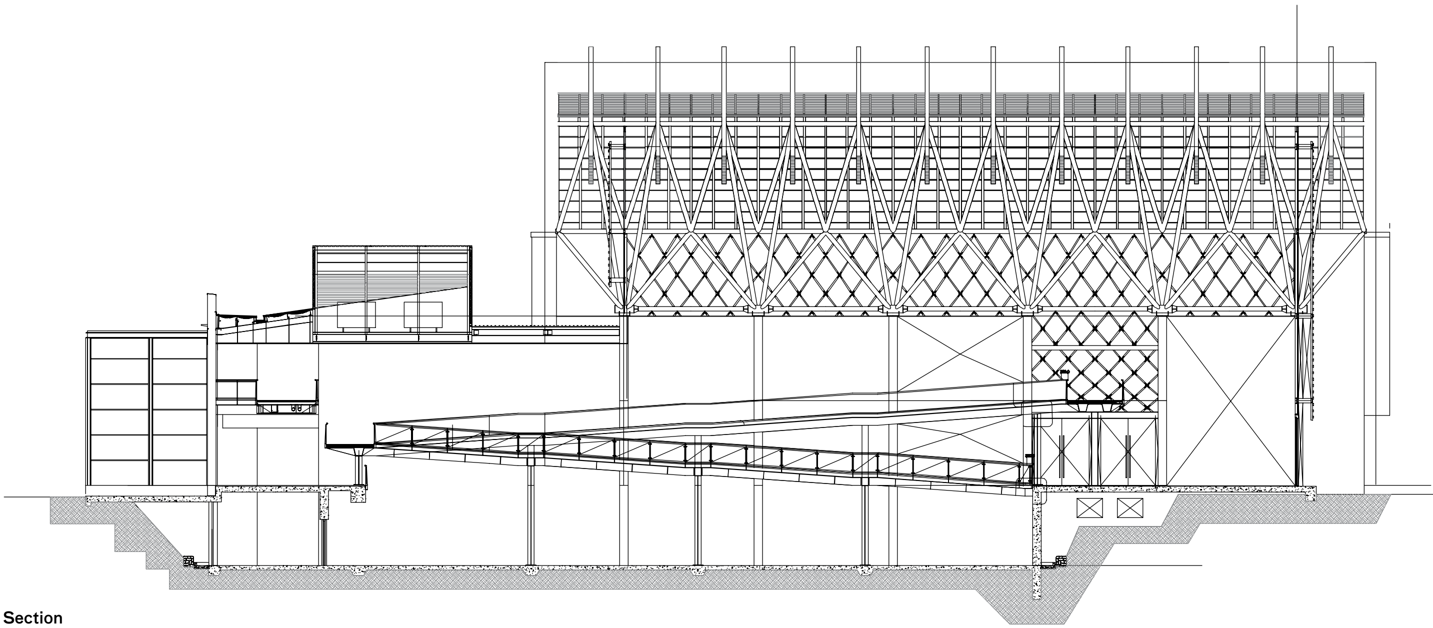




Floor plan



Roof structure



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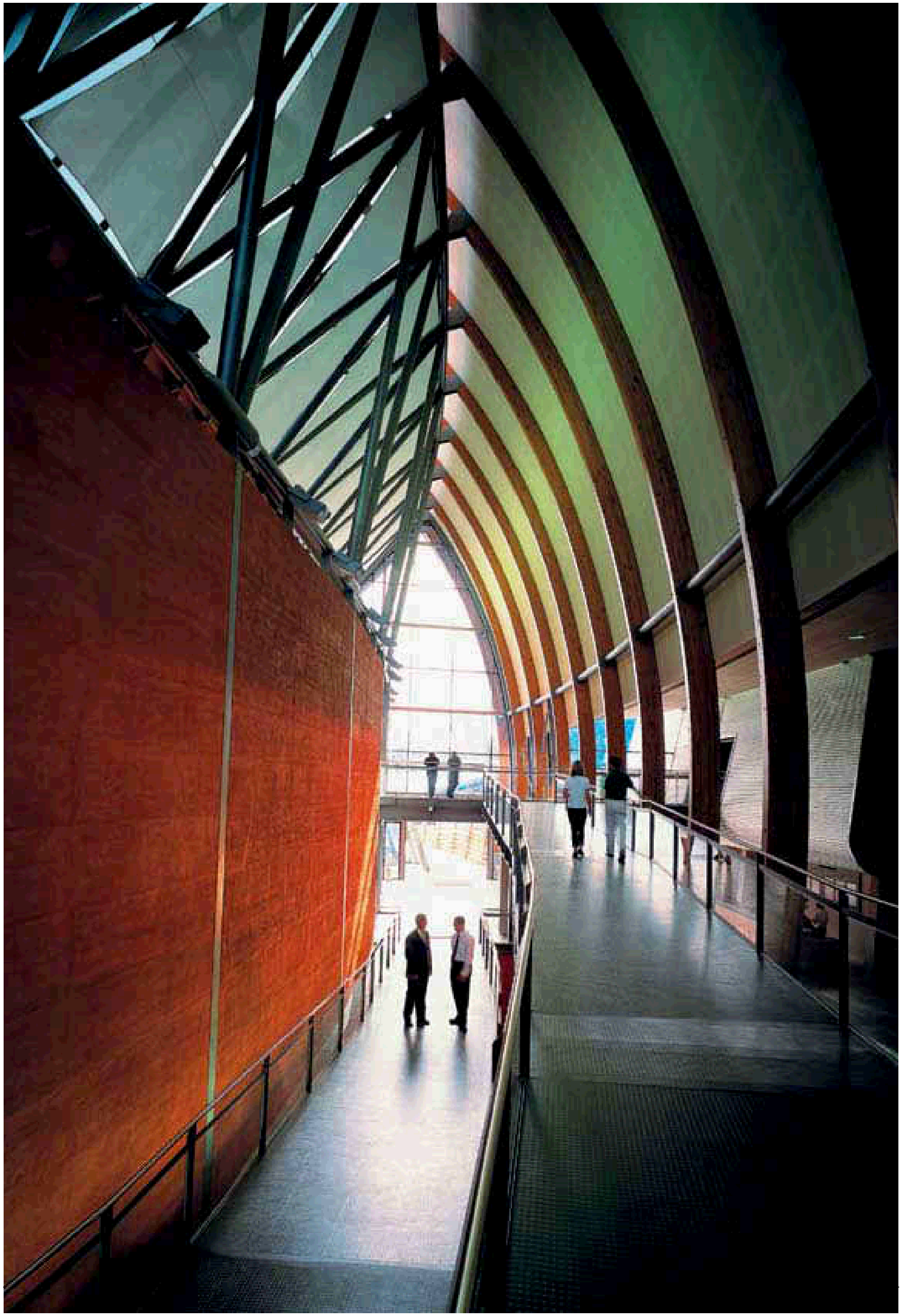


The immense rammed earth wall, an architectural terroir constructed of soils taken from Australia's leading wine districts, guides visitors through the Centre.

# Eden Project Visitor Centre

ARCHITECTURE FIRM
**Grimshaw Architects**
LOCATION
**Cornwall, United Kingdom**
DATE
**2000**

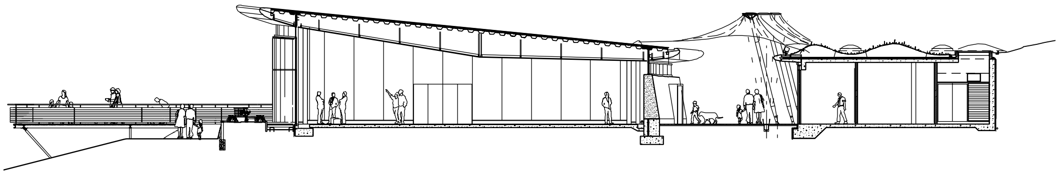
The Eden Project, the leading tourist attraction in the United Kingdom, is considered by many to be the eighth wonder of the world. The complex comprises a number of immense domes that house plant species from rain forests and warm temperate regions around the world. Welcoming visitors to the site is the Eden Project Visitor Centre. While it is often overlooked because of the architectural penumbra created by the enormous biomes, this center serves as an important introduction to Eden, offering educational programs and exhibits while architecturally embodying the ecological philosophies of the park. Although the visitor center was completed in 2000, the biomes were not open to the public until the following year. During that time, the comparatively small rammed earth visitor center accommodated 2 million people who had come to watch the building of the largest greenhouses in the world.

Comprising two adjacent buildings, the center is situated at the edge of a 37-acre site that was once a quarry for mining china-quality clay and derives its crescent shaped plan from the contours of the enormous pit. The buildings are intentionally concealed from the parking lot by a green roof that allows the soap bubble–like biomes to take visual precedent. A long, subtly curved rammed earth wall that extends the length of the building welcomes visitors, drawing them into the courtyard-like street defined on one side by the wall, which is made of high-quality clay taken directly from the site. On the other side, a gabion retaining wall holds back the soil that forms the green roof seen from the parking lot.

Farther into the courtyard, the gabions give way to a split-cedar shingle facade that encloses the restrooms, offices, and storage for the center, all housed beneath the green roof. Overhead, a series of fabric tensile structures shade the courtyard and lead to the entrance to the visitor center's main hall, accessible through an opening in the rammed earth wall. Inside, the space gives way to shops selling plants, cafes, exhibit halls, and educational galleries. An underlying steel structure makes the large open spaces possible and supports the aluminum-clad roof that protects the rammed earth wall from rain. Because this wall is not structural, it acts more like an infill within the steel structure—a modern interpretation of English wattle and daub or cob houses that are traditionally found in Cornwall. On the opposite end of the building a viewing deck offers a dramatic view into the clay mine and the biomes, whose forms and high-tech materials are accentuated by the contrasting natural materials of the visitor center.

opposite, top: Curving earthen walls and a tensile fabric roof create a dynamic space at the entrance to the center.

opposite, bottom: The biomes are slowly revealed on the approach to the visitor center.



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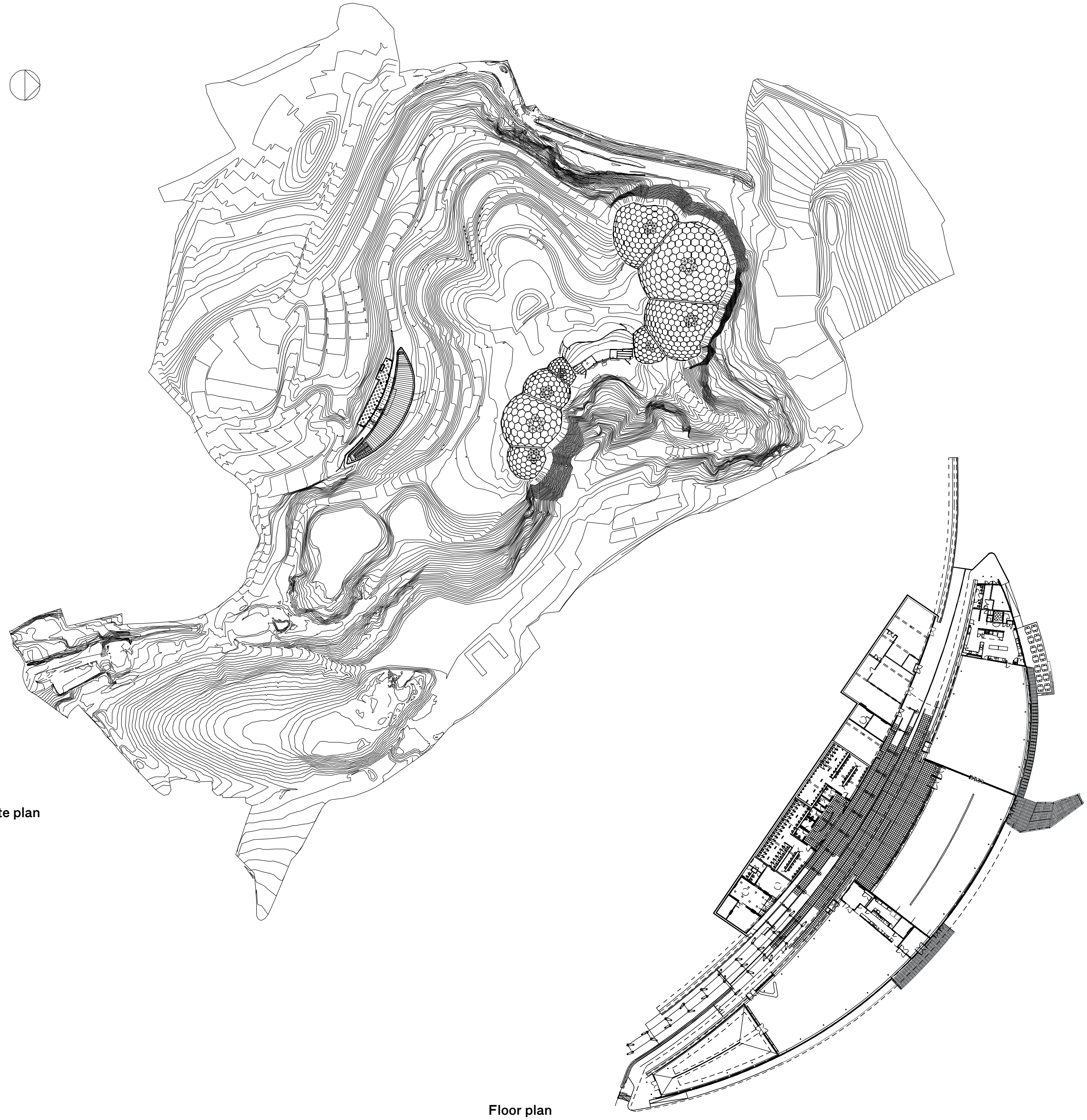


Site plan

Floor plan

top: The enormous intersecting hexagonal geodesic biomes in the former china-clay pit are visible from the center.

bottom left: A view of the grand site is presented to visitors entering the main hall.

bottom right: The ceiling seems to float above the walls, providing well-lit open spaces inside the visitor center for exhibits, cafes, and galleries.

ARCHITECTURE FIRM

**Roger Boltshauser Architekten**

LOCATION

**Zürich, Switzerland**

DATE

**2002**

Located on an island in the Sihl River in Zürich is the oldest historic sports ground in the city—the Sihlhölzli Sports Facility. The complex consists of over 13 acres of playing fields, a gymnasium, walking paths, a music pavilion, playgrounds, and a wading pool, organized on an axial plan in 1932 by architect Hermann Herter. When the original temporary storage buildings that served the sports and leisure grounds had to be replaced, architect Roger Boltshauser was asked to design two permanent storage buildings and a *Zielturm*, or chronometry tower, to time track events. His design drew from the historic axial plan of the facility as well as from Herter's gymnasium sited between the two former creeks surrounding the island. The use of rammed earth and concrete allows the two small outbuildings to mediate between the natural park grounds and the surrounding urban context.

The buildings store tools and sports equipment, provide a ticket sale and information kiosk for the facility, and elegantly reference the classically inspired gymnasium. The sharp-edged concrete found in the roof slab, entrance, and skylights of the storage sheds is a nod to the concrete structure of the gymnasium, and the 18-inch-thick rammed earth walls reflect the contrasting brown stucco infill between the gymnasium's concrete columns. As the rammed earth used in all the buildings does not contain a stabilizing agent, such as cement, at every 18 inches a ¾- to 1¼-inch-thick cement layer was poured to help prevent the surface from eroding. A wall and two clerestory openings of glass block are also a nod to the fenestration of the gymnasium.

The northern toolshed is located near the entrance of the grounds so that it can occasionally be used as a kiosk. The southern storage shed lies opposite, on the embankment facing the riverbed, which creates a symmetry that defines a courtyard in front of the gymnasium where events can take place. This is also the location from where nature paths lead out to the rest of the site.

The chronometry tower, located next to the running track, houses time measurement equipment, the finish-line camera, and a work space where the tower's operator times the track-and-field events. Two large windows puncture the thick walls at the corners without revealing any lintel, which gives the illusion of thinness to the structure while providing an uninterrupted view of the running track from inside. In order to support its height and additional floor, the tower's walls are made of 24-inch-thick rammed earth. A concrete slab was poured directly on top of the rammed earth walls to create the first floor and the roof. Sandwiching the slab between layers of rammed earth articulates the compressed nature of the walls' construction and intensifies the textural and dimensional quality of the building materials. It also evokes the relationship between nature and the urban that is reflected in the park and the surrounding city.

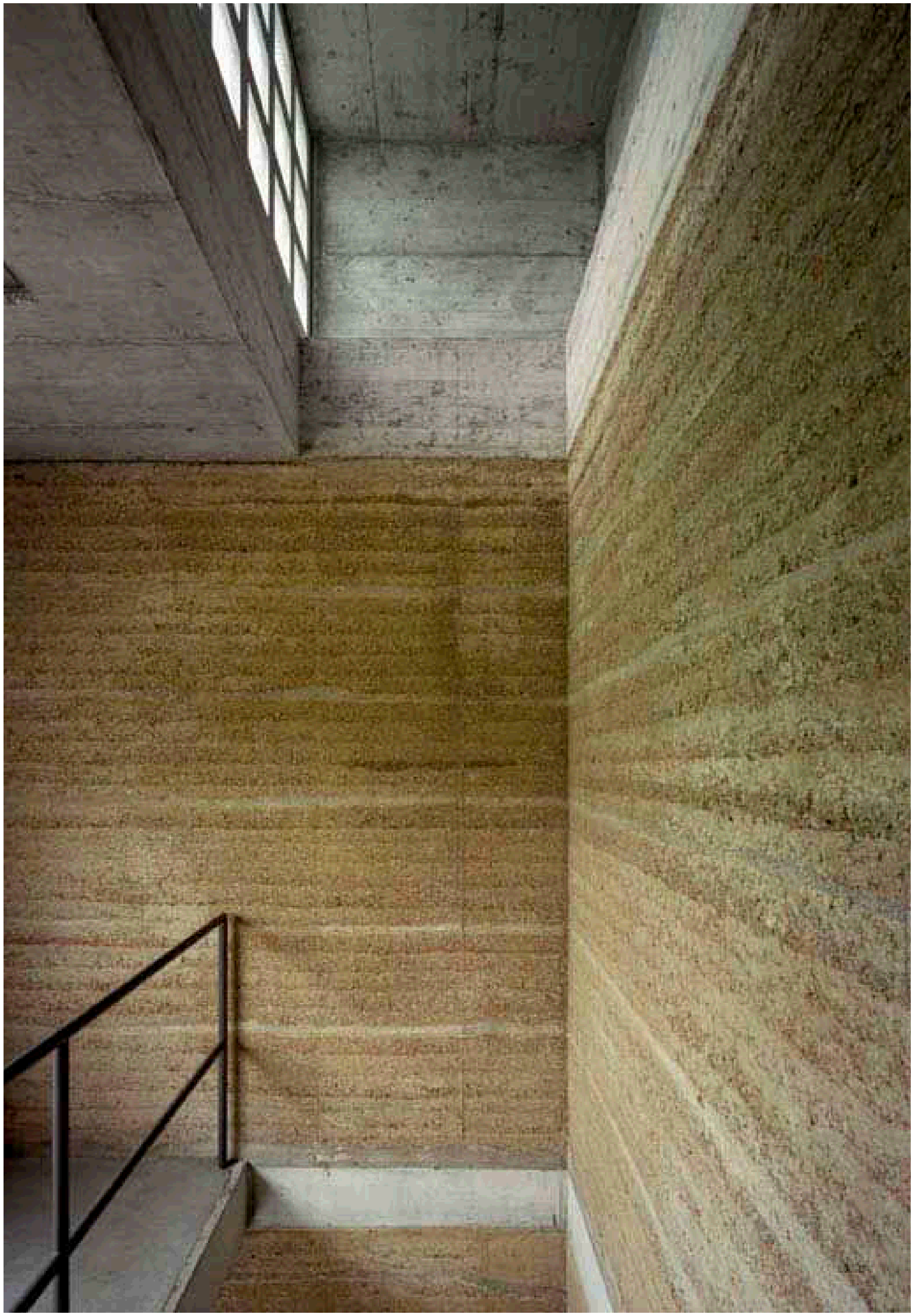
opposite: The chronometry tower

# Sihlhölzli Sports Facility Storage Sheds and Chronometry Tower

Various floor plans, elevations, sections of storage shed 1, storage shed 2, chronometry tower

left: The northern toolshed/kiosk is located near the entrance to the grounds.

right: A courtyard is created between the two storage buildings in front of the gymnasium.



left: Rich earth tones are heightened by the gray concrete and the northern European sky.

right: Subtle lines in the wall surface indicate where thin layers of cement were poured to help prevent erosion in the wall surface.

ARCHITECTURE FIRM

**Atelier FCJZ**

LOCATION

**Yanqing, Beijing**

DATE

**2002**

The Chinese are the world's most prolific builders in earth; there are an estimated 90 million homes in China employing mud brick, wattle and daub, and rammed earth. Thirty thousand earth houses, dating mostly from the Ming and Qing dynasties (1368–1911), can be found in Fujian Province, which also contains the incredible rammed earth, multistory, round, clan courtyard houses of the Hakka. The best-known Chinese achievement is perhaps the Great Wall, largely constructed of rammed earth and one of the world's masterpieces of military architecture.

The Split House is located in the Jundu Mountains north of Beijing, not far from the Great Wall. Designed by Yung Ho Chang, the founder of the first private architectural firm in China and head of the Department of Architecture at the Massachusetts Institute of Technology, it draws from China's legacy of earthen construction. The result is a contemporary design that recalls the time-honored traditions of building with *tu mu*, "earth and wood."

The techniques used to construct the rammed earth walls are based on local construction methods. Local soil was mixed with coarse jute fabric, and lime was added as a stabilizer to provide added strength. At various increments, bamboo was placed horizontally within the wall to reinforce it—similar to embedding rebar in a concrete wall—and to prevent expansion, which can cause cracking.

The Split House also reconsiders the traditional Beijing *si he yuan*, or courtyard houses, that make up much of Beijing's historic center; and it transplants this typology from its dense urban site to the context of the pristine mountain valley, among mountains and water, or *shan shui*. Unlike the urban typology from which it is derived, which creates a courtyard enclosed on all sides by the building, the two halves of the Split House enclose two sides of the courtyard, and the mountains of the valley enclose the other half, thus blurring the distinction between nature and architecture and creating a new type, *shan shui si he yuan*—a courtyard house with mountain and water.

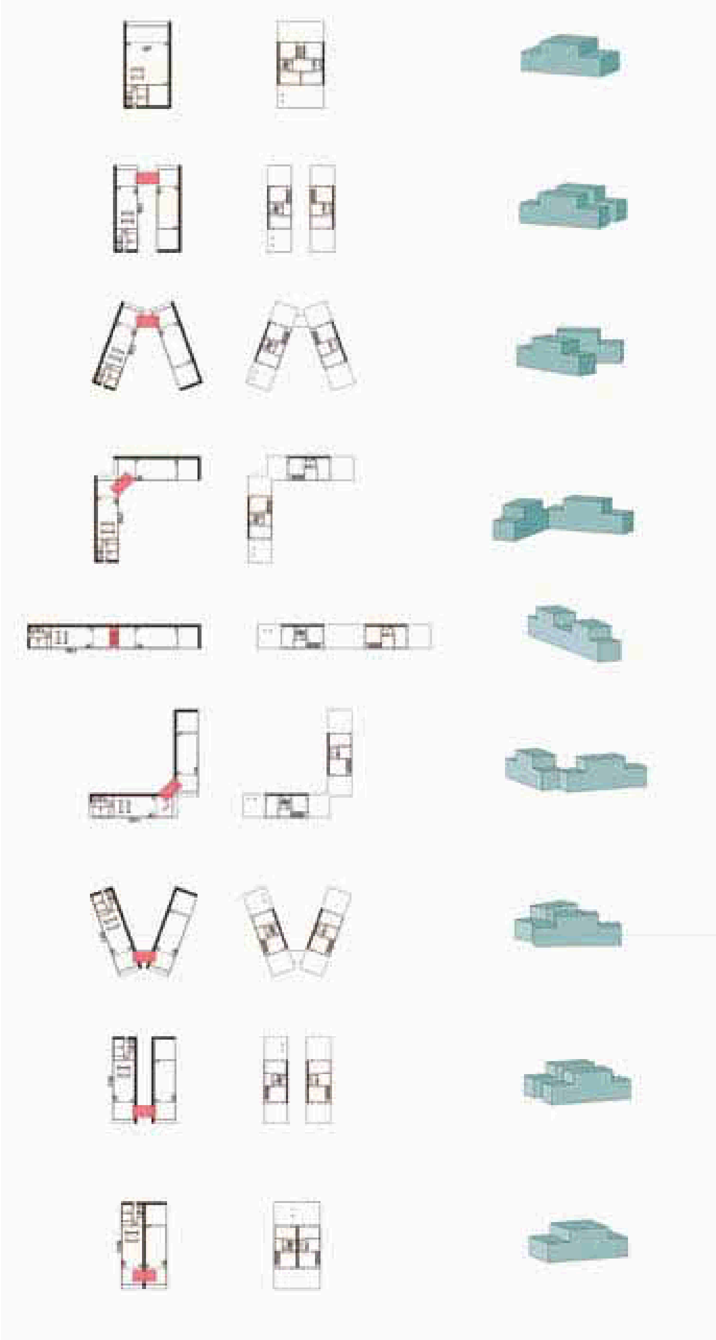
Splitting the house preserved trees that already existed on the site, separated the public and private functions of the house, and opened it to the views of the valley. A natural stream on the site was rerouted through the center of the courtyard and below the glass entrance-lobby floor. The concept of "splitting" also divides the functions of the two primary materials. The thick, rammed earth walls enclose the house with minimal environmental impact. However, the walls are not structural—instead, the laminated wood frame supports the roof and second story. Because the house is split into two halves, each with two floors, it is possible to use only half of the house when the number of occupants is low, keeping maintenance costs to a minimum. Yung Ho Chang designed the house to be a flexible prototype, able to adapt to the specific conditions of various sites. The relationship between the two halves of the prototype can be altered to best fit specific sites within the valley in response to views, streams, topography, and the proximity of the mountains that complete the courtyard. The same set of programmatic, material, and formal elements that make the house "parallel" can also evolve in response to different contexts to create new house typologies: right angle, bar, singular, and back-to-back.

**opposite: The surrounding mountain valley completes the courtyard of the Split House, blurring the distinction between nature and architecture.**

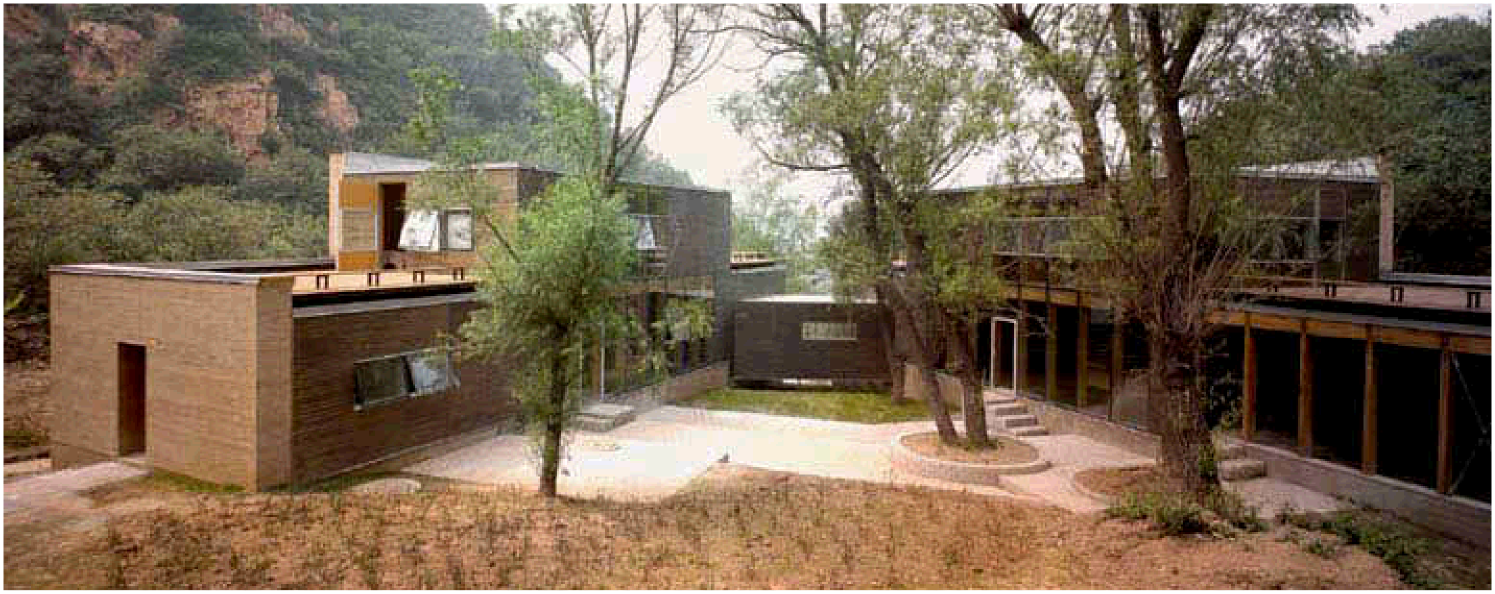
# Split House

Second-floor plan

First-floor plan



Possible variations on the prototype



top: The house was split in the center to preserve existing trees and separate the public and private functions of the house.

bottom: A glass facade defines one side of the courtyard and brings the landscape into the house's interior.

ARCHITECTURE FIRM

**Marte.Marte**

LOCATION

**Batschuns, Vorarlberg, Austria**

DATE

**2001**

The Cemetery Extension and Chapel of Rest is located in the village of Batschuns in rural Austria, adjacent to a serene meadow, mortuary chapel, columbarium, and burial ground overlooking grand views of the Rhine Valley and the Vorarlberg countryside. This project was the winning entry in a competition whose aim was to expand the burial grounds and create a mortuary chapel to serve an existing church and cemetery designed by the prominent modern architect Clemens Holzmeister that was completed in 1923. Because the municipality of nearby Zwischenwasser, host of the competition, recognized the importance of their historic architecture, great care was taken in selecting the winner. Though there was no precedent for a mortuary chapel executed in rammed earth, the jury selected the elegant and minimal design by sibling architects Bernhard and Stefan Marte of Marte.Marte.

The project consists of a cube-shaped rammed earth chapel placed in the corner of the site with two earth walls that extend away from it to define the burial grounds. The walls were constructed of soil taken directly from the excavation of the church grounds, without the addition of any stabilizing additives. Earth was poured into formwork atop a reinforced concrete foundation and compacted into 5¾-inch-high layers using pneumatic tampers. Embedded in the walls of the chapel are a concrete bond beam that provides lateral stabilization and a pipe that drains water from the roof.

Just as members of the congregation participated in the construction of the historic church in 1923, community members, led by master clay builder Martin Rauch, assisted in the construction of the walls of the new chapel, which allowed the small project to be constructed within budget. Utilizing a process called "calculated erosion" by the builder, the 18-inch-thick walls are slightly overdimensioned, a measure that accommodates for erosion and gives the walls a hundred-year life span—a conservative estimate by the architects.

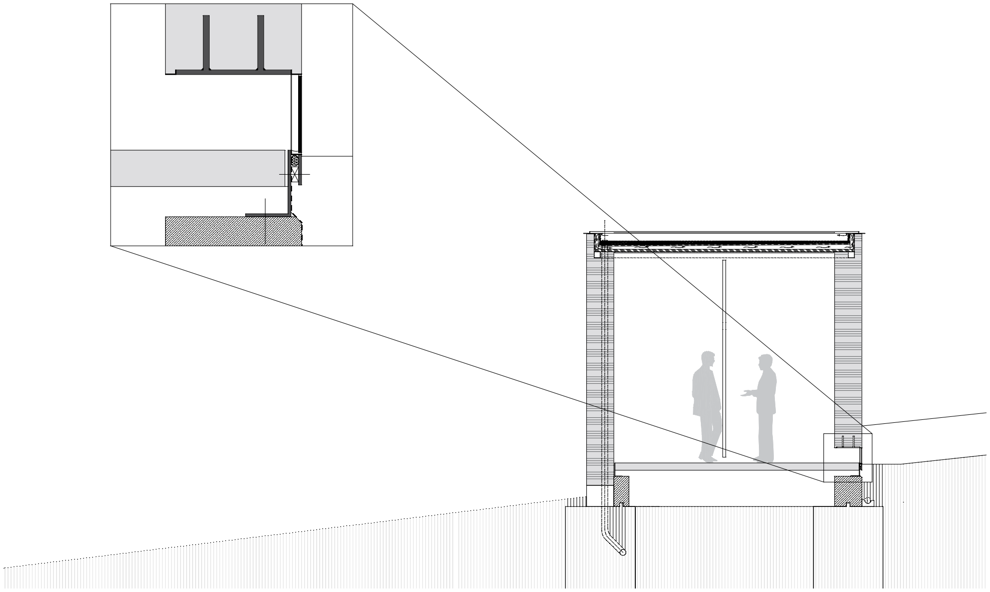
The interior of the chapel is a space entirely enclosed by earth. A rammed earth floor is treated with wax and polished, which makes it more resistant to water damage. Special panels that can hold clay plaster were used for the ceiling, and the continuity of earthen surfaces creates a minimalist space whose subtle details, defined by the use of wood and light, are heightened by its purity. Visitors enter the chapel through two large, asymmetrical, untreated oak doors, whose wood was harvested in Vorarlberg. Inside, light from a slot in the ceiling overhead illuminates the compacted layers of earth. The horizontal layers combined with a vertical strip of wood embedded in the wall evoke the form of the Christian cross. Another wall hovers over a slot at floor level, illuminating the space by reflecting light off the polished rammed earth floor and calling into question the solidity and heaviness of earth. This subtle detail is accomplished by a steel beam concealed in the rammed earth that suspends the wall above the floor.

Outside, two rammed earth walls extend away from the chapel and enclose the gravel-covered burial grounds. The shorter of these walls is 3 feet thick and defines one entrance to the grounds created by a gap between it and the historic cemetery walls. The longer wall slopes up toward the meadow, turns a corner, and increases in height. This taller portion of the wall is a columbarium where names of the deceased are commemorated in copper script and remains are stored in steel frames embedded in the rammed earth.

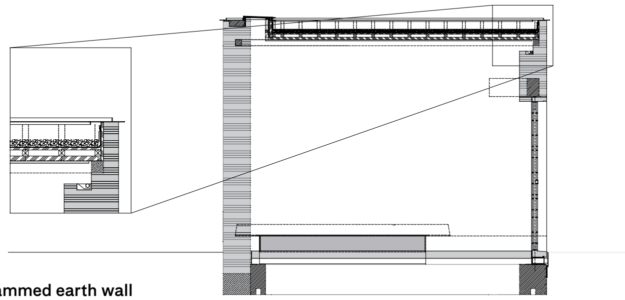
**opposite, top:** The cemetery extension includes a mortuary chapel, an urn wall, and a burial ground sited on a gently sloping hill with a grand view of the Rhine Valley and the Vorarlberg countryside.

**opposite, bottom:** A gap between walls of the historic cemetery and the new addition defines the entrance to the site.

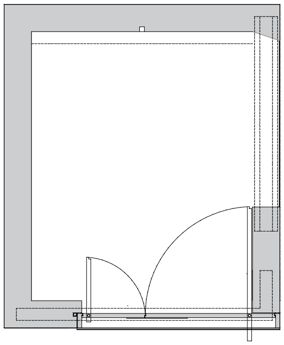
# Cemetery Extension and Chapel of Rest

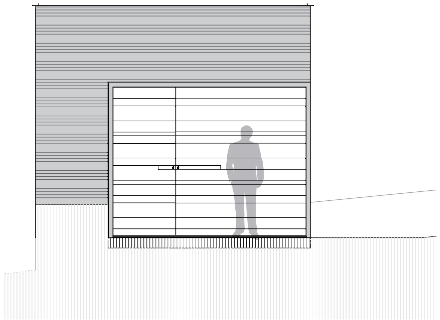
**Section and detail of the floating rammed earth wall**



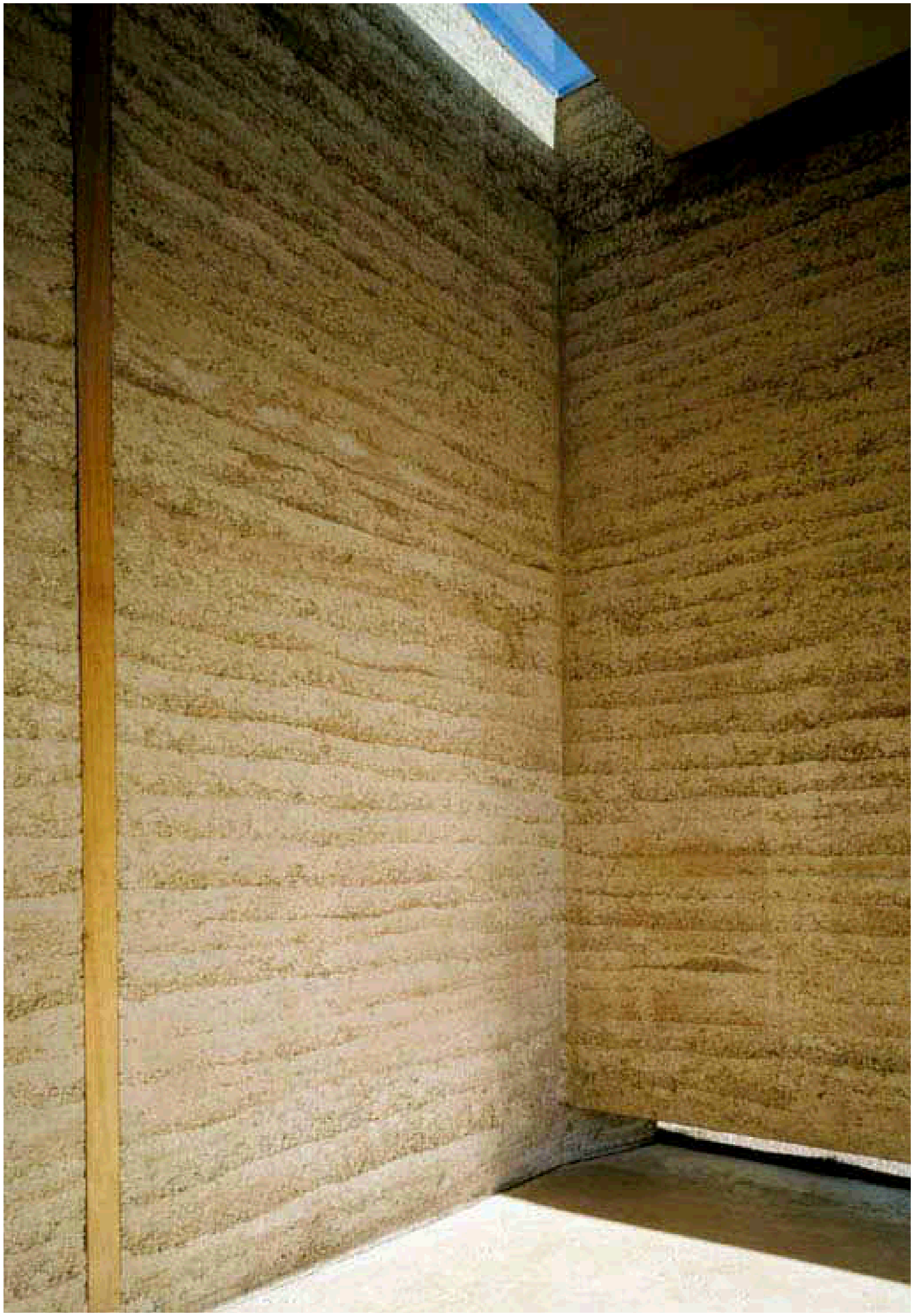
**Section with detail of recessed light embedded in rammed earth wall**



**Floor plan**



**Elevation**



top left: The two large asymmetrical oak doors were made from wood harvested in Vorarlberg.

bottom left: A vertical piece of wood embedded into the horizontal layers of earth evokes the form of the Christian cross.

right: A rammed earth wall floats above the floor, creating a slot that illuminates the interior.

DESIGN FIRM

**Predock Frane Architects**

LOCATION

**Jemez Springs, New Mexico**

DATE

**2003**

New Mexico is the epicenter of earthen construction in North America, but most buildings are historic mud brick structures, the legacy of either the Native Americans or the Spanish settlers who have occupied New Mexico since the sixteenth century. Because of strict zoning regulations, new buildings constructed of earth often emulate the styles that emerged from these vernacular traditions; therefore, rarely in New Mexico is an earthen building a reflection of modern architectural design. The Center of Gravity Foundation Hall, designed by John Frane and Hadrian Predock of Predock Frane Architects, however, is an exception.

The Foundation Hall is part of the Bodhi Mandala Zen Center, a Buddhist compound in Jemez Springs, New Mexico, that has served as a center for the study of Buddhism for more than thirty years. Used primarily as a teaching and meditation hall for the compound, the building is also used as a community meeting place for the town of Jemez Springs and serves as a retreat and meeting place for people and organizations across the country.

While the building references elements found in traditional New Mexican architecture, as well as the architecture of the former Boy Scout camp that the Zen Center now inhabits, in its use of massive earth walls and metal roofs the building is uniquely contemporary. The center also combines those elements with interpretations of Japanese Zen Buddhist architecture. Here the use of contrasting natural and synthetic materials, passive and active environmental systems, and relationships between lightness and heaviness create an impressive space dedicated to the daily ritual of traditional Zen practice.

Monks and students enter from opposite sides of the building between the rammed earth and polycarbonate walls that define the space where rituals take place every day between sunrise and sunset. At dawn, sunlight pierces through pieces of plate glass turned on edge and built into a series of sliding wood panels that make up the east facade, creating a luminous glow that marks the beginning of the day. By midday, ambient light fills the room through a slot between the hovering, folded roof and translucent polycarbonate walls that are a counterpoint to the thick rammed earth. These walls, similar to both the rice paper walls of traditional Japanese architecture and the deerskin or mica windows of Native American and Spanish architecture in Northern New Mexico, create an even glow inside. Later in the day, the western walls glow with the same intensity as the surrounding mountains at sunset. At night, recessed lights in the interior illuminate the building through the translucent wall panels, transforming the building into a lantern.

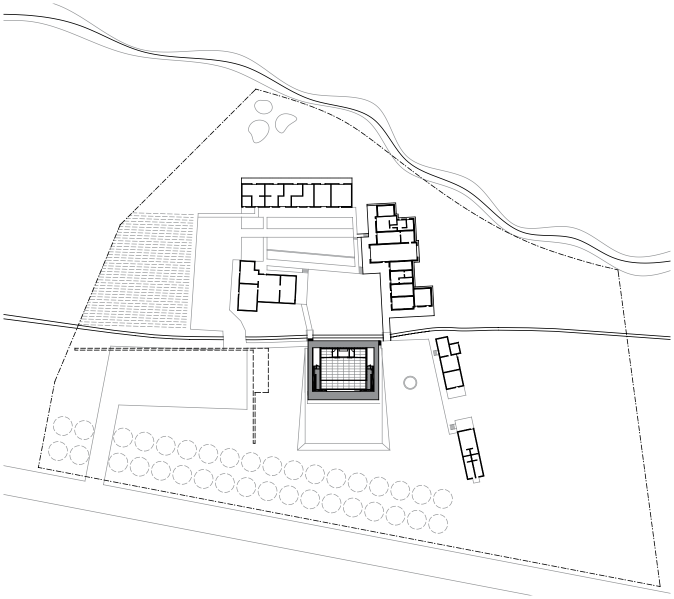
Beautiful phenomenological experiences are not the only outcome of the building's materials and forms, however. Jemez Springs is located in a high-altitude desert with an extreme range of temperatures, and these materials also provide active and passive environmental controls. The thermal mass of the rammed earth walls keeps out the hot temperatures of the summer and radiates this stored heat during the cold desert nights. Thermal transfer is also limited by the multilayer polycarbonate walls, which serve as an insulator. The cantilevered roof edges, overhanging as much as 14 feet in places, block the summer sun but allow the lower winter sun to penetrate the openings to warm the interior and the rammed earth walls. Sliding panels 36 feet long on the east facade and the entry doors to the west enable summer breezes to flow through the building, providing additional cooling through cross ventilation. The hot water from the springs for which Jemez Springs is named heats the building via radiators located at the perimeter of the building's interior.

Because of the translucent walls and transparent glass below the eaves, artificial light is not needed for reading during most of the daylight hours, reducing the building's life-cycle costs. The soil used to construct the rammed earth walls was recycled from an excavation at a nearby construction site. Further ecological consideration was taken by using beams made of recycled wood that support the hovering roof, which itself drains water into a catch basin for use in irrigation.

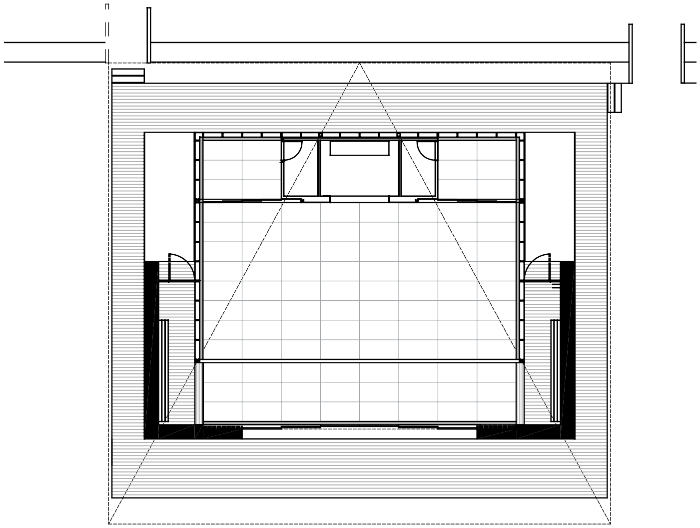
opposite, top: North elevation

opposite, bottom: Indirect light illuminates the interior.

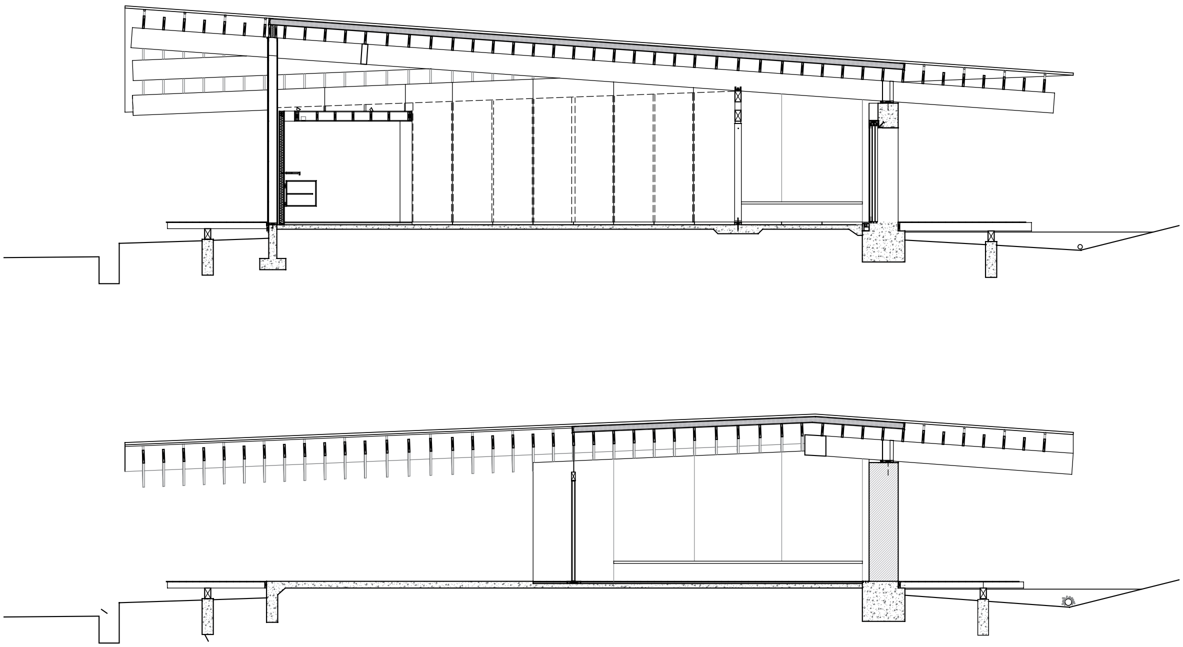
# Center of Gravity Foundation Hall



Site plan



Floor plan



Sections

Translucent polycarbonate panels
reference the rice paper walls of traditional
Japanese architecture.

ARCHITECTURE FIRM

**Cutler Anderson Architects**

LOCATION

**Napa Valley, California**

DATE

**2003**

The Residence at Meteor Vineyards is a 12,300-square-foot private house on a 27-acre site amid vineyards, rolling meadows, and oak groves. Cutler Anderson Architects saw the abundance of vegetation, earth, and ecosystems present on the site as an opportunity to design a residence that incorporated elements and experiences found in the diverse landscape. Soils found on the property are varied in type and color and, in addition to growing grapes, they produce rock-hard rammed earth walls. The walls of the house were made from soil collected from different areas on the property and compacted in layers, creating a wavy, marblelike stratification that accentuates the diverse colors. To allow varying experiences of the natural qualities of the site, the large residence was divided into three distinct parts: a main house organized within an L-shaped plan, with a study and a guesthouse placed at each end.

The main house comprises a grand dining room, living area, bedrooms, and outdoor terraces with dramatic views of the two major ecosystems that surround the house—a large vineyard and a grove of mature oak trees. The house reflects the division of environments present on the property with a material palette divided into wood and earth. Exquisitely joined timber makes up the primary structure of the house, contrasted by rammed earth walls and columns. An inverted-gable butterfly roof channels water into an outdoor pool adjacent to the main living area, which is marked by a massive two-story rammed earth chimney.

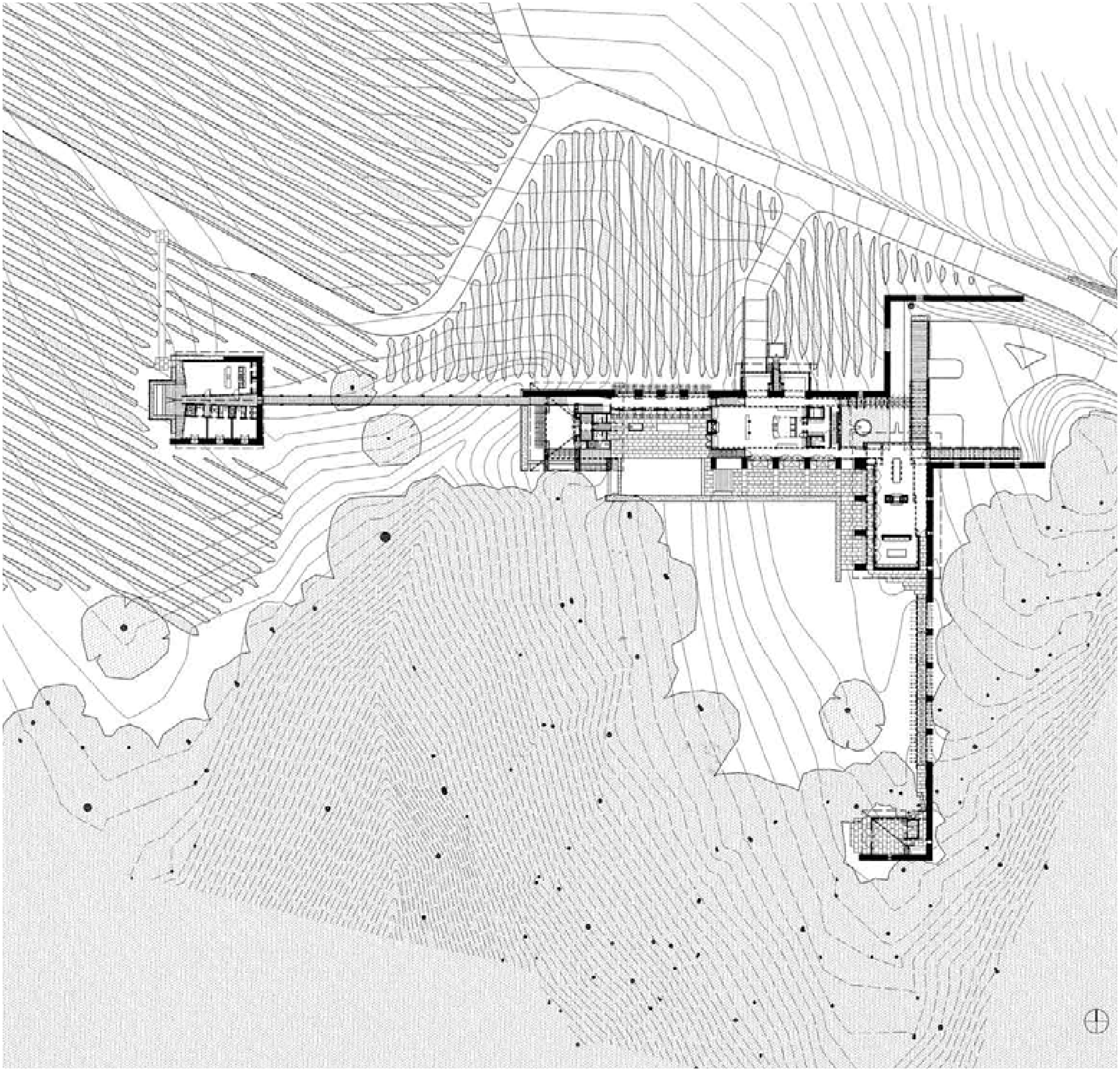
The axis leading from the main house to the guesthouse is a 130-foot-long bridge that floats above the ground, allowing the guests to walk over the vineyard. The bridge extends through the symmetrical rammed earth guesthouse and splits the massive walls, which creates the entrance to the house, provides access to a smaller pool, and frames the view of the hills beyond. A V-shaped metal roof hovering above the earthen walls, supported by a wood structure, creates a band of clerestory windows that brings light into the space. As in the main house, the inverted gable roof funnels water into the pool. Inside are three guest rooms; from each, a small balcony accessed by double doors punctures the rammed earth walls, offering a view out over the vineyard.

At the other end of this L-shaped plan is the study, 360 square feet and surrounded by gnarled eighty-year-old oak trees. The roof slopes to a single corner where, during rainstorms, water pours into yet another small outdoor pool that forms the terminus of the trellised walkway leading to the study. Similarly to the guesthouse, it is enclosed by 30-inch-thick slightly inclined rammed earth walls that define an L-shaped enclosure reaching out into the old oak trees and extending the view through an expansive glass wall.

right: Soil from various parts of the site create a marblelike pattern in the rammed earth walls.

opposite, top: East elevation
opposite, bottom: West facade of guesthouse at dusk

# Residence at Meteor Vineyards



Site plan

top left: Wood joinery is a counterpoint to the canted rammed earth walls.

top right: From the study, a wall of glass opens to the views of the oak trees beyond.

bottom: Eighty-year-old oak trees surround the study.

# Vineyard Residence

ARCHITECTURE FIRM

**John Wardle Architects**

LOCATION

**Victoria, Australia**

DATE

**2002**

The Vineyard Residence was built of rammed earth and exposed timbers to evoke the quality of a traditional vineyard farmhouse, exemplify the owners' passion for viticulture, and represent their move from the city to the country. Architect John Wardle exceeded their expectations with a design concept that is analogous to the grafting of cultivars. He conceived of his clients' move from the city to the country as the grafting of new vines onto old rootstock, and derived every aspect of the house's orientation, program, form, and materials from this idea.

The house is a 4,300-square-foot private residence located in Victoria, Australia, on the Mornington Peninsula. The 59-acre site is adjacent to a vineyard surrounded by natural landscape of manna gum and stringybark trees and cultivated pasture. Within the natural landscape, the house is positioned as thoughtfully as if it were a grape vine and is oriented, like the vines, to the sun: the north elevation of the house is aligned parallel to the rows of grape trellises, and the veranda's wooden shade structure continues past the house, extending into the vineyard—establishing the link between the sun, the house, and the terroir. The house is divided into two parts, a guest wing and a private wing, that are grafted onto the living area via the kitchen, cellar, and study, which are the pivotal working areas—the rootstock—of the house. The private wing contains the master bedroom, and the guest wing contains two bedrooms and the garage.

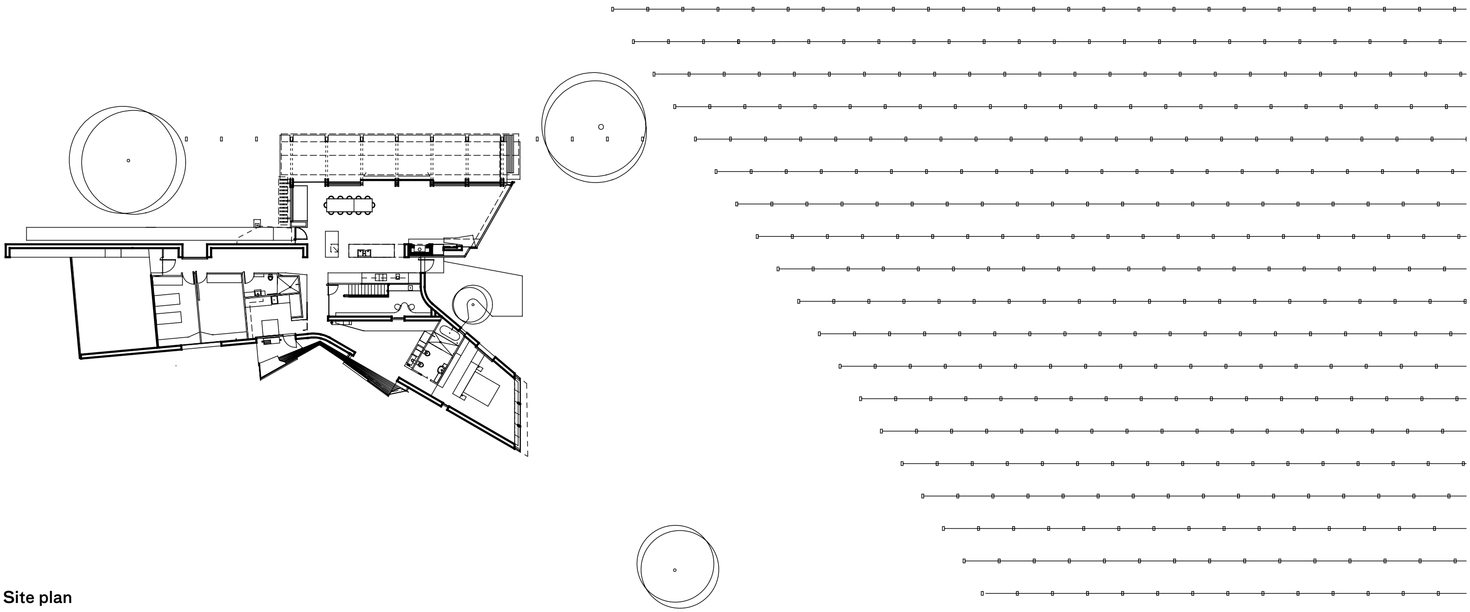
The prominent position of the house offers a panorama that encompasses the vineyards, rolling hills, and Mount Eliza in the distance. Because of the dramatic vistas in all directions, a hierarchy of filtered, panoramic, and framed views was established within the house. A screen at the entrance of the house offers privacy while allowing the owners a filtered view of arriving guests. Panoramic views are offered from the main living room, which opens to a veranda on the north side of the building, from the kitchen and its east-facing terrace, and from the study, which opens to the garden on the southern facade. The master bedroom frames a view of the vineyard through a large opening defined by the tapering and angled rammed earth walls—a metaphor for a cultivar precisely pruned with shears. This creates a dynamic form on the exterior and an equally powerful space within the master bedroom, a radical departure from the typically static quality of earthen structures.

The hierarchy of the vineyard also applies to materials used in the house: the earthen walls take prominence over all other materials. The earth used to construct the walls was taken from a quarry only 6 miles away. Crushed granite, normally used in highway construction, was added, along with a small amount of off-white cement as a stabilizer and a solvent-based silane water repellent specifically made to weatherproof stabilized earth structures. Two inches of insulation were sandwiched between the interior and exterior of the wall as a thermal break. In reverence for the soil, all other materials, as well as plumbing and electrical chases, are not integrated into the rammed earth walls. A shadow created by the reveal where the floor and ceiling meet the rammed earth wall heightens the distinction between them and reinforces the importance of the rammed earth.

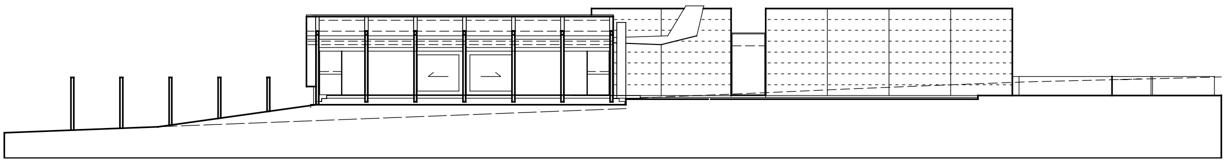
Other materials in the house take on aspects of grafting and folding. Additional interior walls are faced with a golden sassafras veneer and seem to grow from the rammed earth walls, unfolding to become shelves or places to sit. The wood also clads the ceilings in the living area, kitchen, and main bedroom. The architect's use of metal was inspired by grape leaves—aluminum sheets are contoured to reflect the light from the sun, as is the stainless steel mesh over the ironbark structure of the veranda. To complete the analogy, a steel drainage system unfolds from the roof and is bent to carry water away from the structure.

**opposite, top: View of the northern rammed earth wall and the ironbark veranda**

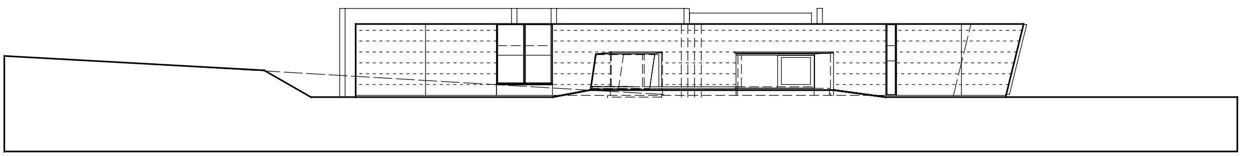
**opposite, bottom: The terminus of the rammed earth wall is a dynamic gesture toward the vineyard.**

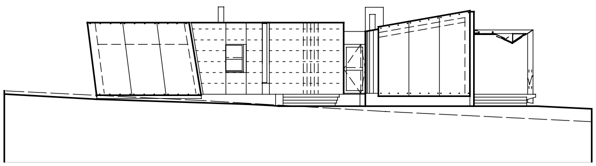
Site plan



North elevation



South elevation



East elevation

top left: A glass wall in the master bed-room frames a view of the vineyard that is defined by the tapering and angled rammed earth walls.

top right: Each column on the veranda is made of two meticulously grafted pieces of wood.

bottom left: A steel gutter is folded and bent like grape leaves to carry water away from the roof.

bottom right: Golden sassafras veneer unfolds across the surface of the interior, becoming furniture, such as seats or mantels.

ORGANIZATION

**Design Build BLUFF**

LOCATION

**Red Mesa Chapter, Navajo Nation, Utah**

DATE

**2004**

Design Build BLUFF is a semester-long course offered by the University of Utah's College of Architecture and Planning, dedicated to providing housing for families with unique needs and in challenging circumstances, predominately members of the Navajo Nation. With the unemployment rate more than double the national average and with 43 percent of the Navajo Nation population below the poverty line, Design Build BLUFF (DBB) provides a noble service. Founder Hank Louis worked with the late Samuel Mockbee in Alabama, and in 2000 he brought the ideas of the Rural Studio to the Utah desert. In 2004, eight architecture students enrolled in Louis's studio designed and built the fourth DBB house over the course of a semester. The house, innovative in both its contextual and cultural responsiveness, was named for client Rosie Joe, who resides there with her family. Rosie selected the site and humbly requested that the house have a kitchen. To this the students added three bedrooms, a bathroom, and a living room, to arrive at a 1,200-square-foot off-the-grid home with a budget of $30,000.

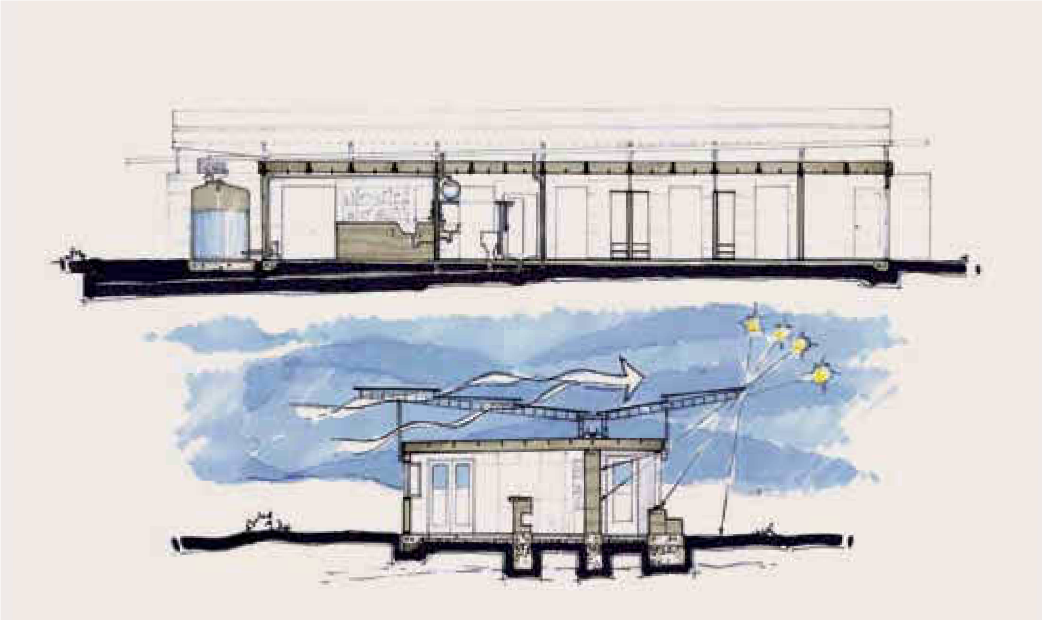
The site lacked any utilities, which demanded that most of the work in constructing the house be done by hand. Electricity to power lighting and small electric appliances in the house is supplied by photovoltaic panels, and a propane tank powers the refrigerator and the stove, but those are the only active energy-consuming appliances in the house. The house is primarily cooled and heated passively via the rammed earth wall, the central spine of the house that regulates the interior temperature in both the summer and the winter. This 18-inch-thick thermal mass was constructed with sand and clay excavated from the site and compacted to form an architectural feature reminiscent of the ancient stone walls constructed by the Anasazi, the ancestors of the Navajo. In the summer, the rammed earth is in shade, remaining a constant temperature, but in the winter, it is exposed to direct sunlight and stores its heat, radiating its warmth back into the house throughout the day and night. This seasonal rhythm is regulated by an ingenious and dynamic roof structure calibrated to respond to the position of the sun throughout the year. Trusses made of steel reinforcing rods, typically used to strengthen concrete, form an inverted roof profile that diverts water to a cistern for domestic use, directs views out to the remote landscape, and shades the house from the sun.

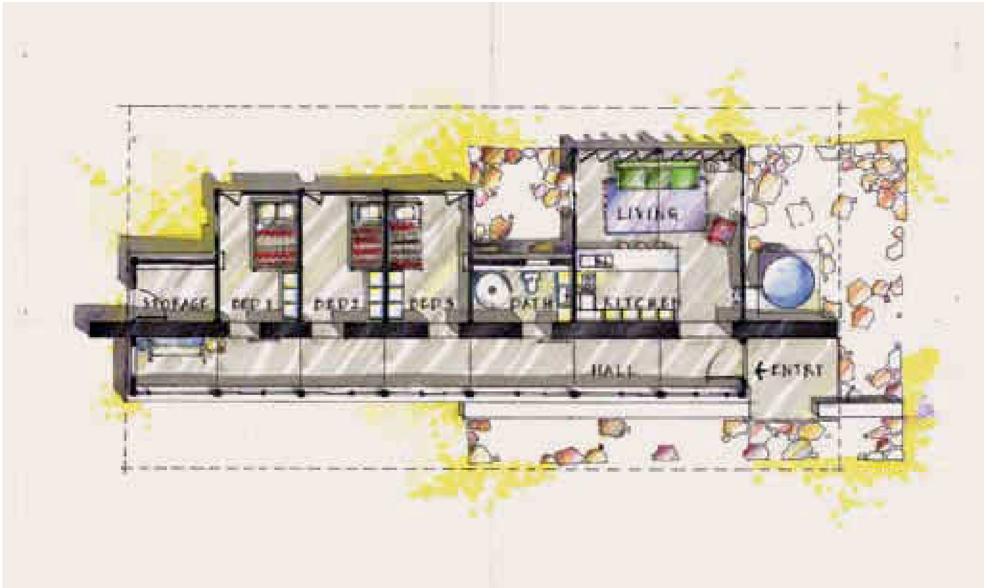
During winter months, however, the sun penetrates through the south-facing wall of windows along a hallway within the house. The warm air absorbed by the thermal mass moves into the bedrooms and living spaces through the openings in the rammed earth wall. An insulative wall system made of compacted straw sandwiched between clear acrylic panels keeps the warmth in the house. Doors that close off spaces inside a house are not a traditional part of Navajo homes, and here the architects used this precedent to create a constant flow of air between the south- and north-facing divisions of the house.

opposite: Located far from utilities on the Navajo reservation, the Rosie Joe House is powered by photovoltaic panels and propane.

right: The thermal mass from a central spine of rammed earth passively heats and cools the house.

# Rosie Joe House



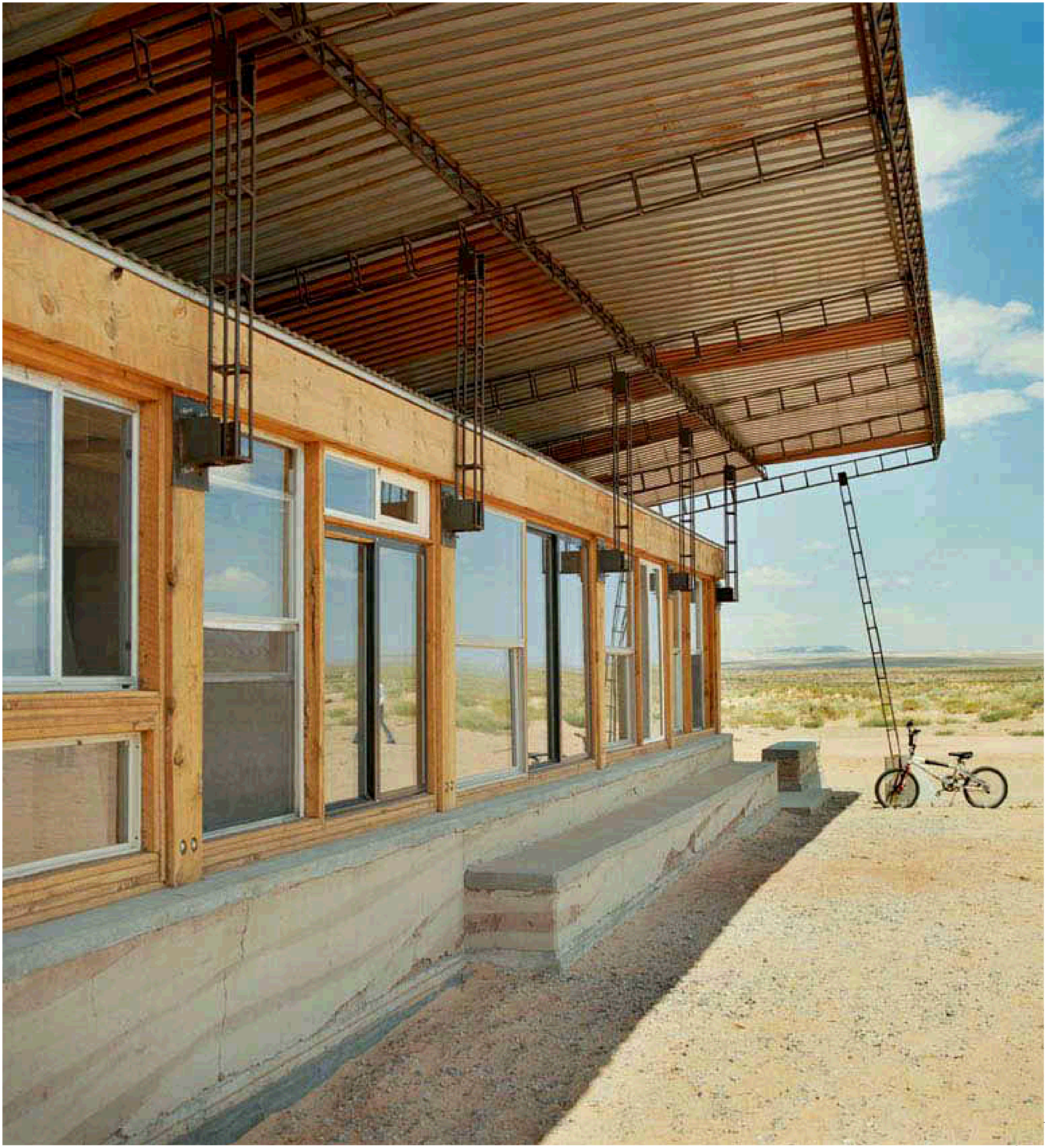



top: Drawing illustrating how water collected from the roof is diverted into a cistern and how the roof's design responds to seasonal solar angles

bottom left: Rosie Joe comfortably weaves a traditional Navajo blanket in a space insulated by compacted straw sandwiched between translucent acrylic panels above and below the windows.

bottom right: Floor plan

opposite: Metal brackets anchor the roof structure to the house.



# Zousei Architecture

ARCHITECTURE FIRM

**Manabu + Nez/Loco Architects**

LOCATION

**Tsukuba, Japan**

DATE

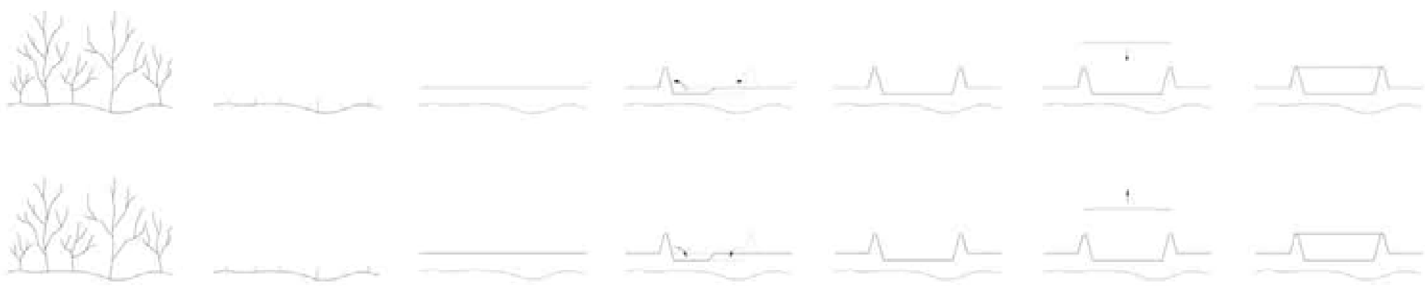
**2005**

The number of earthquakes that occur in Japan has prompted very stringent building codes that do not permit rammed earth construction. Though it possesses very high compressive strength, it has very little tensile strength, and if it is not reinforced, an earthquake can crumble rammed earth walls to the ground. Nevertheless, Tokyo-based Manabu + Nez/Loco Architects proposed using *zousei*, the art of excavating and piling soil, in their entry for a design competition whose brief was to create a concept house that impinged as little as possible on the environment. In addition to questioning the nonacceptance of earth architecture technologies in Japan, the architects sought to blur the spatial boundaries found within the typical house. Their design also blurred the boundaries between residential construction and large-scale construction.

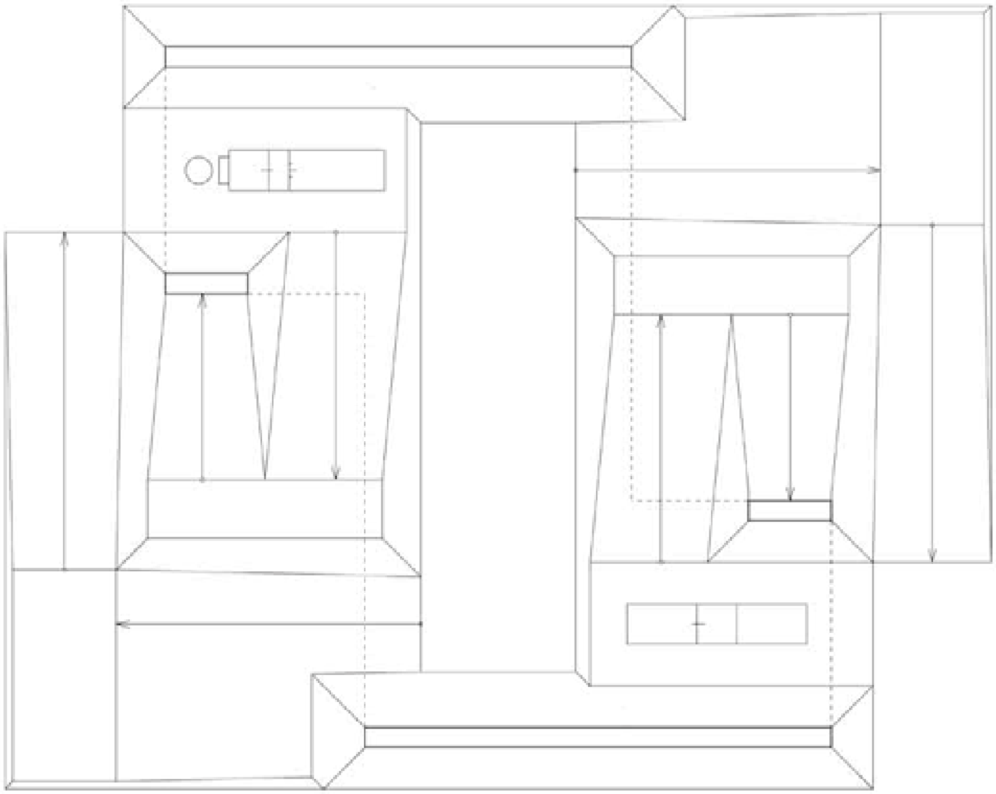
The house was located in a Tokyo suburb on a perfectly flat site that the architects describe as like any other suburb in Japan. The soil used to construct the rammed earth walls was taken directly from the excavation of the foundations, using construction techniques and equipment more commonly employed for large-scale earthwork projects than for small residential projects. A new type of landscape was created using backhoes, rollers, concrete-mixing trucks, and earth tampers—a topography for living. Canted masses of rammed earth were formed to make walls, floors, and sloping planes that created a loose division of spaces connected in a variety of ways. The result was a conceptual interpretation of a house that blurred the divisions between inside and outside, landscape and architecture, natural and artificial.

From the interior, a rammed earth ramp took visitors to the roof, a continuation of the house's open-ended circulation system. The roof was constructed of portable steel plates, commonly found on construction sites, where they are used to cover excavations or to provide traction for heavy machinery. Here, the large steel plates were supported entirely by the compacted earth and were welded together to form a continuous roof structure that also served as a bridge linking indoors, outdoors, and two distinct spaces within the house. To demonstrate the ability of the house to return the landscape, when the exhibition of the house ended, the steel plates were removed and the house was left to erode gradually and be reclaimed by the surrounding vegetation.

opposite: A rammed earth ramp connected the interior of the house to the roof.



Diagrammatic sections



Floor plan

left: The house was constructed using techniques and equipment more commonly found on large-scale earthwork projects then on small residential projects.

center: The roof was constructed of steel road plates.

right: The house was constructed entirely with soil from the site, which was returned to its original state through natural processes.

top: The architects explored zousei, the art of excavating and piling soil, in their design for a concept house that blurs the spatial boundaries found within the typical house.

bottom: Canted masses of rammed earth make walls, floors, and ramps that create open, connected spaces.

ARCHITECTURE FIRM

**Kerry Hill Architects**

LOCATIONS:

**Paro, Thimphu, Punakha, and Gangtey, Bhutan**

DATE

**2005**

Most structures in western Bhutan are constructed of earth. Wattle and daub is commonly used for interior walls, but rammed earth is the dominant building technique in the region. From humble houses to massive fortified monasteries, buildings are constructed by compacting soil between wood shuttering, using handheld tampers, and then rendered with a white lime plaster to prevent erosion. Earthen building traditions have thrived here because of Bhutan's political and geographic isolation; but recent developments by aid agencies and tourism have begun to change this well-preserved heritage, and earth is increasingly being replaced with concrete. Amankora Bhutan Resorts, however, have challenged the increasing influence of "modernization" in the country. Although tourists pay as much as $4,000 per night for a luxury suite in these five-star accommodations, the architecture reflects much humbler ideals.

The four resort hotels are located in small villages, and tourists are encouraged to travel between the lodges to experience the diverse landscapes and cultures of the country. The Amankora Resorts derive their name from the Sanskrit words *aman*, peace, and *kora*, a circular pilgrimage, in the national Bhutanese language, Dzongkha. Visitors making the pilgrimage between lodges travel through Bhutan's central and western valleys, which reach heights of up to 9,800 feet above sea level, through forests and glacial landscapes, over precarious suspension bridges crossing raging rivers, surrounded by snowcapped mountains. Between treks, visitors can enjoy respite with modern amenities such as high-speed internet, fine dining, spa treatments, and shopping at each lodge.

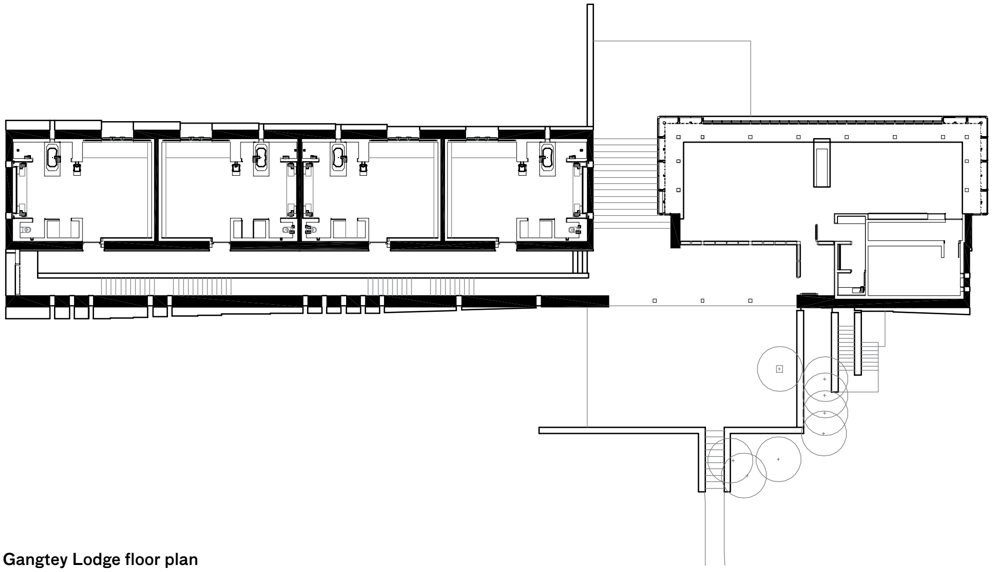
The materials, forms, and proportions used by Kerry Hill Architects in the design are Bhutanese in spirit and are informed by traditional regional architecture. Much of this inspiration comes from the remote Gangtey Goemba—a massive rammed earth monastery constructed in the seventeenth century of wood, earth, and stone—close to where one of the hotels is sited. The lodges balance contemporary and traditional architecture; here, the past and the future come together in a spa that has the essence of a monastery.

The interiors are an exercise in contrasting traditional and contemporary materials. Floors, interior walls, and ceilings alternatively use different textures of wood representing varying levels of refinement: plywood, local milled lumber, and rough sawn lumber . Stone, a common element in Bhutanese architecture, is employed for interior and exterior flooring surfaces and retaining walls, as well as in the construction of massive outdoor tubs. Though fabrics designed specifically for the spa were woven from nettle, yak hair, and wool and employ traditional motifs and patterns, they appear modern in the spare aesthetic of the interiors.

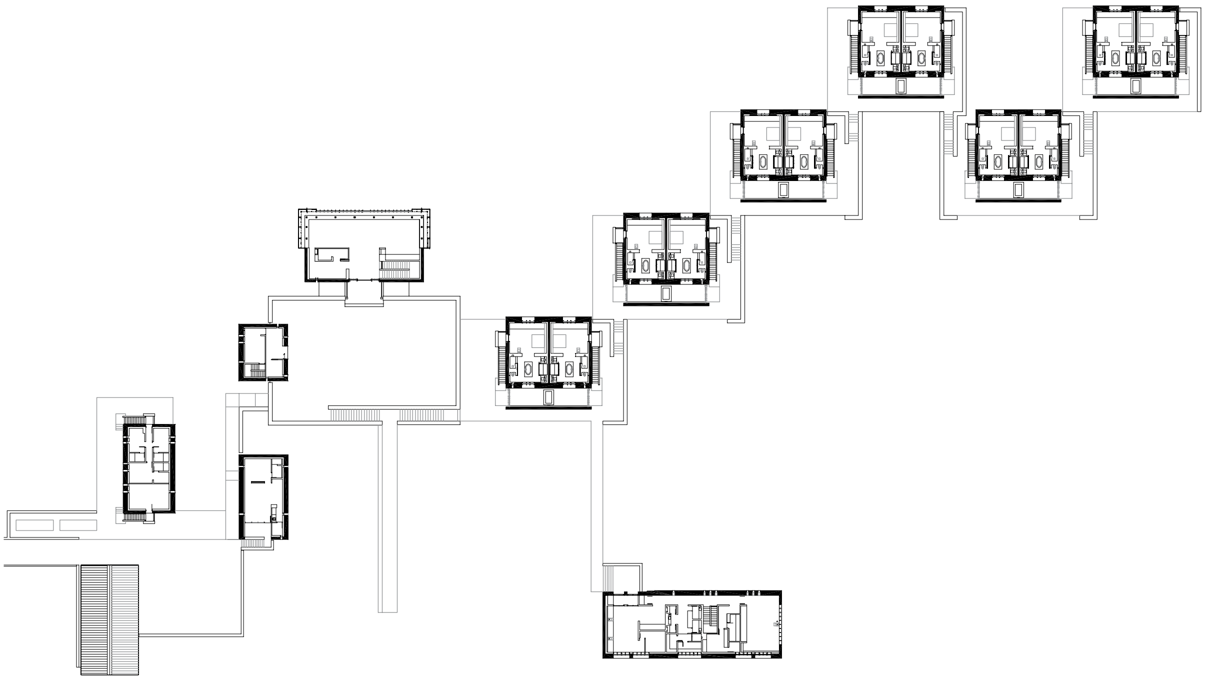
Exterior walls are made of locally sourced soil that was carefully stabilized with a small amount of cement and waterproofing additive. This was then poured into metal formwork and compacted in layers using pneumatic tampers; small holes left by the tie-rods that held the formwork together recall the construction process. The exterior surface is treated with a sealant that prevents moisture penetration. These features make them structurally superior to traditional earthen walls and more resilient to seismic activity. Whereas traditional rammed earth walls are often protected with plaster, the exposed earthen walls of the resort ironically suggest a different kind of protection—that of traditional Bhutanese building practices in a global society.

opposite: The Amankora Bhutan Resort lodges are located in forested mountains up to 9,800 feet above sea level.

# Amankora Bhutan Resorts



Gangtey Lodge floor plan



Amankora Lodge floor plan

top: Canted rammed earth walls and refined wood detailing are modern takes on a centuries-old Bhutanese building tradition.

bottom left: Small holes in the wall recall the construction process and were created by the tie-rods that held the formwork together.

bottom right: Interiors are entirely enclosed in different textures of rough-cut, milled, and veneer wood for floors, walls, and ceilings.

ARCHITECTURE FIRM

**Christopherchris Architecture**

LOCATION

**Mornington Peninsula, Victoria, Australia**

DATE

**2006**

Australia's Mornington Peninsula, outside of Melbourne, is known for its farms, wetlands, vineyards, and coastal scenery. When the young Australian architecture office Christopherchris Architecture was asked to design a house on a hill with vast vistas of the surrounding landscape, they took it upon themselves to create a house that controls the phenomena of views and light by carefully revealing them through a sequence of experiences that begins upon arrival at the house.

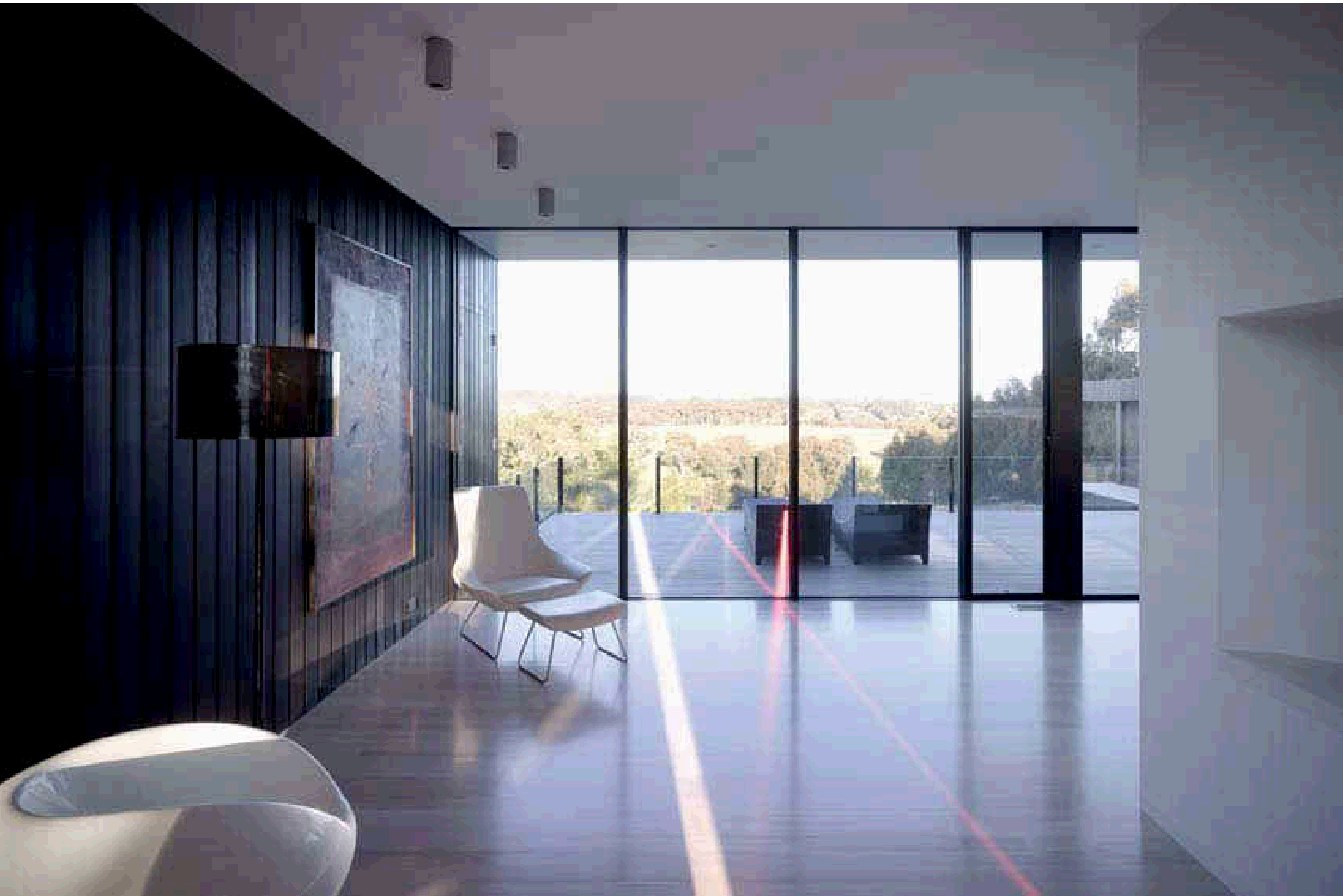
A long, elegant rammed earth wall that runs the entire length of the entry facade is interwoven with several other materials that create a striking composition. Dark stained cedar panels contrast and intersect the light-colored rammed earth wall to articulate the roof and entry. Both earth and wood are broken by slits of glass, and the roof plane is interrupted at the corner by a white cedar volume that rests upon the earthen wall and frames a large glass opening. The elegant and complex facade, however, is a visual barrier, filtering what lies beyond from the eye. At the entry a hint of what is to come is presented through the transparent glass sidelights that surround the cedar door, and entering is a visual release, tantamount to breaking through a dam; the view is released through a glass facade, across a wood deck, down the hill, and across the valley to the bucolic landscape beyond. Inside, the house appears much larger than it does from the exterior due to the quality of light in the space. The long earthen wall also conceals the fact that the house is L-shaped. From the interior, at the intersection of the two wings, a second-story master bedroom, contained in the elevated white cedar box, acts as a hinge, marking the location of the kitchen and the point from where the three children's rooms extend out to the landscape to frame the unsurpassed view.

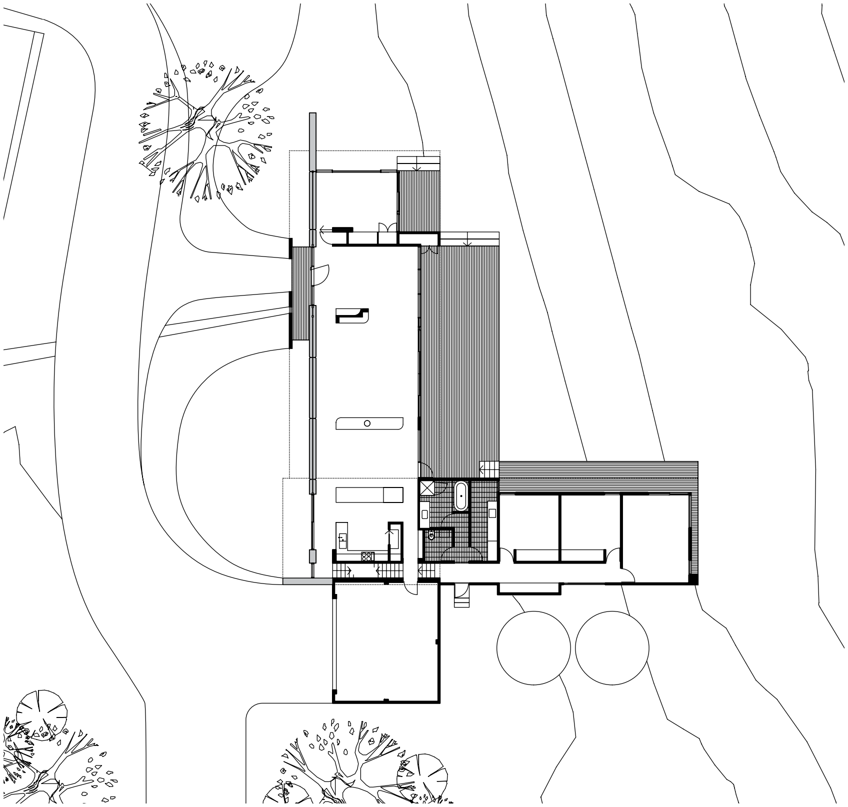
Careful detailing of materials also brings the exterior inside in a number of remarkable ways. The long rammed earth wall is exposed on the interior, defining a corridor that runs the length of the house, which is visually extended into the landscape as the wall continues past the glass opening at the terminus of the hallway. A stained cedar wall also continues through the glass from outside to become a closet and storage area, separating the living area from the guest bedroom. Light also slips into the interior of the house through long horizontal slits between the rammed earth wall and the roof and through tall vertical slots in the facade; the interior light is either diffuse or focused depending on the time of day. An opening in the wall where the first and second floors of the house meet contains a small spot of red glass. Light comes through this window only for a very brief moment each day, marking the passage of time. A tall, thin piece of red glass near the entry creates a laser-sharp shaft of red light across the floor of the living room during the afternoon. Because this phenomenon lasts for several hours, it becomes a measure of the constantly changing position of the sun and stands in contrast to the vista, which is timeless and still.

opposite, top: The south side of the house is a long, elegant rammed earth wall interwoven with dark cedar and glass.

opposite, bottom: View of the valley from the main entrance

# Red Hill Residence



Site plan

bottom left: A large fireplace and entertainment center separates the kitchen from the living area.

bottom right: Dark panels of stained cedar move from the exterior to the interior, bringing the outside into the house.

opposite: The long rammed earth wall is exposed both on the exterior and the interior and defines a corridor that runs the length of the house.

DESIGN FIRM

**Gallo Powell Consortium**

LOCATION

**Tucson, Arizona**

DATE

**2006**

The legacy of earthen architecture in Arizona is diverse and extensive. Native Americans, Latinos, and more recently a growing population of Anglo-Americans have left traces of earth in the desert landscape. Often, Southwestern architecture responds stylistically to past architectural legacies but ignores the poetic and environmentally responsiveness of these earthen traditions. Such is not the case for the Back 40 House. It was designed by two recent graduates from the University of Arizona School of Architecture, Andy Powell and Jason Gallo, who examined ancient desert dwelling principles while employing current technologies in environmental thinking and making conscious efforts to lean away from any trace of historical stylistic mimicry.

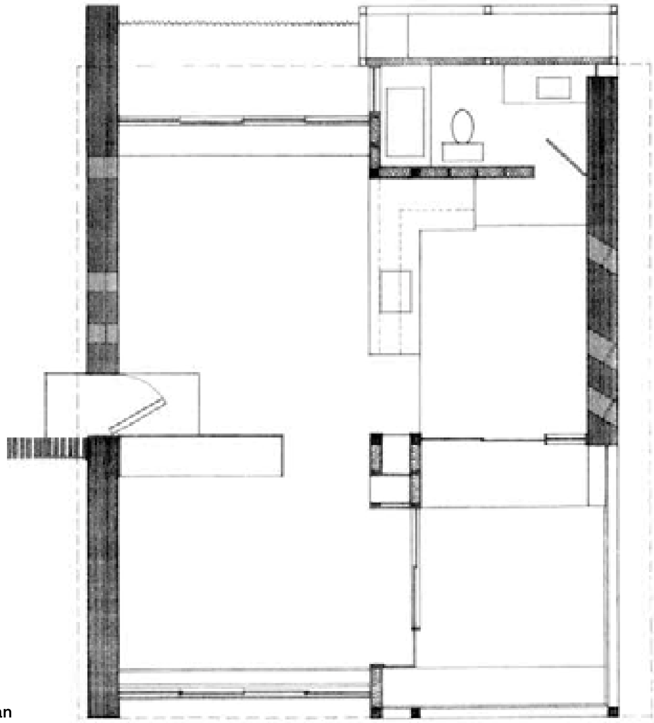
The client, Powell's parents, named the Back 40 House after their backyard, where they wished to have a guesthouse. For his design thesis, Powell elected to take on the project from concept through design and construction drawings and, with the help of his partner, Gallo, the construction of the house. The design was inspired by the pit houses built by the Hohokam Native American culture that once inhabited the Tucson Basin. Like these traditional houses, for which builders first dug a 2-foot-deep impression in the soil to moderate interior temperatures in the harsh desert climate, the living room of the 750-square-foot Back 40 House is buried below grade. After digging the pit, the Hohokam would construct a wooden framework upon which mud, made from the soil taken from the pit, was applied. Here, that framework was a reusable plywood form, reinforced with 2-by-12-inch whalers that allowed a crew of four people to build a 6-by-8-foot rammed earth wall section each day, using soil excavated from the pit.

The soil used to construct the walls was combined with 4 percent cement for stabilization, mixed in a cement mixer, and carried to the forms in buckets. To avoid solar gain, openings in the 18-inch-thick walls are tiny and angled slightly south to capture only moments of the winter sun. These small light shafts never exceed 12 inches in width and therefore do not require concrete lintels. The roof is anchored to the wall using long threaded rods that extend down through the wall and into the foundation. Irregularities in the earthen wall that would make the roof structure difficult to level are resolved by placing 1-inch rigid insulation below a bond beam made of wood and a steel channel that is compressed using the threaded rods. The roof joists are then attached to a box beam, giving the appearance that the roof structure is reaching out to grab the thick walls.

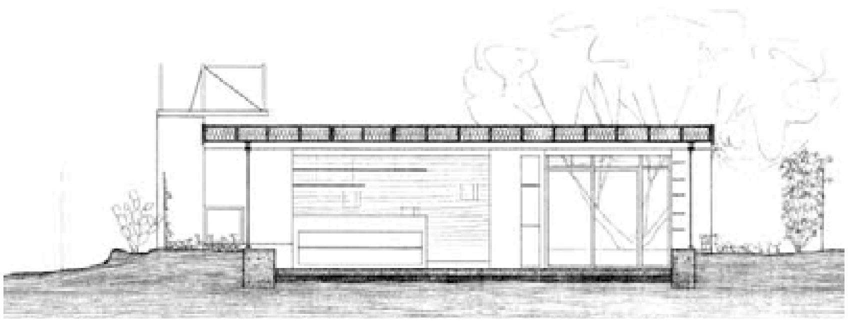
In addition to its structural innovations, the roof also responds to environmental concerns. Twelve inches of recycled cotton insulation buffer it from the Arizona sun. A central gutter channels water to a reflecting pool that irrigates the garden and a wall of climbing vines. On the roof a passive solar system heats water for domestic use, and this water also warms the house through radiant tubes embedded in the concrete floor slab. Gray water from the sinks and baths is directed to the landscape to irrigate a mesquite tree and other vegetation that in turn, shade the house from the desert sun.

# Back 40 House

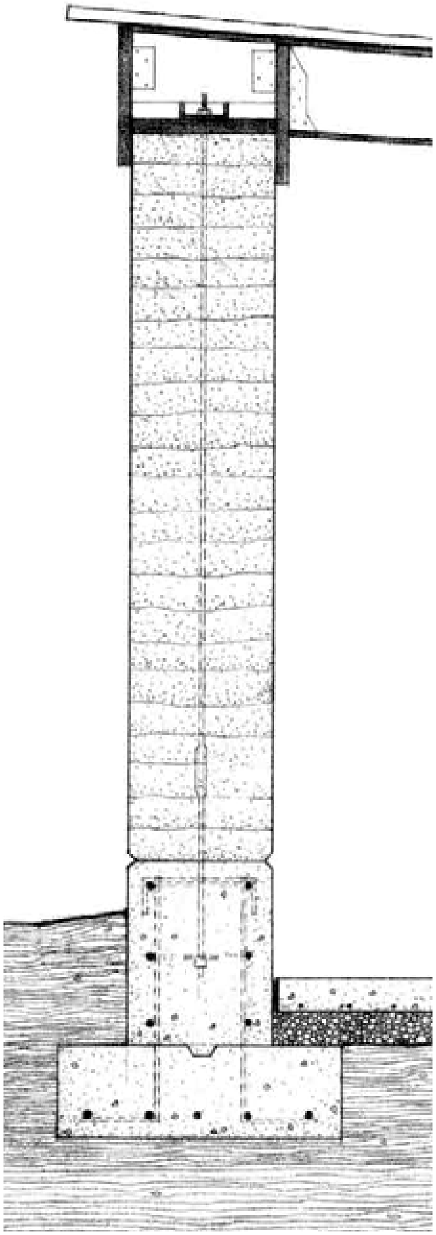
Small windows that puncture the thick walls are angled to avoid any summer solar gain and are small enough to not require a lintel.



Floor plan



Section



Section of the wall-and-roof assembly

top: Water from the roof collects in a reflecting pool that irrigates the garden and a wall of climbing vines.

bottom left: Like the ancient houses of the Tucson Basin, the Back 40 House is buried slightly below grade to help keep the interior cool.

bottom right: East elevation

ARCHITECTURE FIRM

**Hotson Bakker Boniface Haden**

LOCATION

**Osoyoos, British Columbia, Canada**

DATE

**2006**

The Nk'Mip Desert Interpretive Centre is the first of several Native American cultural buildings in British Columbia that plan to use expressive architecture to convey the rich history and promising future of native culture. The Osoyoos Indian Band, which belongs to the larger Okanagan Nation that extends south into the United States, hired Hotson Bakker Boniface Haden to design the Desert Interpretive Centre as part of a larger master plan, on a 200-acre site that will eventually include a winery, golf club, and resort hotel.

The site is adjacent to 1,800 preserved acres of the Great Basin Desert—an expansive Canadian biome that lies south of the Okanagan Valley in Osoyoos, British Columbia. This unique environment is on the northernmost tip of the Great American Desert that extends to the Sonoran Desert in Mexico, and it is considered among the most beautiful and endangered landscapes in Canada. The climate is dry, with temperature extremes ranging from 0° Fahrenheit in the winter to 104° Fahrenheit in the summer. The Osoyoos are proud of their historical role as stewards of this unique landscape and wanted the concept for the center to promote sustainability and draw attention to the fragility of the desert—to reflect their own core values. As a focal point of the community, the center was also an opportunity to develop an architectural identity that was authentically south Okanagan—a reaction against the imported faux–Santa Fe style commonly found in the region.

The approach to the partially earth-sheltered building is designed to intentionally divert the view away from the development to the west. Views of the desert rising up behind the building toward the mountains in the distance are, instead, revealed through a series of concrete walls that lead to a courtyard at the end of a massive rammed earth wall. This is the largest rammed earth wall in North America, at 262 feet long, 18 feet tall, and 24 inches thick. The wall is constructed of local soils mixed with a small amount of cement and color additives to create layers of earth that evoke geological sedimentation. Each layer of colored soil was pneumatically compacted to approximately 50 percent of its uncompacted height. The interior and exterior of the wall were left unfinished to reveal the stratification of soils and the memory of the wooden formwork. Unlike traditional rammed earth, generally a solid mass, this wall is made up of two layers of earth that improve its thermal performance. The exterior and interior walls are similarly constructed 10-inch-thick rammed earth that sandwich 4 inches of R32 insulation to improve the thermal qualities of the wall. This light-weight insulation cavity also allows openings in the wall to be larger, which the architects took advantage of to create the enormous horizontal window that defines the entrance to the center.

An auditorium, exhibition space, gallery, gift shop, and pit house make up the major program within the building and present information about the Osoyoos and their historical relationship with the land. Outside, an open-air amphitheater, teepee, rooftop native planting exhibit, and snake research and demonstration area—an award-winning project where visitors can see endangered rattlesnakes—continue the exhibit. The center also serves as a trailhead for guided and unguided walks through the 1,600 acres protected as a conservation area by the Osoyoos—a continuation of their dedication to sustainable practices.

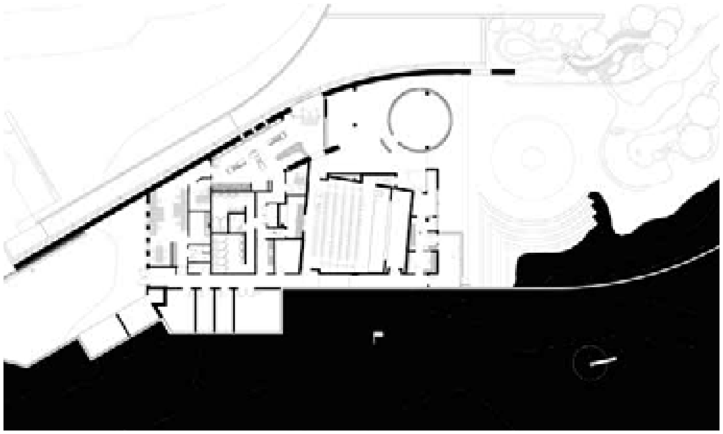
The design of the building also promotes environmentalism in other ways. As an earth-sheltered building, the landscape continues onto its roof, so it has a smaller visual imprint on the landscape and more space for native species of plants to be reintroduced on the site. This habitable green roof also provides greater thermal stabilization and insulation for the interior spaces, supplementing the radiant cooling system embedded in the roof slab. The floor slab contains radiant heating, and the

opposite, top: The building fits perfectly within the surrounding desert landscape without referencing historical or regional styles.

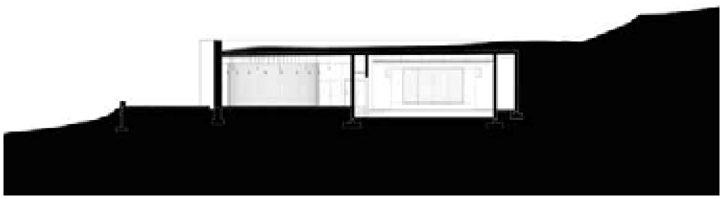
opposite, bottom: Local soil mixed with color additives accentuates the rammed earth layers reminiscent of geological sedimentation.

# Nk'Mip Desert Interpretive Centre

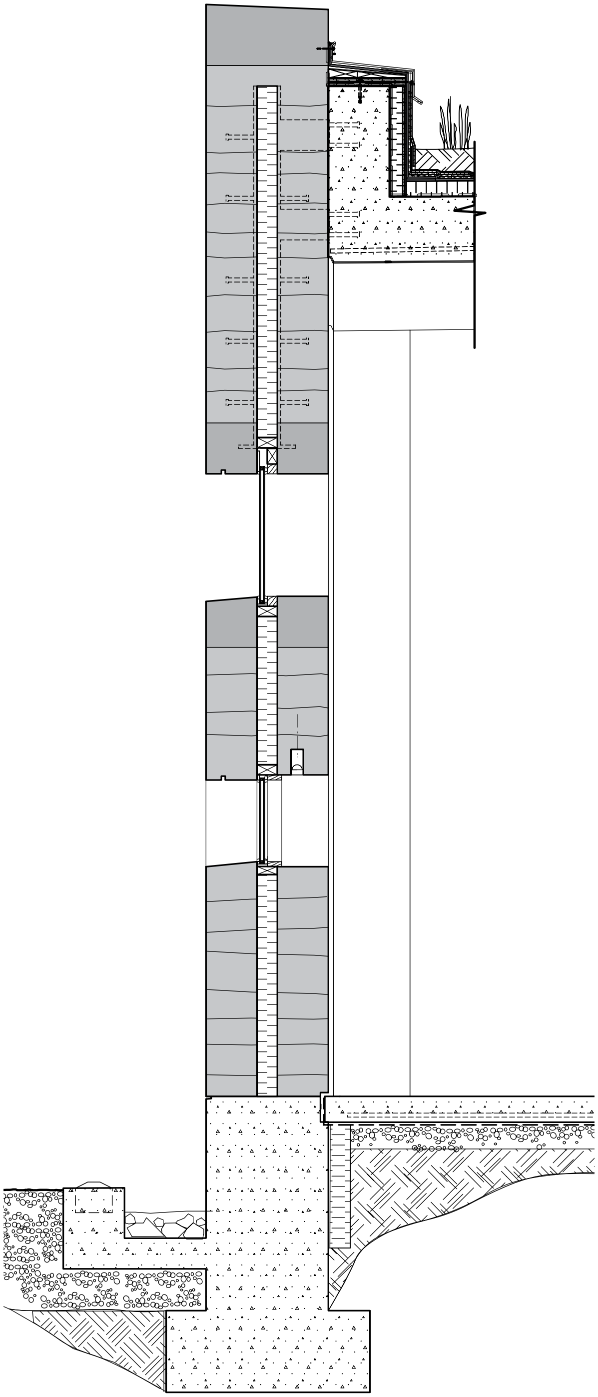
two systems, coupled with natural ventilation, create a comfortable and quiet environment and save up to 50 percent over traditional heating, ventilation, and air conditioning costs. Because water is a precious resource in the desert, low-flow faucets, waterless urinals, and dual-flush toilets are used in the building. Blue-stain pine, which is tinted blue by a pine beetle epidemic, is typically undesirable in finish construction. However, the wood was used throughout the building because of its low cost and availability. Sustainability also played a social role: band members participated in the construction process, learning the craft of making rammed earth walls.



Site plan



Section



Section of wall-and-roof assembly showing insulated rammed earth wall


top: The path to the main entrance guides guests along the massive rammed earth wall that frames views of the mountains in the distance.

bottom left: Blue-stain pine was used throughout the interior of the building.

bottom right: South-facing view of outdoor amphitheater seating

ORGANIZATION

**Drachman Design-Build Coalition**

LOCATION

**Tucson, Arizona**

DATE

**2006**

The Drachman Institute is a research and public service unit of the College of Architecture and Landscape Architecture at the University of Arizona, dedicated to the environmentally sensitive and resource-conscious development of neighborhoods and communities. It has a particular focus on the proposition that "housing is the building block of neighborhoods and neighborhoods are the building blocks of communities." The work of the Drachman Institute targets the development of demographically diverse neighborhoods and promotes well-designed, regionally appropriate housing that conserves land, energy, and water; it contends that good quality and innovative architectural design and technology, sensible community planning, and landscape architecture that fosters beautiful and healthy private and public space are the cornerstone of this goal. To accomplish this, students, staff, faculty, and citizens are engaged in a collaborative, research-based outreach enterprise to make communities healthier, safer, more equitable, and more beautiful. Through the institute, professors of architecture Mary Hardin and John Folan formed the Drachman Design-Build Coalition and partnered with Chicanos Por La Causa (CPLC)—an Arizona-based community development corporation committed to building stronger, healthier communities—to create Residence 1: a three-bedroom, two-bathroom house with a kitchen, living room, laundry room, carport, and garden.

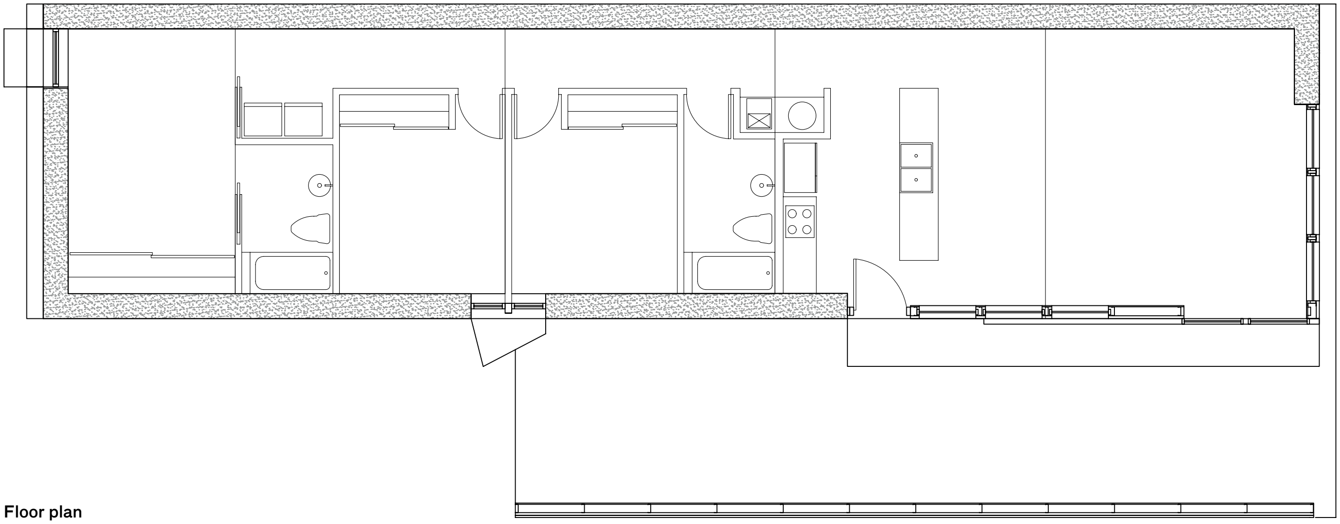
The house is sited on a long, narrow infill lot with east-west solar exposure and surrounded by houses constructed between the 1920s and 1950s, most of which are in poor condition. To assist a stable working family in this distressed area, where the annual income is below 80 percent of the mean for Tucson, CPLC provided home-ownership and budget-counseling courses to the client, and the Drachman Institute funded the design and construction of an energy-conscious prototype house. All of the construction work, except for the concrete floor, plumbing, and mechanical work, was done by University of Arizona architecture students and faculty. The xeriscape garden, made up of desert plants that require very little water to maintain, was designed by students in the Landscape Architecture School and planted by local high-school honor students.

Residence 1's walls are made of 18-inch-thick rammed earth and form a continuous 76-foot-long barrier along the western facade. The rammed earth has no openings that might allow for solar gain and takes advantage of the "flywheel effect" whereby solar energy absorbed by the wall during the day is released into the cool night air before it can enter the interior of the home. It also encloses the house below the carport on the east side of the building, keeping it protected and cool and further contributing to the interior comfort of the house. The remaining structure is constructed of a steel frame clad with galvanized metal, which reflects the desert sun, and the cladding for the ceiling is made of inexpensive plywood sheathing. Additional exterior walls are made of translucent, ultraviolet-resistant polycarbonate sheeting that admits even, cool light into the house. This lightweight material is also used on a large sliding door that opens up to the carport, extending the space of the living room and creating an outdoor living room that can be used eight months out of the year.

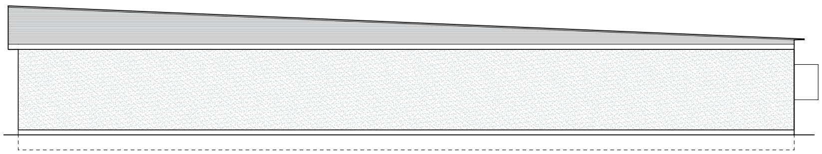
Outside, the xeriscape garden also contributes to the quality of the microclimate surrounding the house. Deciduous paloverde trees are planted on the south side of the house to shade the portion of the rammed earth wall that is not below the carport. Fast-growing eucalyptus trees planted along the west side of the house assist in shading the earthen wall and minimize thermal gain from western exposure. A lemon tree and a pomegranate tree are planted near the carport to take advantage of water runoff from the metal roof. Plants that require little water, such as agave and ocotillo, fill the front yard.

opposite: Translucent, ultraviolet-resistant polycarbonate sheeting allows filtered light to enter the house during the day and transforms the house into a lantern at night.

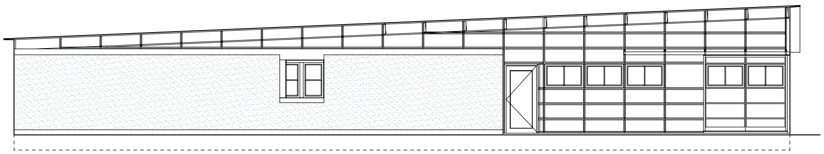
# Residence 1



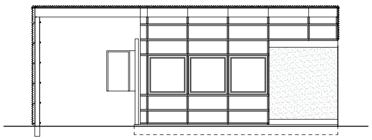
Floor plan



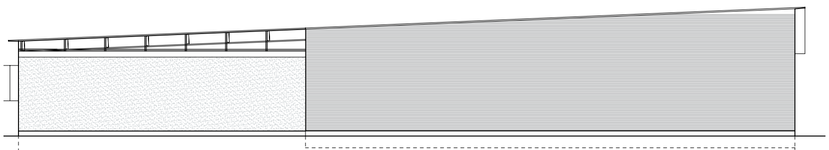
West elevation



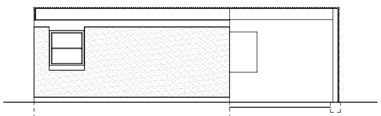
East elevation behind carport



North elevation



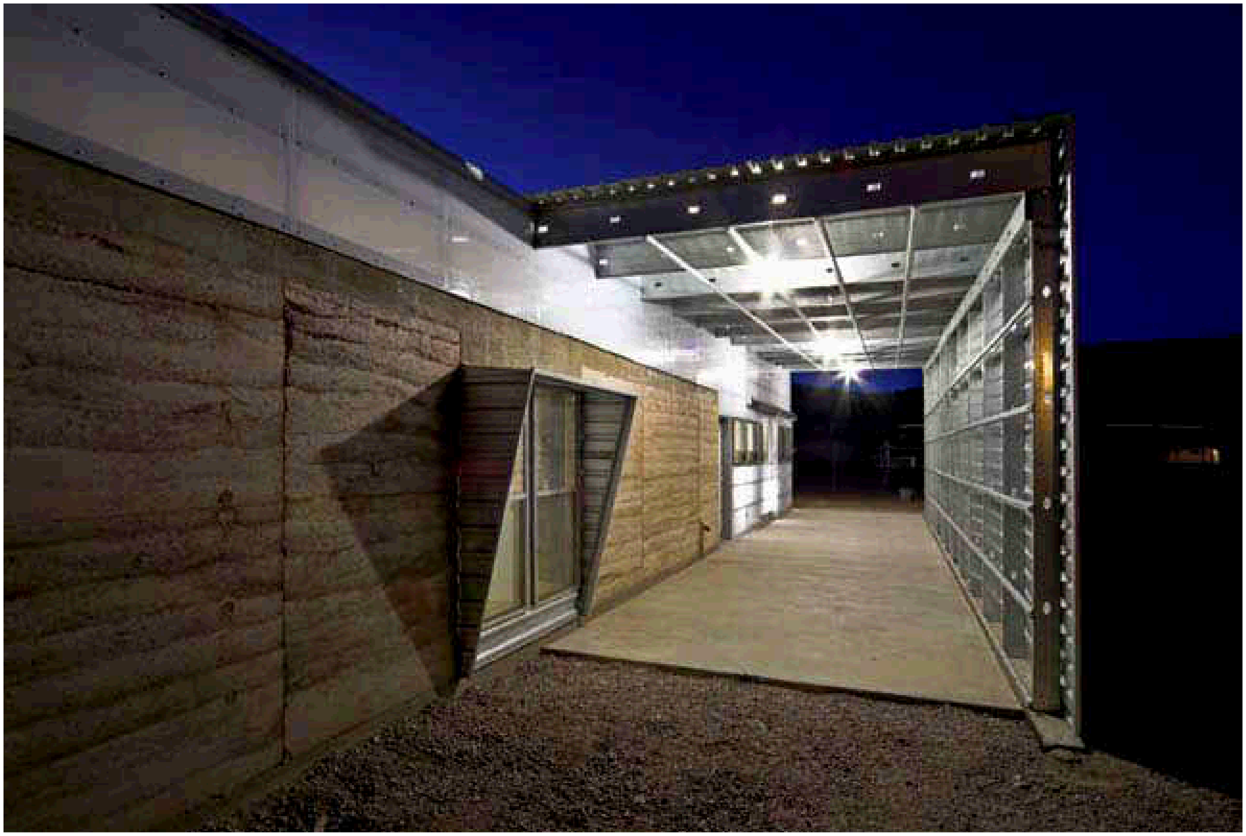
East elevation

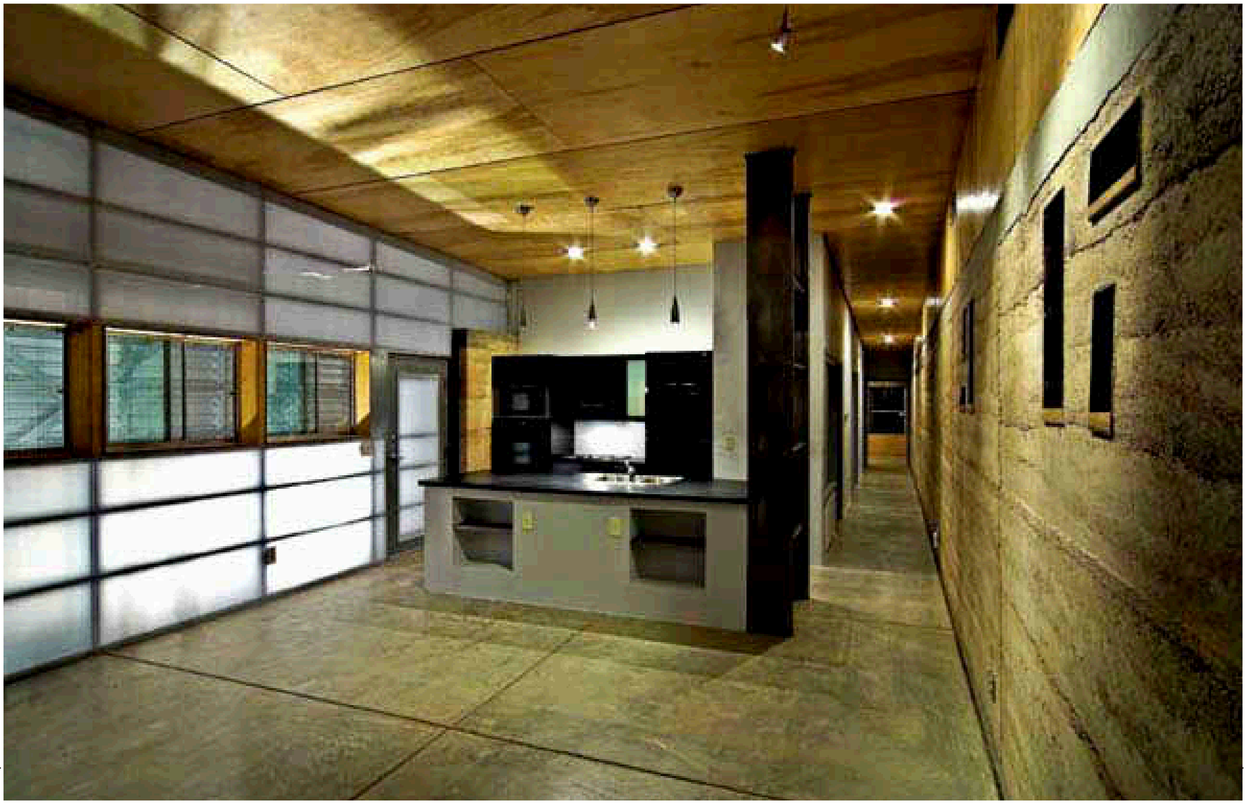


South elevation

opposite, top: The carport doubles as an outdoor living room that can be used eight months out of the year.

opposite, bottom: Simple materials, such as plywood, polycarbonate sheeting, rammed earth, and concrete, are the interior finish materials.





# 2—Mud Brick

Ingredients: Mud, straw, and water. Method: Mix and shape into a brick and bake in the sun until dry. This simple recipe results in perhaps one of man's most important inventions—the mud brick. It is a building module so versatile and durable it has been used for floors, walls, and roofs throughout the world for thousands of years. Exemplary of its elegance, the Arch of Ctesiphon is considered one of the architectural wonders of Mesopotamia. When it was constructed in 400 C.E. this Parthian Persian structure was the largest single-span unreinforced masonry vault in the world, measuring 115 feet tall, 86 feet wide, and 163 feet long, and constructed entirely of mud brick.[1] The world's first skyscrapers, tower houses constructed over five hundred years ago in the city of Shibam, Yemen, reach heights up to 96 feet. Mud brick can be stacked even higher. The minaret of nearby Tarim, Yemen, reaches 175 feet.

Humankind's first cities were also constructed of mud brick. As agricultural knowledge increased, builders realized that agricultural soil, mixed with the straw left over from grain harvests, was highly suited for creating a durable building module. One of the earliest cities, Çatalhöyük, an Early Neolithic site in Turkey, a mud brick town of 8,000 people, dates back as far as 9500 B.C.E.[2] Archaeological excavations at Jericho, the oldest continuously inhabited city in the world, show evidence of mud brick being used as early as 8350 B.C.E.[3] Perhaps there is some connection between the word *urban* and the name of one of the world's oldest cities, Ur, a mud brick settlement that dates back to 5300 B.C.E.; it may have been the largest city in the world at 65,000 inhabitants between 2030 and 1980 B.C.E.[4] At the same time mud brick was being used in the proto-city of Ur, it was also coming into use in the developing cities of ancient India.[5] Archaeologists have also discovered a colorfully decorated 3,700-year-old mud brick in Egypt, one of a pair of bricks that would have supported a woman's feet while she squatted during childbirth.[6] Quite literally, the use of mud brick and the birth of civilization went hand in hand.

Descriptions of tools, methods, and techniques for making and building with mud brick are well documented in the hieroglyphs of ancient Egypt. Egyptian builders also developed a technique for constructing catenary vaults of mud brick without the use of supports. Called Nubian vaults, they can be traced as far back as the construction of the granary vaults for the Ramasseum around 1300 B.C.E. in the city of Gourna.[7] Early proto-pyramids called mastabas were also constructed of mud brick. A mastaba, which means "mud brick bench" in Arabic, was a tomb whose shape resembled furniture found in Egyptian homes. It was beneath these great mounds that important members of the royal family were buried. So revered was mud brick that even after stone became the preferred building material in the construction of the pyramids, the pharaoh Asychis had his built of earth, inscribing on the only stone within it: "Despise me not because of the pyramids of stone, for I excel them as much as Zeus surpasses the other gods. For by plunging a pole into a lake and collecting the mud which hung to the pole, men made bricks and erected me."[8]

The oldest remnants of mud brick on the European continent, which can be traced to the Stone Age city Sesklo in Greece, were mud brick dwellings that housed a population of 3,000 to 4,000 around 5300 B.C.E.[9] These early dwellings, with exterior mud brick walls on stone foundations and a roof supported in part by columns, eventually developed into the *megaron*, the ancestor of the Greek temple. Third-century B.C.E. Athens was also constructed entirely of mud brick, and according to the extensive writings on mud brick by the Roman architect Vitruvius, there were three types: the *pentadoron*, five palms long in both dimensions, for public works; the smaller *tetradoron*, four palms, for private works; and the *Lydian*, one and one-half feet long by one foot wide, a size later adopted by the Romans.[10]

Probably the greatest dissemination of mud brick came through the expansion of religious ideologies. The material was widely used in the construction of mosques and Muslim cities, and the spread of Islam beginning in the eleventh century also expanded mud brick technology throughout Africa, particularly in sub-Saharan and North Africa.[11] The Great Mosque of Djenné in Mali, the largest mud brick building in the world, built in the early twentieth century, is evidence of the strong foothold of mud brick construction nine hundred years after its introduction to the region. Islam spread throughout North Africa and then to Spain, where mud brick became widely used in all building types, from agricultural to religious. Subsequently, Spanish exploration and colonization had the most influence, spreading mud brick throughout the Americas.

When Spanish explorers arrived in the Americas, mud brick was already heavily in use, particularly in Peru, where the settlement of Cerro Sechín shows mud brick in use since 1000 B.C.E. The Huaca del Sol in the coastal desert south of Trujillo, Peru, a

164-foot-tall pyramid whose construction terminated with the use of more than 140 million mud bricks in 450 C.E., was the largest pre-Columbian mud brick structure built in the Americas—larger than any mud brick pyramid of ancient Egypt.[12] Chan Chan, located three miles west of Trujillo and built between 850 and 1470 C.E., was the largest mud brick urban center in pre-Columbian America, with a population estimated to be 30,000 at its height.[13]

Mud brick was also in use in North America, appearing around 500 B.C.E. The residences of the great city of Tenochtitlán during the fifteenth century, one of the largest cities in the world at the time, with 200,000 inhabitants, were constructed primarily of mud brick. The Spanish conquest later propelled the use of mud brick in both North and South America with the construction and reconstruction of cities throughout the new world, particularly the United States' Southwest. The city of La Villa Real de la Santa Fé de San Francisco de Asís, known more commonly as Santa Fé, New Mexico, is the second oldest city and the oldest capital city in the United States, and it is famous for its city center of mud brick churches, shops, and hotels planned on the Law of the Indies—a set of guidelines signed by King Phillip II of Spain to instruct Spanish colonists how to create and expand towns in Spanish America, and thought to be influenced heavily by Vitruvius's Ten Books of Architecture.[14] In the heart of the city is the Palace of the Governors, a mud brick building constructed in 1610 as the original capitol. It is the oldest public building in the United States still in continuous use, currently serving as the New Mexico History Museum. Today, New Mexico is the leading consumer of mud brick in the industrialized world, and the history of mud brick, as well as its etymology, can be traced from New Mexico directly back to the ancient Egyptian builders. *Adobe*, as mud brick is more commonly known, is a Spanish word whose origins are from the Arabic *al-tuba*, "the brick," which came from the Coptic *tobe,* and from Egyptian *dbt,* meaning "brick."[15]

It is often assumed that Spanish and Native American traditions are the only mud brick legacies that exist in the United States. However, during early European settlement, architecture on the East Coast was influenced by English earth building. The home of Paul Revere, the famous American patriot who warned the colonists of the British military advance during the American Revolutionary War, is the oldest house in Boston. Built in 1680, the house is post and timber with mud brick infill—a common form of construction at that time.[16] After the loss of the American Colonies—for which Paul Revere deserves partial credit—forced the British to look toward Australia as the solution to penal overcrowding, they introduced mud brick traditions to the island continent.[17]

Mud brick is ubiquitous because the soils required to make it are as varied as the cultures, periods, and locations that employ it. The Spanish word *zoquete* means mud in northern New Mexico; in northern Mexico, it is used to describe a simpleton. When asked what the relation between the two meanings was, *adobera* Jesusita Jimenez, a mud brick mason from Presidio, Texas, said that "it is because mud is a material so simple that anyone can use it." No special soil is required for making mud bricks. An ideal soil would have coarse aggregate like pea gravel, varying sizes of sand, silt, and clay; however, the absence of any one of these will still result in an acceptable brick.[18] Nevertheless, the soil composition required to create a high-quality brick has been extensively studied. Larger particle sizes of aggregate and sand help create a stronger brick, and silt and clay bind the various components together. When dry, a mud brick with more clay is less strong but more water-resistant. More aggregate means greater strength, but the resulting brick is more susceptible to erosion. The range of percentages of each ingredient to make the optimum mud brick is, as defined by various experts: 2–7 percent gravel, 61–62 percent sand, 22–32 percent silt, and 14–15 percent clay.[19] The beauty of the material is that making it is not an exact science; its potential is strengthened by its variety.

Of course, making mud bricks is not possible with all soils, but too much or too little of any of the necessary ingredients required to make a mud brick can be corrected by the addition of straw, the third most important ingredient next to soil and water. Straw also has other benefits. As a binder, it provides reinforcement, increasing the strength of the brick. It also allows the mud brick to dry more evenly by wicking water from the center of the brick, which prevents cracking as it bakes in the hot sun. Other organic additives besides straw are commonly included, depending on the resources that are available to various cultures. Cactus mucilage, ox blood, paper, corn husks, and manure are examples of binding agents that increase the durability of the material. Manure dries odorless and has the added benefit of repelling insects. Cactus mucilage increases the adhesion of mortar and plaster and helps repels water.

In modern mud brick production, additional stabilizers are occasionally included in the mixture to increase strength, cohesion, and water impermeability, ensuring the structural and economic fitness of the material. Common additives are lime, portland cement, and bitumen. Historically, Assyrians would waterproof mud brick by laying each one in bitumen mortar. Today, emulsified asphalt is an ingredient in modern mud brick production, which insures against erosion or that the material lives up to a performance standard, such as a building code. In the largest mud brick factory in the world, located in Alcalde, New Mexico, stabilizers are added to the mud bricks not for their structural performance, but rather to prevent them from being damaged by rain as thousands of mud bricks cure unprotected in the open air.[20]

Once the ingredients for making a mud brick are prepared, the mixture must be shaped. Many types of mud masonry are formed by hand, taking on several forms: conical, hemispheric, and dentiform, to name a few.[21] The shape of each of these allows it to be stacked in a specific arrangement or to dry either on the ground or on the wall itself. Archaeological evidence shows that in pre-Hispanic architecture, reeds were used to make molds for mud brick. Today, molds are commonly made of wood and can be designed to make one or several mud bricks at a time, depending on the number and strength of the brick makers. The mud mixture is poured into the mold and leveled, then the form is removed, and the process continues. With this process, one person can produce about three hundred mud bricks per day. Industrialized production of mud bricks in modern brickyards employs large, mobile equipment: mud is poured into a hopper and machines fill steel molds. This process can produce up to 70 mud bricks at a time and up to 20,000 mud bricks per day.[22]

With the wealth of historic mud brick structures throughout the world, particularly in developing countries, architects are raising questions about their use in today's culture. Mathias Klotz's Casa Corralones is an excellent example of a historic mud brick agricultural building converted into a house for modern living. But the humble mud brick has long since surpassed its role as a purely tectonic and pragmatic material, and today its use often symbolizes a builder's or architect's attitude toward the contemporary world. For example, the juxtapositions between the United States and Mexico or between the industrialized and nonindustrialized world, are expressed by setting mud brick in cement mortar in the walls of *Prada Marfa*. In other projects, mud brick represents an understanding of the importance of ecological, contextual, and cultural thinking. In the Arrillhjere Demonstration House, the Camacho Residence, and the Bodega en Los Robles, the use of mud brick demonstrates the client's or architect's desire to build responsibly and ecologically. When used for building housing, schools, and cultural projects, mud brick is more than an environmentally and economically responsible material—it is also socially and politically salient. There is a long history of employing mud brick in a way that makes a political statement, as when Asychis rebelled against stone in pyramid construction almost 3,000 years ago or in the Greek distinction between the sizes of mud brick in public and private work. Today, after being used for at least 10,000 years, mud brick has evolved from a simple building system to one that can represent ideals that reflect a broad range of environmental, economic, social, and traditional values in reaction to an increasingly industrialized and homogeneous world.

ARCHITECTURE FIRM
**Antoine Predock Architect**
LOCATION
**Albuquerque, New Mexico**
DATE
**1967–1974**

New Mexico has a long and rich history of earthen architecture. The oldest continuously inhabited buildings in the United States, found at Taos Pueblo, are multistory earthen structures built by Native Americans in the 1100s. In the sixteenth century, Spanish settlers introduced mud brick, which radically transformed native building practices and created an architectural tradition distinct to northern New Mexico. Many types of vernacular architecture evolved from these two cultures, and during the twentieth century many Southwestern architectural styles, such as the Pueblo and Territorial styles, emerged. Unfortunately, as the appeal of these styles grew, architects began to employ superficially motifs inspired by the traditional buildings in new earthen and nonearthen structures, with no regard for scale, structure, and meaning.

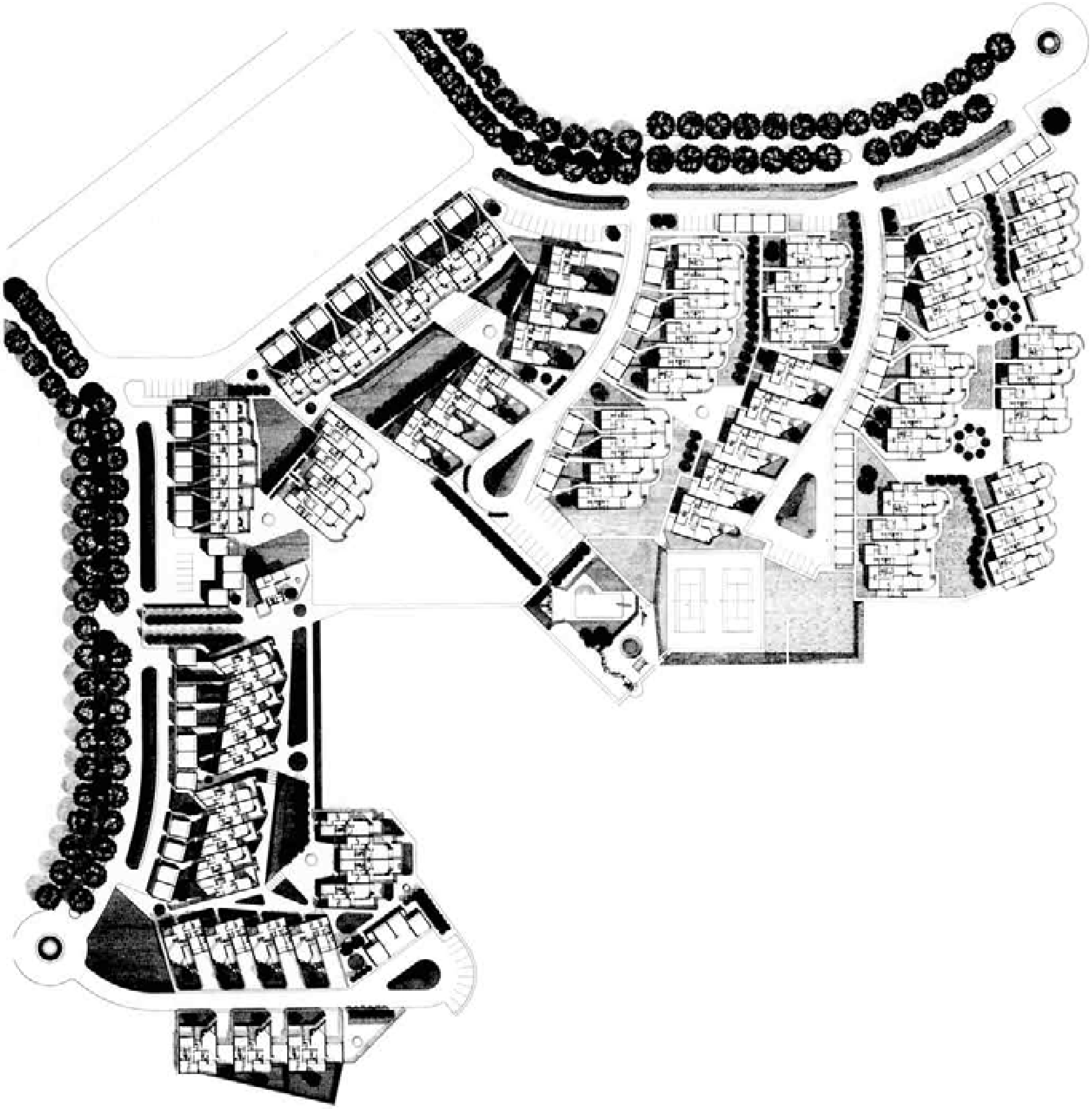
Nestled in the desert landscape of suburban Albuquerque, however, is La Luz, a groundbreaking contribution to contemporary earthen architecture that respects past building traditions but also draws from alternative sources for inspiration. It was the first suburban housing development in the world constructed entirely of mud brick, and it was also the first major project for renowned architect Antoine Predock, designed and built between 1967 and 1974. To design a project that works within the language of modern architecture while fitting within the regional historic context, Predock intentionally looked beyond the regional styles and instead found inspiration in the desert landscape.

Mud brick, brown cement stucco, and white trim are common to the Pueblo style that emerged in the region in the early 1900s; the architecture of La Luz combines these traditional materials with concrete and large glass openings without the decorative pastiche typical of Southwestern-style architecture. Rather than copying the forms of traditional architecture, Predock found inspiration in the silhouette of basalt outcroppings common to the Albuquerque landscape and designed the building to emulate their forms. In opposition to the traditional architecture of the region, which closes itself off from the landscape and elements—a defense mechanism from colonial times when settlers fortified their buildings against attack from Native Americans—La Luz embraces the landscape and opens up to views of the Sandia, Manzano, and Los Pinos mountains in the distance.

It is also a model for suburban development. Unlike most suburban housing that sprawls into the landscape, La Luz is compact. Clustered within 42 acres are ninety-six homes adjacent to 500 acres of land stretching to the Rio Grande River that were preserved for public open space. Each dwelling is connected to this public landscape, while also having its own private outdoor space as well as access to semipublic communal patios and squares. The buildings are also directly connected to the land as all of the mud bricks used to build the homes were made directly on site to reduce transportation costs and are stabilized with a small amount of asphalt emulsion. La Luz proved that large-scale developments can be constructed of earth while being ecological, profitable, and timeless. Today, almost thirty-five years after the community's inception, it joins the legacy of historic earth structures in New Mexico and is listed in the National Register of Historic Places.

opposite: The architecture of La Luz represents a new take on building in New Mexico without historical pastiche.

# La Luz Community



Site plan

top: La Luz with the backdrop of the Sandia, Manzano, and Los Pinos mountains.

bottom left: The architecture of La Luz is minimal and modern.

bottom right: Each apartment opens onto its own private outdoor space.

# Matthews Residence

ARCHITECTURE FIRM

**Will Bruder + Partners**

LOCATION

**Phoenix, Arizona**

DATE

**1981**

It makes sense that one of William Bruder's first widely published works of architecture is constructed of mud brick. He descends from a line of architects in the United States Southwest who actively explored earth as an appropriate building material for the region. Bruder apprenticed for the visionary architect Paolo Soleri at Cosanti, an experimental town in the high desert of Arizona, seventy miles north of metropolitan Phoenix. Soleri was trained by Frank Lloyd Wright, whose proposals for Broadacre City and design for a mud brick house in El Paso, Texas, are the genesis of modern earthen architecture in the United States.

The Matthews Residence is a multi-level private residence in Phoenix—an ideal location to attempt a modern approach to mud brick architecture. Modern architecture had already taken hold in the area thanks to Wright's Taliesin West, and mud brick is a well-established building material in the region, used traditionally by both Spanish-speaking and Anglo residents. During the summer, temperatures in Phoenix average around 105° Fahrenheit and only 7 inches of rain fall per year, so mud brick, which has a thermal mass that helps keep houses cool, was the perfect choice. Additionally, to assist with keeping interior temperatures low, the first floor of the house is underground—a technique used by the Native Americans of the region.

The Matthews Residence is much more than an exercise in thermal performance, however—it also reflects Bruder's background as a sculptor. Most striking are the layers of curved mud brick walls that surround the central living space. The exposed mud brick walls are both pragmatic and sculptural—buffering the desert heat and creating a series of dynamic spaces where Bruder manipulates light and challenges the conventions of mud brick construction. Each brick course in the double layer walls is cantilevered at the end of the wall, expressing the limited tensile possibilities of each structural mud brick. The desert light washes down the wall, heightening the texture and color of the raw earth.

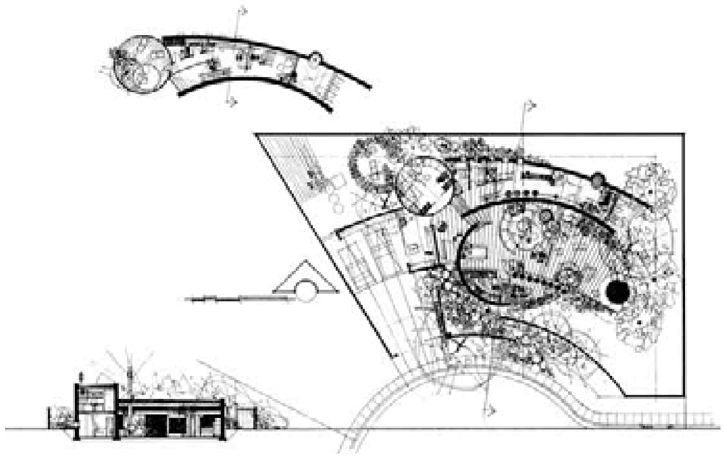
Because the walls shield the harsh desert light, while at the same time manipulating light to create intriguing spaces and textures, the house becomes an expression that is specific to the Phoenix landscape. Bruder describes the house as a "contemporary approach to adobe and earth technology architecture" that needs no historical references and is a bold combination of "the spirit of adobe with the spirit of our high tech society," where the capabilities of one of man's oldest materials can be reconsidered in a modern age.

opposite, top left: At the terminus of the double-layer wall, mud brick is cantilevered.

opposite, bottom left: The wall surrounding the house is also constructed of mud brick.

opposite, top right: Mud brick walls were left exposed to reveal their texture, color, and structure.

opposite, bottom right: Curved walls, varying floor heights, and exposed beams create dynamic interior spaces that are very different from those in traditional mud brick houses.



Floor plan and section composite drawing




ARCHITECTURE FIRM

**Arkitekt Sverre Fehn AS**

LOCATION

**Norrköping, Sweden**

DATE

**1991–1992**

Norwegian architect Sverre Fehn designed the Eco House as part of a competition entry for a tourist and sports center near the Mauritzberg Castle in eastern Norway. The proposal called for golf courses, tennis courts, and equestrian facilities, as well as three hundred residential units that varied in size from 270 to 2,700 square feet. While Fehn's proposal won the competition, it was never realized. But in 1992, architects Mikko Heikkinen and Markku Komonen and Professor Beng Ludsten, under the direction of Fehn, led a group of students from the Technological University of Helsinki to build one of Fehn's prototypes. Over the course of eight weeks during a summer architecture course students constructed the house in Norrköping, Sweden.

Typical of Nordic building, the prototype is a heavy-timber frame construction; however, the desert influence evident in the design grew from the familiarity with earthen construction Fehn gained during a trip to Morocco when he was young. The challenges presented by combining Nordic and Mediterranean architecture are visible in the structure and interior spaces, as well as in the enclosing building material itself. Like traditional earthen roofs in Morocco, which are made of layers of organic matter covered with earth, the heavy wooden frame of the barrel vault supports laminated wood and is covered in cork, bark, and finally earth. The walls are also constructed of earth, but the mud bricks normally used in desert architecture were radically revised to allow them to perform in the cold, humid climate of Scandinavia.

Fehn developed a mud brick with a high straw content for use as an infill for the Nordic timber-frame structure. Straw is typically used as a binding agent and helps mud brick dry evenly in the intense heat of the desert, but it also provides insulation, so a much higher amount of straw was used in each mud brick intended for use in the chilly Scandinavian climate. However, the large amount of straw that was mixed with the earth absorbed water and required a special process of removing it from the bricks to ensure that the bricks would dry properly. As is common, mud and straw were combined in a cement mixer and poured into wooden forms. Weights were then placed on top of the forms to squeeze the mixture and remove excess water from the bricks. The bricks were allowed to dry in the open air for two weeks and turned every two days after the excess water was removed.

The increased straw content also made these much lighter than standard mud bricks, allowing for larger sizes to be used. The larger bricks weighed nearly 18 pounds, rather lightweight for a mud brick of the unusually large dimensions of 21 × 11 × 8 inches. These "Norbricks," short for "Norwegian Bricks," as the team dubbed them, were then coursed in the timber-frame structure with mud mortar and covered with a waterproof plaster on the interior and the exterior to protect them from the humid Scandinavian weather.

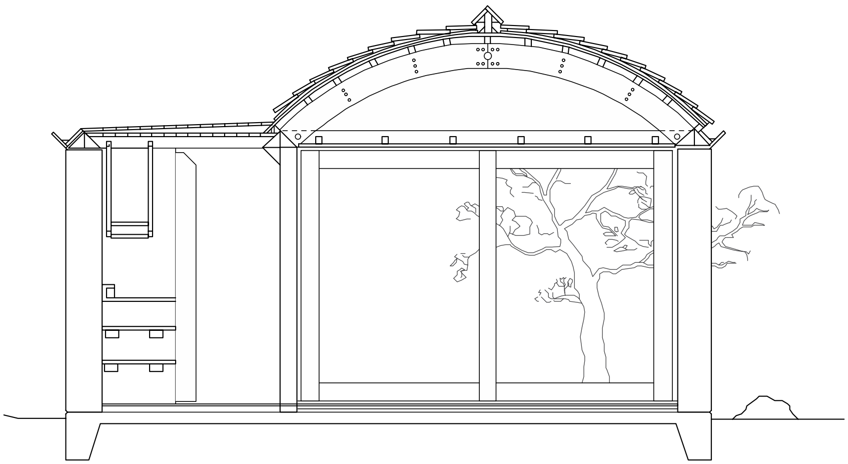
opposite, top: From the exterior, the vaulted roof, small openings, and thick plastered walls clearly demonstrate Mediterranean influences but appear at home in their Scandinavian context.

opposite, bottom: Entry

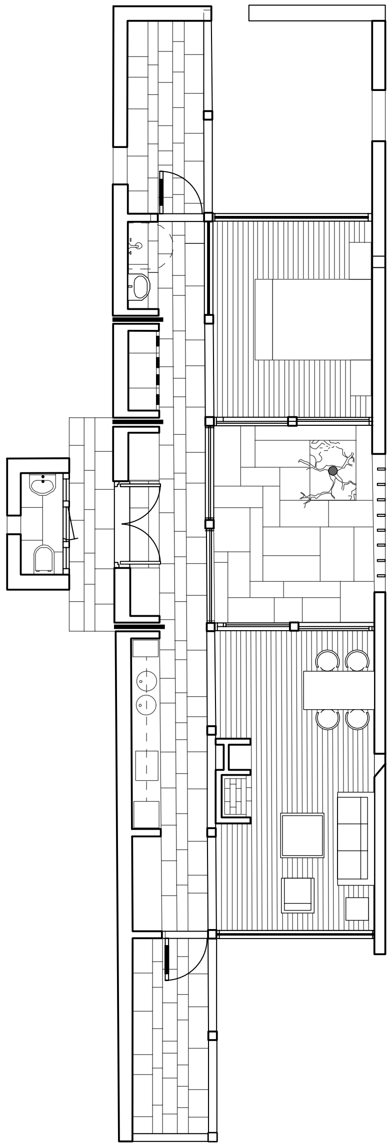
above: Norwegian mud bricks, or "Norbricks," dry in the sun.

# The Eco House

Master plan from Fehn's winning competition



Section



Floor plan

The vaulted roof  is reminiscent of traditional Nubian architecture and Nordic shipbuilding techniques.

# Camacho Residence

ORGANIZATION
**The Adobe Alliance**
LOCATION
**Ojinaga, Chihuahua, Mexico**
DATE
**1995**

On a small plot of land on a hill in the dusty border town of Ojinaga, Mexico, sits a small compound with domes and Nubian barrel-vault roofs constructed of mud brick and plastered with mud mixed with straw. The forms might as easily be found along the Nile River in Egypt, where the Nubian vault has existed for thousands of years. Amid the brightly painted concrete-block houses in the neighborhood, the small house might seem out of place, but against the backdrop of the Santa Cruz Mountains and the Rio Grande Valley, which is reminiscent of the Nile River valley, it is very much at home.

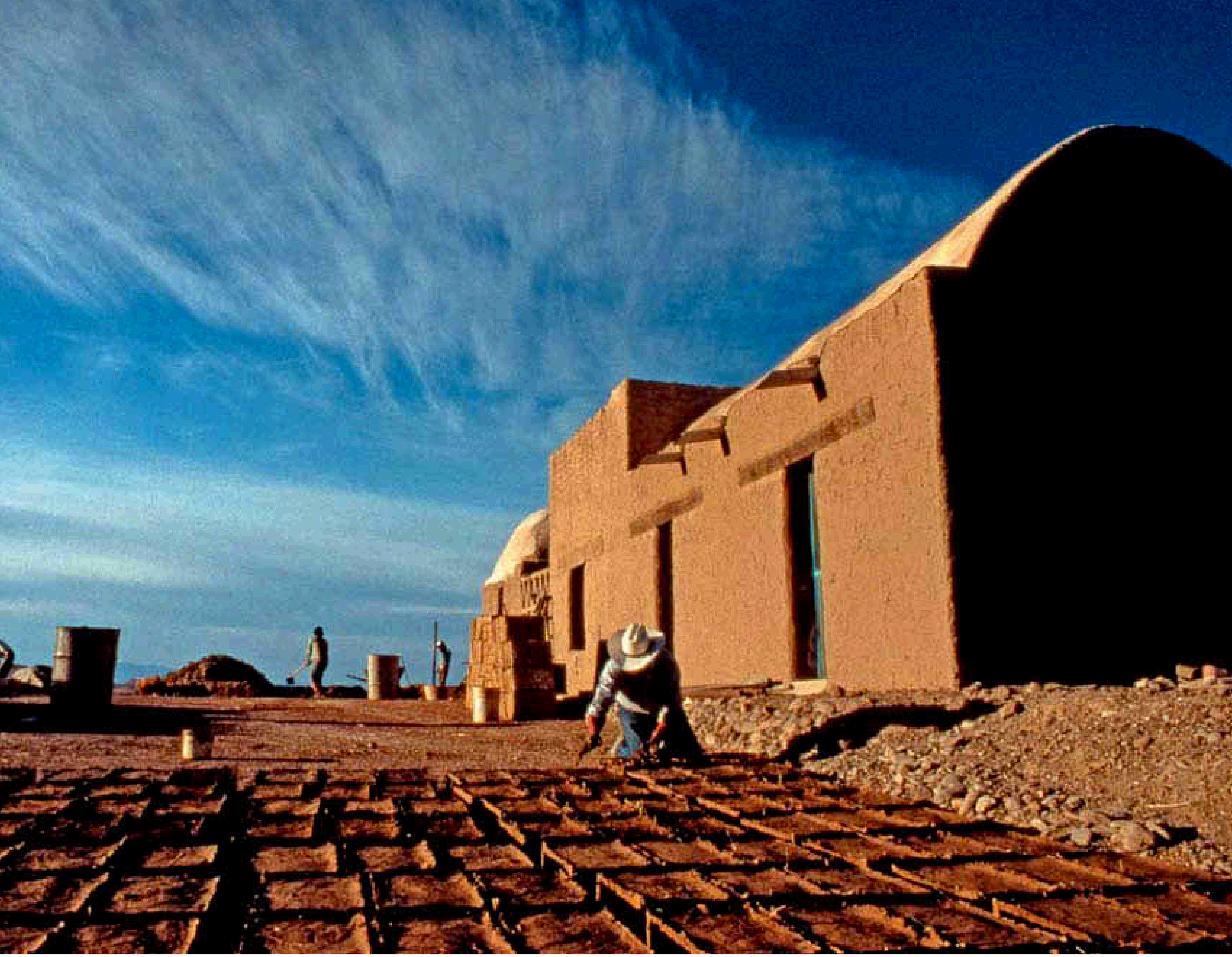
Simone Swan, who designed the house, is the director of the Adobe Alliance, an organization dedicated to helping communities apply cooperative building techniques in earth architecture. Swan's formal architectural education came late in life when she met the Egyptian architect Hassan Fathy in Cairo in 1975 and served as his apprentice for three years. With Fathy, she learned that building with mud brick—particularly houses constructed entirely from mud, including the roof—using a technique of catenary vaulted roofs that required no wood or formwork, could be of tremendous value in providing low-cost housing. Inspired by Fathy's desire to house the poor and intrigued by the idea of transplanting his ideologies, Swan set out in 1994 to disseminate mud brick and Nubian vault construction techniques on the border of Texas and Mexico. With this, she also promoted the concept that the benefits of mud brick can extend beyond home construction, transforming building and economic culture through the education of masons, mud brick makers, and vault builders.

Like Fathy, Swan believes that building with mud brick is more than just the creation of walls. For her, building with adobe is a political act. To encourage the role of women in a male-dominated culture, Swan hand-picked a local woman, Jesusita Jimenez, and trained her to be a master builder and head the building crew. This was also consistent with her belief that the entire process of building a house should challenge convention. Making mud brick is a labor-intensive activity that requires little specialized skill; rather than arriving at ways to reduce the amount of labor in construction, Swan encourages it. This has had an important impact on this small border town, where local unemployment rates are 50 percent and interest on home loans can be as high as 48 percent.

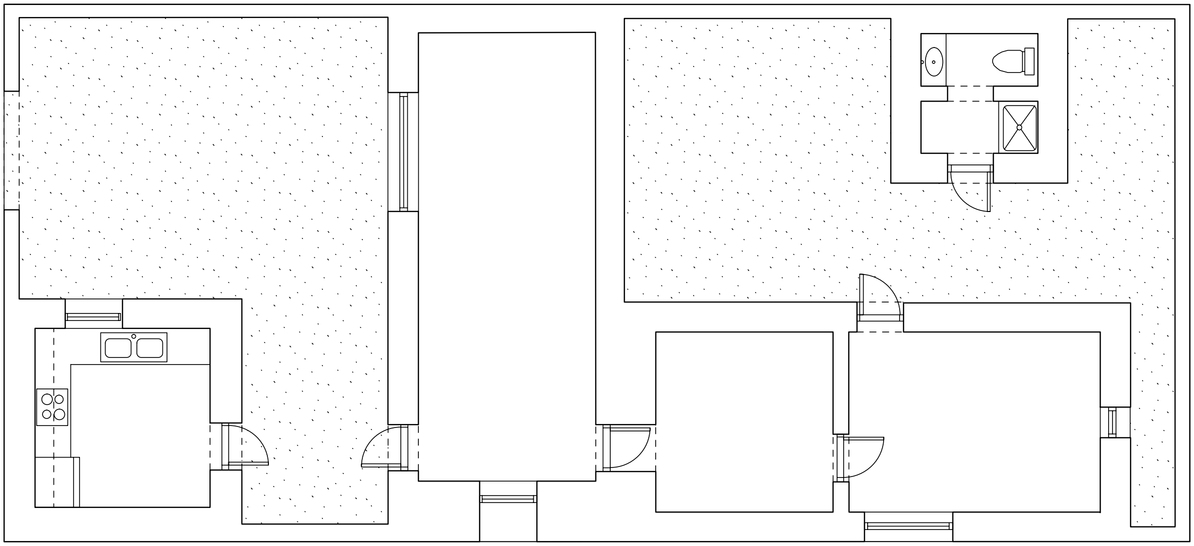
The story of the Camacho Residence began when Swan was invited to Ojinaga by the Partido de la Revolución Democrática, a left-wing political party concerned with social welfare in Mexico, to present her ideas on enabling owner-built mud brick housing. At the presentation, Daniel Camacho, an unemployed farm worker, asked Swan to teach him how to build a prototype, which in turn Swan could use for demonstration purposes. They agreed to work together, and Swan set out to design Camacho's four-room, 550-square-foot house.

The design of the Camacho Residence is a study in simplicity. Thick walls protect it from the desert heat without the need for air conditioning, an impressive feat considering that nearby Presidio, Texas, just across the border, is often the hottest city in the United States. Living and sleeping areas offer respite from the heat and odors of the detached kitchen. Floors, walls, roof, and even furniture are constructed of earth. The sofas and coffee table were made of stacked mud brick that was then plastered with another layer of mud, creating a continuous surface of earth from floor to wall to furniture to ceiling. Small bookshelves are also embedded within the thickness of the massive earthen walls. The narrow living room feels much more spacious due to the loftiness of the vaulted roof above, and the dome over the kitchen makes the ritual of humble food preparation more special.

The house cost only $5,000 to build and its construction taught valuable skills to the people who helped Camacho. Jesusita Jimenez became an expert at dome and vault construction and many of the laborers acquired skills for making and building with mud brick. Jimenez later invited these laborers to be her crew and went on to construct several more houses in the region, including Swan's own home in nearby Presidio. Swan and Jimenez continue to offer mud brick– and vault-making workshops at her home in Presidio and throughout Mexico and the U.S. Southwest. Camacho became a successful businessman and a well-known mud brick maker, selling up to 5,000 bricks a month, which he makes on the property adjacent to his house.



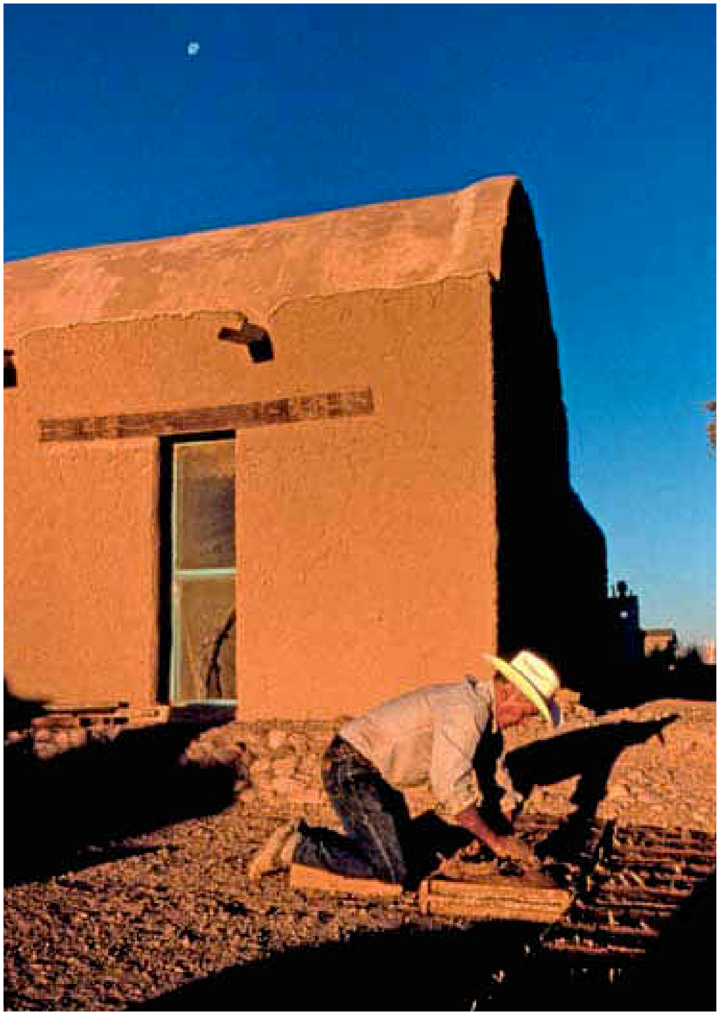
Daniel Camacho and his crew make mud bricks in the hot Ojinaga sun.

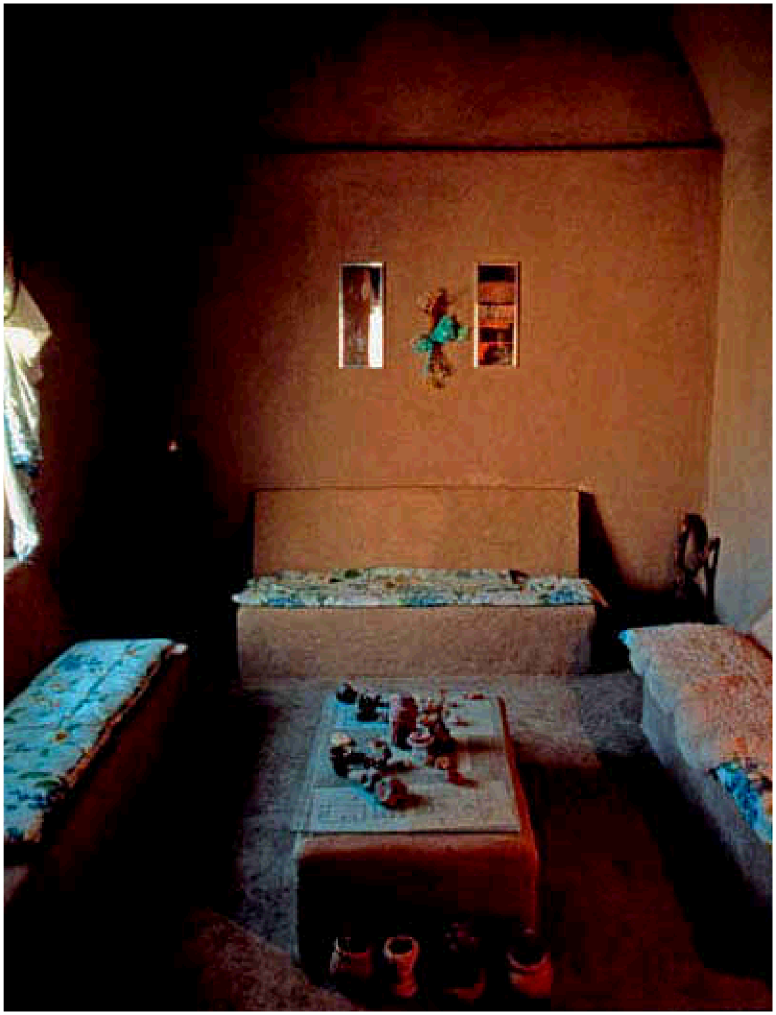


Floor plan

top left: Simone Swan oversees the construction of the walls as her crew prepares to construct the vaulted roof.

top right: Camacho mixes mud and straw together to make mud bricks and to plaster the walls.





left: In the process of building his own house, Camacho also became a successful businessman, selling up to 5,000 bricks a month.

right: Floors, walls, roof, and furniture are made of earth.

ARCHITECTURE FIRM

**Brendan J. Meney Architects**

LOCATION

**Alice Springs, Australia**

DATE

**1997**

At age 64, Olive Veverbrants, a Western Arrernte woman, established the Gloria Lee Ngale Environmental Learning Centre in Alice Springs, Australia, to provide Aboriginal people a place to gain hands-on experience and share knowledge about building techniques and food production practices that directly contribute to healthier, more sustainable lifestyles. Aboriginal communities are often affected by economic hardship and are unable to obtain decent housing for their members. In response to this, the Arrillhjere Demonstration House was conceived as a vehicle for the center to teach hands-on building techniques suitable to the Australian outback so that participants could take those skills back to their communities.

The center is surrounded by a desert with long, hot summers and dramatic temperature changes. The average rainfall in Alice Springs is approximately 11 inches per year, and in summer the average daily maximum temperature is 97° Fahrenheit, with highs reaching 113°, but the diurnal temperature can be up to 82° and a thunderstorm can cause temperatures to drop to 59° within ten minutes. The house is designed to take advantage of the radical Central Australian environment, where soil, rain and sun are the most valuable resources available.

The house's thick earthen walls are built of 14,000 mud bricks handmade from the red soil found on site and stabilized with bitumen for water resistance and to decrease life-cycle maintenance costs. Architect Brendan Meney chose small bricks—4 × 5 × 12 inches—to increase productivity due to their lighter weight and manageability. To provide a thermal mass equivalent to that of much thicker and denser earth walls, the bricks were coursed in two layers with a 2-inch cavity between the inner and outer walls that was filled with sand.

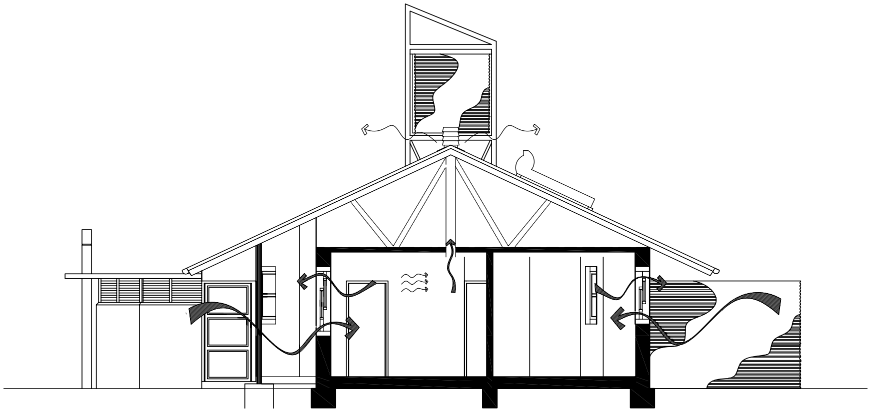
The walls were built atop a foundation that was constructed of rammed earth taken directly from the excavation of the building footprint and stabilized with 10 percent cement. The rammed earth foundation proved less expensive than one that uses costly concrete with steel reinforcement, and the labor-intensive process, which requires hand tamping layers of soil, also generated employment. Outdoor verandas and the interior floors are constructed of rammed earth, and the interior walls are finished with earth-based paints, whose high clay and mica content lightens the interior naturally.

Active and passive solar and water collection and distribution systems, and passive cooling systems are critical to the house's self-sufficiency. Photovoltaic panels connected to 24 batteries managed by a solar regulator and inverter provide enough electricity to power all the lights and appliances in a typical Australian home. Rainwater is collected by the roof and stored in two large steel tanks that each hold 6,000 gallons. A photovoltaic-powered solar pump sends this water to an elevated tank that creates pressure for domestic use. The solar-heating system mounted on the roof next to the photovoltaic panels heats water; a backup fire-heating system kicks in during cloudy spells. Rain is the only source of water available to the occupants, and the architect calculated that even during an exceptionally dry year, the tanks will collect enough water for three people, each consuming 16 gallons per day, during the year. Water-saving devices contribute to conservation and are attached to all kitchen and bathroom fixtures, and a composting toilet was installed instead of a flush toilet. Gray water, the wastewater from showers and sinks, is reused to irrigate a fruit tree orchard.

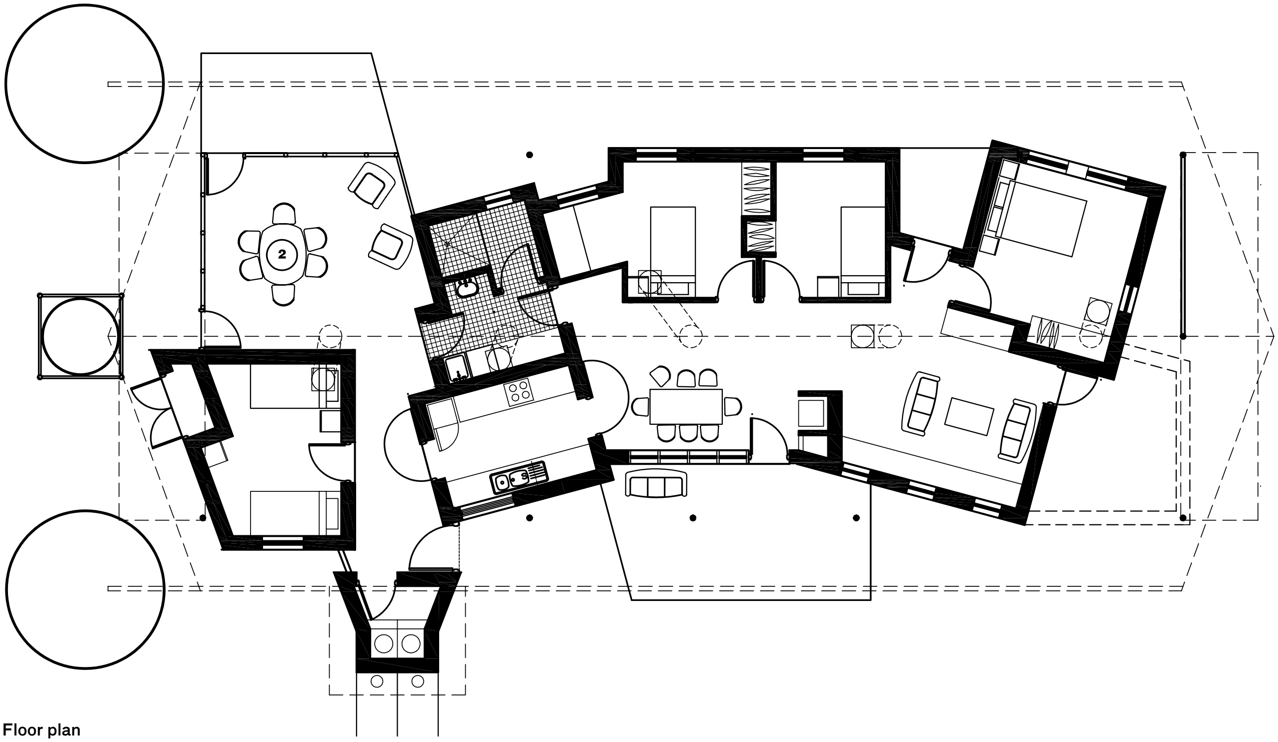
The roof is also critical in ameliorating the effects of the long hot summers without the need for energy-consuming air-conditioning systems. Its large canopy is structurally separated from the walls and supported by a metal frame, which allows for maximum airflow around the structure. Stationary ridge vents connected to flexible ducts take advantage of this natural ventilation and help remove dust from the interior of the house. The roof canopy also keeps the entire structure and the outdoor spaces beneath it in constant shade during the summer, while allowing the sun to warm the walls in the winter.

# Arrillhjere Demonstration House

North elevation



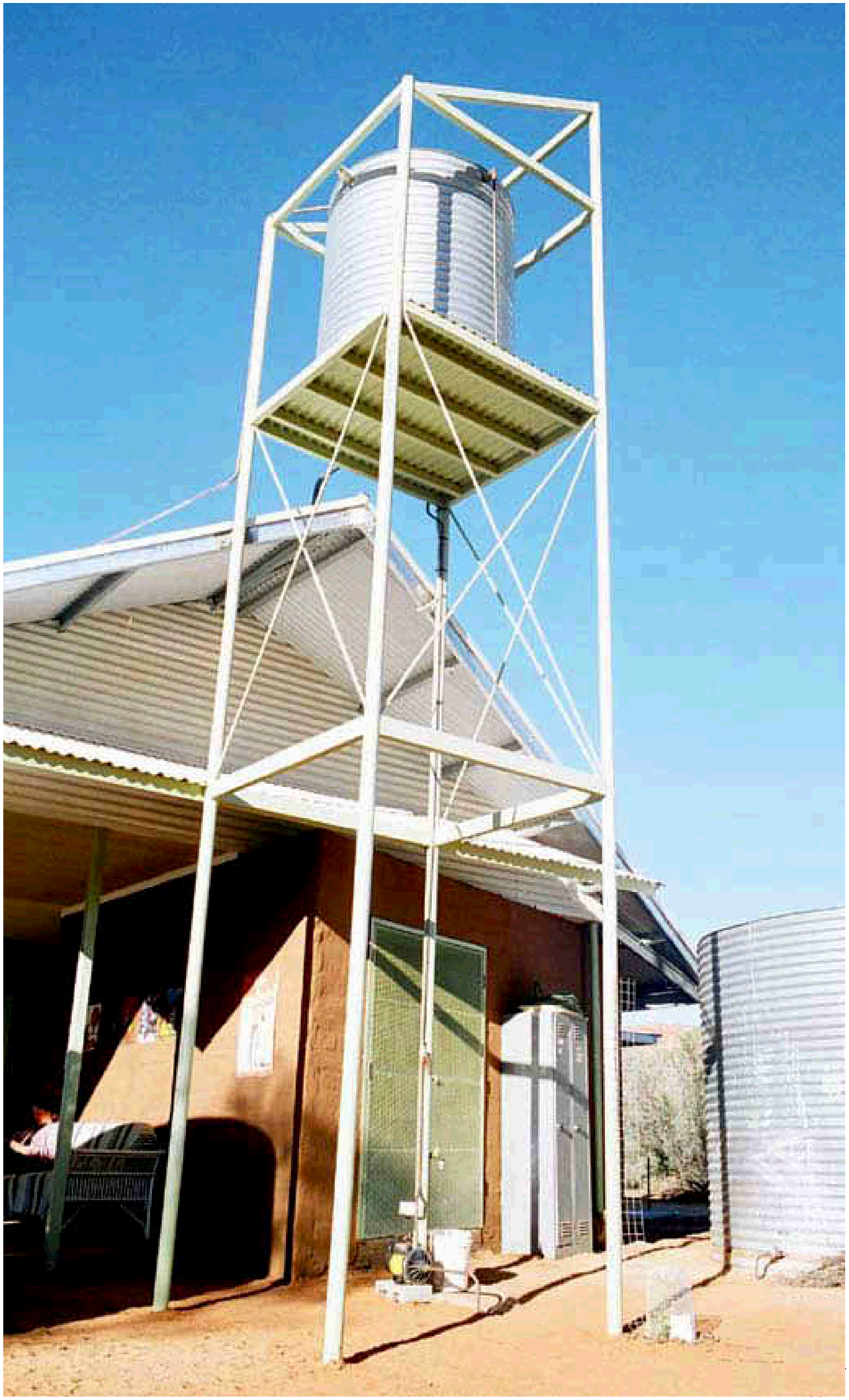
Section showing air circulation



Floor plan

top left: Locals wishing to gain experience in sustainable building practices made 14,000 mud bricks by hand from the red soil of the site.

above left: As the mud brick walls are not structural, they were stacked on top of a stabilized rammed earth foundation beneath a steel roof structure.



above: The mud brick walls are protected from erosion by the detached roof canopy and clay-based paints.

right: Rain water collected by the roof is stored in two large steel tanks that each hold 6,000 gallons then pumped to elevated storage tanks to provide water pressure.

# Druk White Lotus School

ARCHITECTURE FIRM
**Arup Associates**
LOCATION
**Shey, Ladakh, India**
DATE
**2001**

The Druk White Lotus School, located in Ladakh, India, a Tibetan plateau that is one of the last strongholds of indigenous Buddhist culture, was created to prepare the children of Ladakh for the challenges of the twenty-first century through modern education. In 1997 the Drukpa Trust, a charity based in the United Kingdom to advance learning according to the universal philosophy and nonsectarian practice of Tibetan Buddhism, asked Arup Associates to propose a master plan that would ultimately serve 750 elementary and high school students. The first phase of this long-term project was a nursery and infants' school that uses both traditional and modern building materials and employs methods that respond to the extreme conditions of the high-desert environment.

The location of the school presented the project's primary challenge. Ladakh is the highest plateau region in Northern India, reaching up to 11,000 feet above sea level. The average rainfall in this high-altitude desert is less than 2 inches per year, and winter temperatures can be as low as -30° Fahrenheit. With winter come heavy snows, making access only possible by air. Furthermore, the region is prone to seismic activity.

This unique environment initially prompted Arup to employ highly sophisticated engineering software and modern building materials to address the environmental challenges, but the firm soon discovered that costs associated with importing industrial materials were far too high and looked to local building traditions. The result is an architecture that is much like the education offered at the school—a collaboration between technological advancements and tried-and-true traditions to produce a model for appropriate and sustainable modernization.

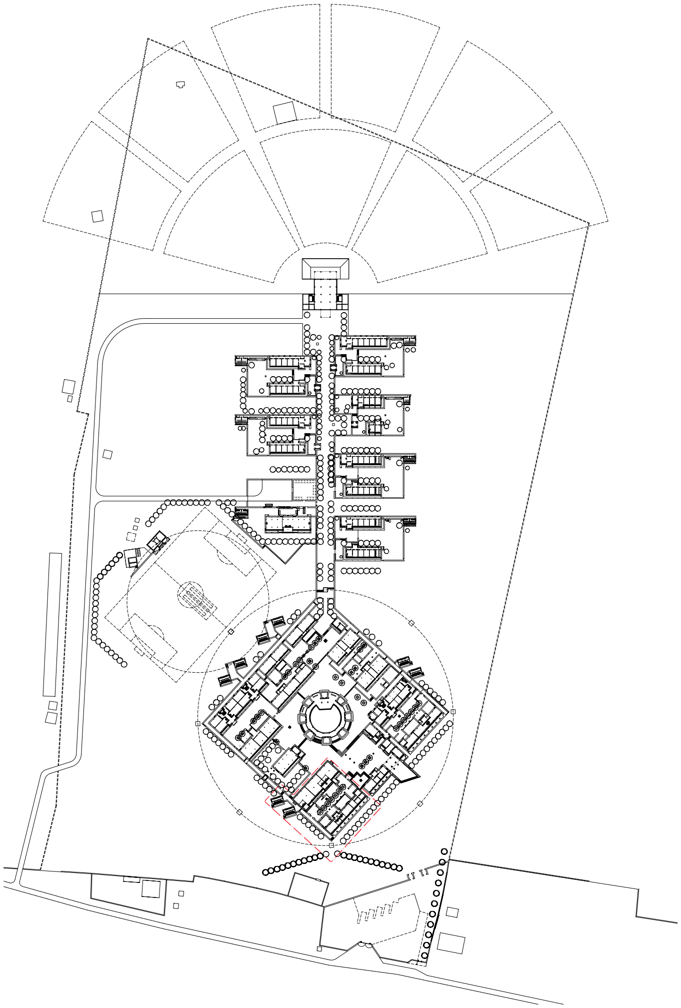
Although the climate is harsh, sunshine is abundant, and in order to make the most of this rich resource, Arup's design takes advantage of solar energy through both active and passive technologies. Photovoltaic panels charge batteries that do everything from run computers to pump water. To create a passive solar heating system for the school, Arup Associates designed a ventilated Trombe wall system constructed of mud brick, granite, and glass. The mud brick's thermal mass stores the winter sun's warmth for evening heating, and granite surfaces protect the brick from erosion. Spaced in front of the thick walls is a double layer of glass, and above and below the massive walls are adjustable openings that allow heat to be transferred from the air cavity between the glass, and earthen wall to the room inside. This allows for the temperature of the rooms to be controlled and keeps the young students comfortable.

Because traditional mud brick walls are not earthquake safe, Arup designed a timber-frame wood structure, based upon Japanese joinery techniques, that serves as the primary load-bearing structure and is infilled with mud brick. The large beams are connected by steel plates and provide large open spaces inside; outside, they project beyond the double-glazed windows to support sunshades and trellises for climbing vines. The structure also supports a roof made up of a tightly arranged row of willow branches covered with rock-wool insulation, waterproof felt paper, and is covered over with a layer of grass and mud. The roof is an improvement on traditional earthen roofs, which lack insulation and waterproofing material, and it prevents the heat collected in the Trombe walls from escaping.

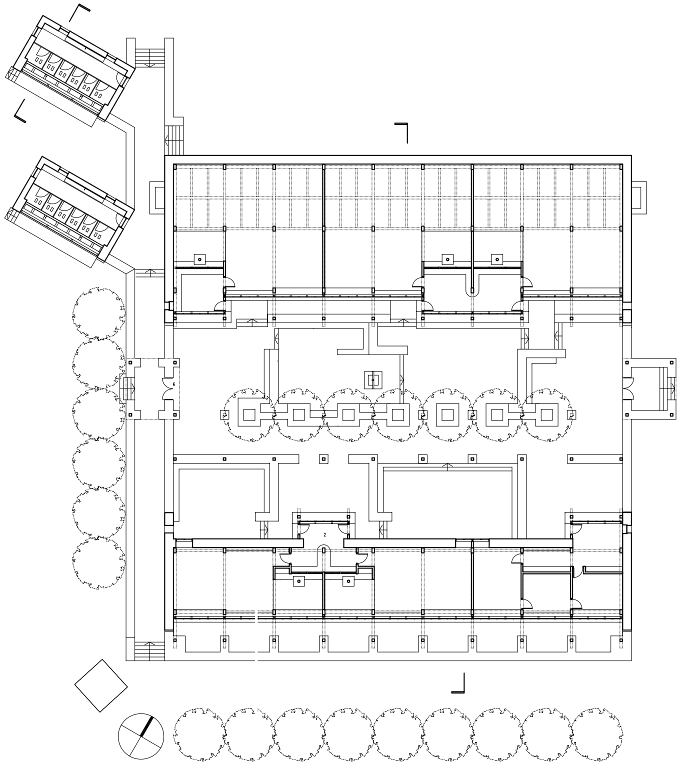
Arup's master plan, when finished, will include several innovative mud brick and granite buildings in addition to this school. The entire complex will ultimately be organized on the pattern of the traditional nine-square south–south east facing mandala, a geometric pattern that represents the cosmos metaphysically and symbolically in Tibetan Buddhism; and it will be surrounded by a series of concentric circles made up of low walls, tree plantings, and stupas. Scheduled for completion in 2011, the complex will include a library, computer and science labs, dining halls, faculty and student housing, and an open-air temple that will serve as the heart of the campus.

opposite, top: South elevation of the Nursery and Infant School and Junior School

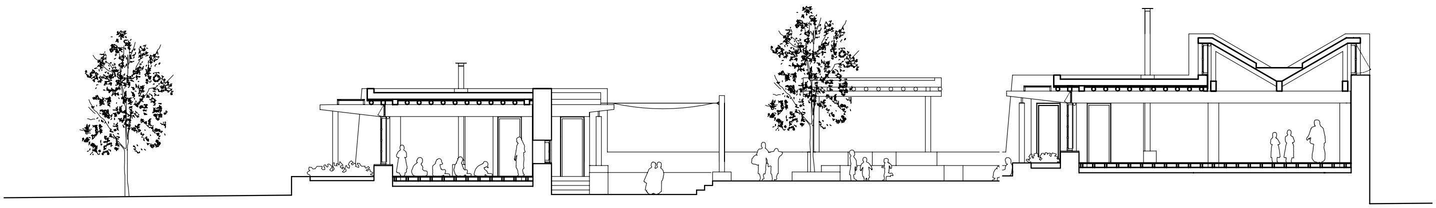
opposite, bottom: A wall of glass allows the thick granite and mud brick walls to absorb and retain heat from the sun.

Site plan (detail shown right)



Floor plan



Section

top left: Granite cladding protects the mud brick walls.

top right: Warm materials make a comfortable learning environment for the children.

bottom: The timber-frame structure was designed for stability during earthquakes, and the mud brick infill is the thermal mass.

# Bodega en Los Robles

ARCHITECTURE FIRM

**José Cruz Ovalle, Arquitecto**

LOCATION

**San Fernando, Chile**

DATE

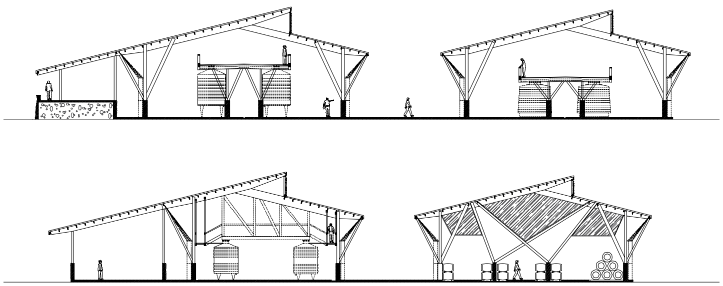
**2002**

The Bodega en Los Robles, a wine cellar built by Chilean architect José Cruz Ovalle in 2002 in San Fernando, Chile, is the centerpiece of the country's first organic vineyard. Both architect and client felt it was important that the architecture reflect the values of a winery that focuses on making wine through organic growing and processing methods. By careful placement of the buildings and the use of innovative green technologies and materials, Cruz Ovalle created a complex of buildings that are sensitive to the context of the vineyard and the environment.

The wine cellar complex comprises several large warehouses organized along a symmetrical axis. Each warehouse is slightly skewed from this axis, creating dynamic interstitial spaces through which guests pass while visiting the winery. These displacements create a spatial relationship between the buildings that encourages a connection between the architecture and the landscape by defining views to the vineyard and creating spaces where people can gather to discuss the production of wine. The skewed placement of the buildings also creates a Venturi effect, which increases airflow around the buildings to promote a cool environment for wine storage. The use of natural materials such as wood, stone, and mud brick, which are common to Chile's historic building traditions, is also expressive of the client's desire to have wine storage buildings that are as sensitive to the natural landscape as the vineyards

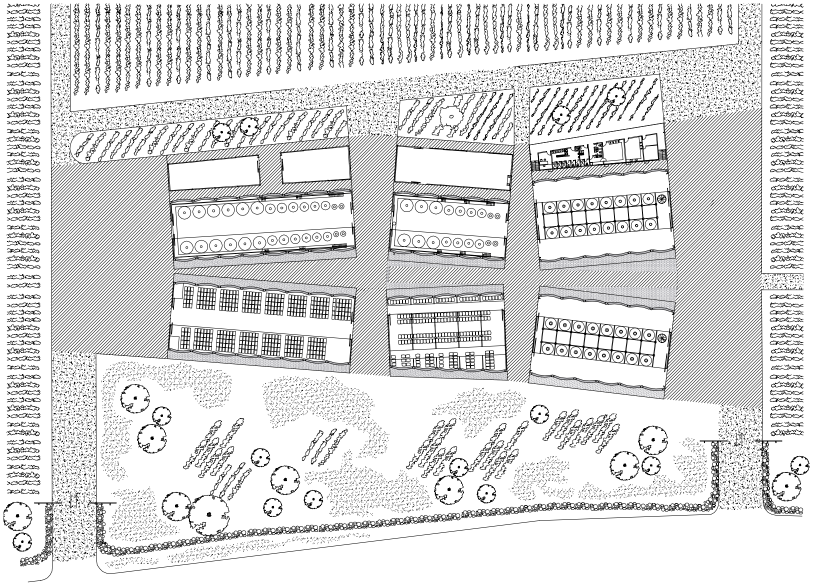
The stones used for the foundation and the perimeter paving allow water to percolate naturally back into the soil, and their thermal mass helps keep interior temperatures constant. Wooden slats that define the building enclosure above mud brick walls allow air to circulate through the wine storage areas and admit a filtered, gentle light into the structure. As has been the tradition in the region for centuries, local artisans created the mud bricks by blending straw with soil from the site and walking horses over the mix to combine them. In order to expose the natural beauty of mud brick, the designers did not cover the gently curved mud brick walls with plaster. The thermal mass associated with the walls helps control internal temperatures, and their curvature improves the acoustics within the wine cellar, which is important as the building is not only a place to make and store wine, but also where wine tastings and presentations about ecological wine production can take place.

right: Wooden slats encourage air circulation and introduce a filtered light into the interior.

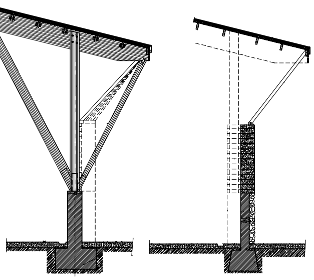


Sections

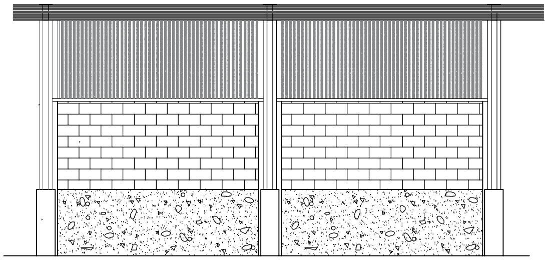
Subtly curved mud brick walls, ventilating wood louvers, and stone foundations and pavers found on site are the primary architectural elements of the wine cellar.



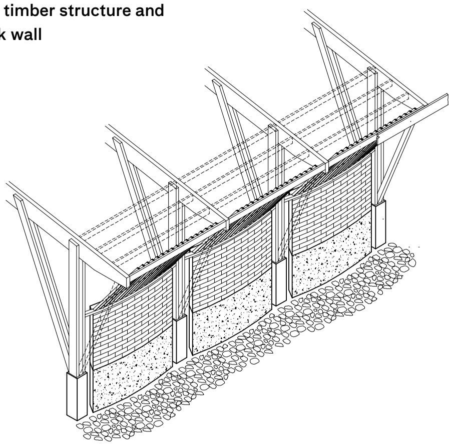
Site plan



Section details of timber structure and through mud brick wall

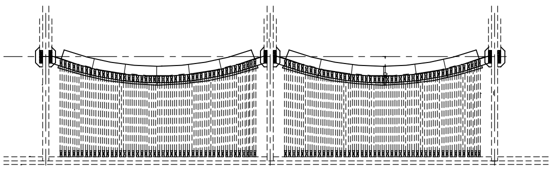


Elevation detail of curved mud brick infill walls



Isometric drawing of mud brick infill walls

Plan detail of curved infill walls



Reflected ceiling plan detail showing overhang of wood screens above mud brick walls

opposite, top: The wine cellar complex comprises several large warehouses organized along an axis parallel to the vineyard.

opposite, bottom: A forest of wooden trusses comprises the interior of the wine storage area.

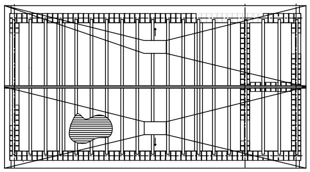
ARCHITECTURE FIRM
**Rafael Mattar Neri, Arquitectos Asociados**
LOCATION
**Pecaya, Venezuela**
DATE
**2003**

Pecaya is a small, impoverished town in Venezuela known for its mud brick houses and for spirits made from the agave cocuy, a succulent plant native to the region. But in the 1960s, production of the 53-proof Cocuy Pecayero was made illegal in Venezuela. This caused the economy of the town, which was already in a poor region, to fall into decline, and clandestine production of the alcohol continued. But in 2001 a cooperative organization formed, which pressured the government to allow people to process Cocuy legally in a communal distillery that would be constructed in the village. The criteria for the design of the distillery as defined by the cooperative was that it fit within the sociocultural and economic context of Pecaya and that it give the villagers a feeling of ownership of the new building.

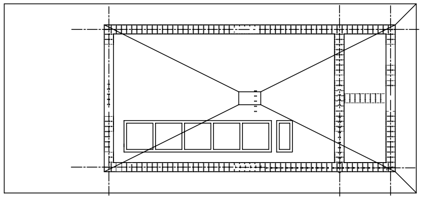
Local artisans developed and constructed each architectural element used in the Cocuy Pecayero Distillery, following local building traditions, and virtually all the materials used to make the building were found on site. The calcium-rich Pecaya soil is ideal for the production of mud bricks. No stabilizers, such as cement or lime, were used in making the bricks; only mud and fiber from the cocuy plant were necessary, and after two weeks of drying in the sun, the bricks were ready to be used in construction. The walls are made of two parallel layers of mud bricks to improve the stiffness of the wall and to keep the interior climate constant: this is important for the distillation process, especially in an environment where the temperature can vary greatly between day and night.

Airflow and protection from the sun are necessary for the production of the alcohol. Fenestration was created in the thick earthen walls by stacking mud brick at a diagonal to create triangular openings that required no lintel. The indirect light and welcome breezes offered by these openings is reminiscent of past Cocuy Pecayero production, which traditionally took place in the shade beneath the cují trees.

The roof is largely constructed from materials that come from the same plant used to make the liquor. The round trunk that grows from the center of the plant was used to make the roof rafters, which were laid directly atop the mud brick walls. Smaller sticks cut from the maguey plant were attached horizontally on top of these beams, and these were overlaid with a textile of woven cocuy fiber. A thin coat of the same mud mixture used to make the bricks was then applied to the woven fiber surface to create a waterproof and insulative roof. Colorful woven rope, also made from cocuy fiber and used traditionally by the Pecayeros in the construction of hammocks, was woven into a net to enclose the gable end of the roof that still allows breezes to filter through. The colorful rope also designates the entrance to the distillery and symbolizes a brighter future for the community.



Floor plan



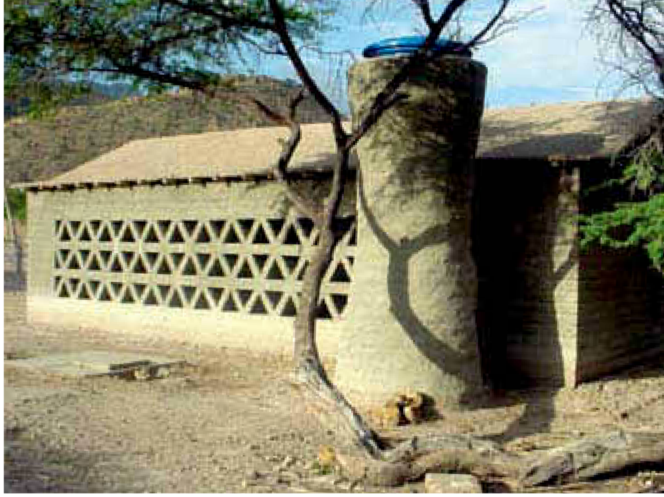
Roof plan

opposite, top left: A view of the entrance to the distillery shows its rural site surrounded by cují trees.

opposite, top right: The walls, roof, and water tower are all constructed and plastered with earth from the site.

opposite, bottom: Light and air pass through a screen created by diagonally placed mud bricks.

# Cocuy Pecayero Distillery


ARCHITECTURE FIRM

**Mathias Klotz Arquitecto**

LOCATION

**Acuelo, Chile**

DATE

**2004**

With so many earthen structures on the planet it is important to consider how existing buildings can be adapted to respond to changing lifestyles. The restoration of Casa Corralones by Chilean architects Mathias Klotz and Magdalena Bernstein is an example of a historic structure that was transformed to create a hybrid architecture that balances heavy and light, old and new.

In 1860 the original building that was to become Casa Corralones was constructed to house feed grain and for other agricultural uses. At that time, the linear barn was a two-story structure with thick mud brick walls at the base; the second level was built on a wood platform made of pine flooring within the heavy timber-beam roof structure. The building was surrounded by a large overhang and roofed with fired clay tiles. In 1985 an earthquake caused the center of the second-floor structure to collapse, leaving a double-height void inside, which inspired Klotz and Bernstein when they began to reconsider the nineteenth-century barn.

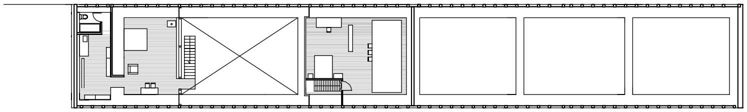
The 25-foot-tall space was preserved to create a grand living room in the center of the house. Flanking each end of this space are the portions of the second-story floor that survived the earthquake, which were preserved and used as the master bedroom and a space that can serve as either a study or play room. Beneath these elevated spaces are the kitchen, guest and children's bedrooms, and bathrooms. The internal atrium creates visual connections that extend across the main living space. This is a radical transformation of the original space, which was a series of 20-by-30-foot dark, segregated storage rooms.

With the removal of the walls that divided the spaces, they became connected by light, an effect that is magnified by the white plaster on its mud brick walls. The cladding in the upper floors is made of bright, untreated pine, and the stairway landing is suspended from the rafters by thin cables, further enhancing the quality of light. The thick timber beams also become much lighter, and seemingly thinner, as light enters through a clerestory of glass inserted between each truss. This band of windows fills the space with an abundance of indirect light—a grand departure from the small openings of the original structure.

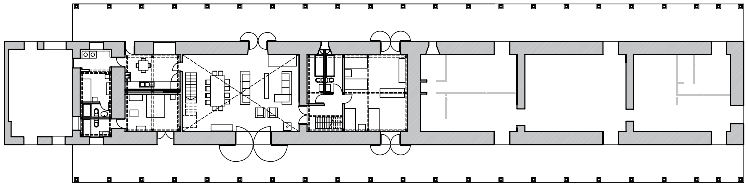
right: Indirect light enters through clerestory windows that run along two sides of the house.

opposite: The double-height living space is brightened by a long clerestory window.

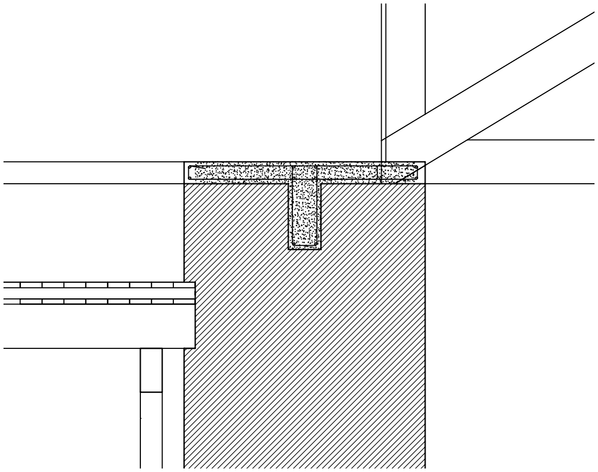
# Casa Corralones



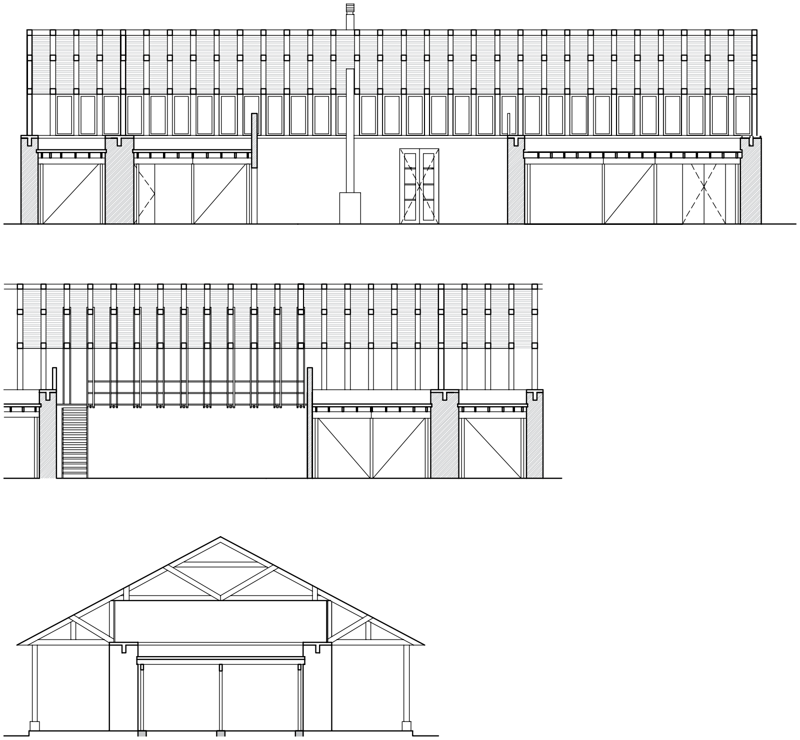
Second-floor plan



First-floor plan



Detail of bond beam on top of thick mud brick wall



Sections

The second-story platform is made of pine flooring; the heavy timber beams original to the building are overhead.

Casa Corralones at night

ARTISTS

**Elmgreen & Dragset**

LOCATION

**Valentine, Texas**

DATE

**2005**

Mud brick and the dry, desolate West Texas desert are not typically associated with Prada, the Italian fashion company that has retail outlets worldwide, but the increasing popularity of mud brick has created a demand for the material, making it it a status symbol in the Southwestern United States. The humble earthen houses that make up the residential district of Marfa, Texas, now fetch several hundred thousand dollars as second homes for New Yorkers, Houstonians, and Los Angelenos. Mud brick construction, at one time a strong building tradition in the region, has been transformed by the forces of supply and demand. The costs associated with earthen construction have become very high, leaving the descendants of dwellers in traditional earthen structures unable to afford mud and forcing them to occupy the more affordable premanufactured homes. Much like the knock-off Prada bags that are a consequence of the high price tag of authentic Prada merchandise, adobe knockoffs—faux dobes with adobe-style motifs, fake logs protruding from their facades, and brown stucco—are the preferred style of premanufactured Southwestern homes. The dichotomies found in the Big Bend region of West Texas—between wealth and poverty, the United States and Mexico, real and surreal—are what make this minimalist sculpture that replicates a luxury boutique where the Fall 2005 line of Prada shoes and bags are displayed, so intriguing.

*Prada Marfa* is sited near the United States–Mexico border and surrounded by immense ranches, each several thousand acres or larger and owned by some of the wealthiest people in the United States. Most of the ranch owners have ties to oil, and more recently dot-com wealth, including Amazon.com CEO and founder Jeff Bezos, who has announced plans to construct a spaceport just down the road from the faux boutique. Appearing like a UFO in the sky within view of *Prada Marfa* is a Tethered Aerostat Radar System, a lighter-than-air, inflatable, aerodynamic balloon filled with helium and air that provides low-level radar surveillance along the southwest border of the United States. A short drive away are some of the most important works by the renowned American minimalist artist Donald Judd. Spaceports, art, wealth, poverty, and the tension of the border seem somehow equally at home in and foreign to this environment. The isolated "store" is no different; with its delicate interiors and massive walls, which represent both the influx of wealth and past traditions, it fits within the complex geopolitical and cultural framework of the middle of nowhere, Texas.

*Prada Marfa* was constructed of 2,500 mud bricks made by machine and express shipped to the site from a factory in Alcalde, New Mexico, over 500 miles away. Not unlike the luxury goods that fill the installation, the mud bricks manufactured at this adobe yard primarily supply a growing population of affluent Southwesterners enamored of the romantic notion of living in houses constructed from earth. Unlike the traditional method, where bricks are laid in an earthen mortar, the bricks used to build *Prada Marfa* were set in cement. The juxtaposition between the industrial and traditional materials is a nod to Judd, whose vast and priceless collection is housed in similarly constructed mud and cement military structures in Marfa; and the combination also represents the bipolar nature of the context in which it is built.

In Marfa, mud has been used to construct buildings in the region since pre-Columbian times, and the U.S. military, who came to the region to protect West Texas from Mexican bandits after the Pancho Villa raid, introduced the use of cement mortar in the construction of their mud brick buildings. The walls of cement and mud of *Prada Marfa* tell the history of the diverse groups that have inhabited the area. By representing a metaphorical border between art as commodity and commodity as art, the installation, its wares, and its materials also represent a conceptual interpretation of the latest wave of inhabitation in the region—Judd, and later a gentry of gallery owners, artists, art lovers, and fashionistas.

**opposite, top:** The art installation, located on an isolated road in West Texas, replicates a luxury boutique.

**opposite, bottom:** A local rancher visits the sculpture.

# Prada Marfa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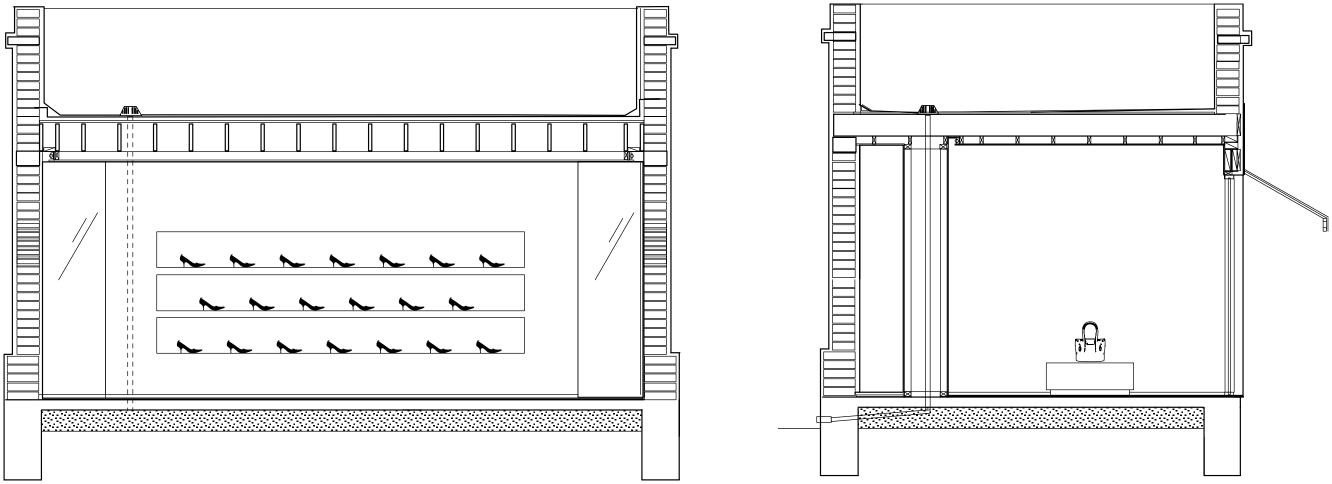
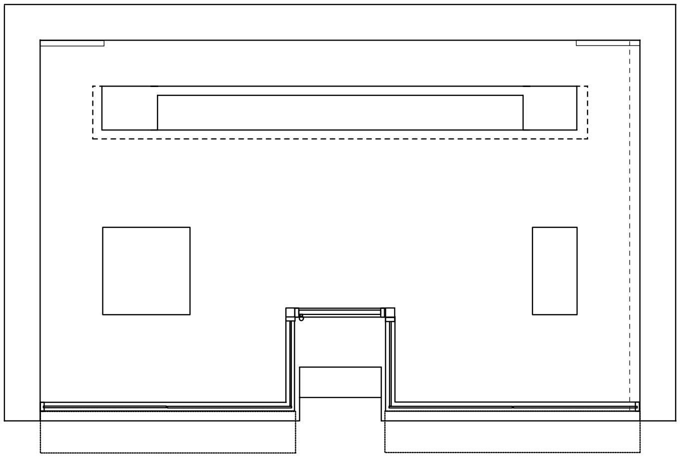


Sections



Floor plan

top: The mud bricks used to build *Prada Marfa* were set in a cement mortar, like the walls Donald Judd had constructed in Marfa.

bottom: The Fall 2005 line of Prada shoes and bags are displayed within the mud brick structure.

# Christine's House

ORGANIZATION
**Rural Studio**
LOCATION
**Mason's Bend, Alabama**
DATE
**2006**

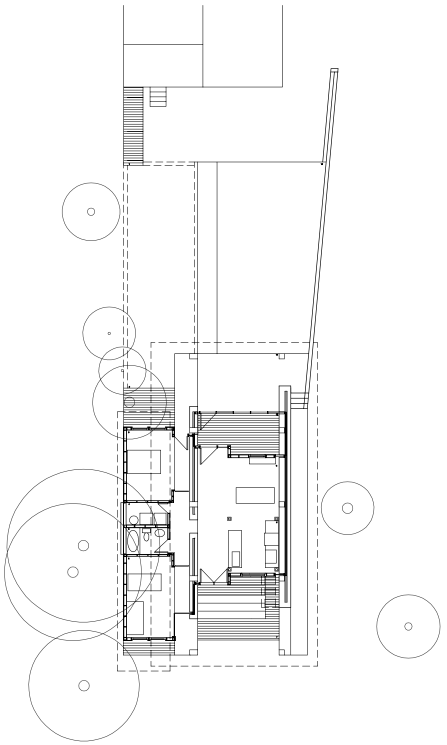
Mason's Bend is a small hamlet near the Black Warrior River in Hale County, Alabama, home to a cluster of experimental architecture projects built by the Rural Studio. Among the collection of buildings created by students of the Auburn School of Architecture as gifts for the town's impoverished residents are five houses, a rammed earth community center and chapel, and a basketball court. Christine's House, a recent addition to the body of work that the Rural Studio has contributed to the neighborhood, designed and built as a master's thesis project by two students, reexamines the use of earth as a building material in rural Alabama. With this innovative house Amy Green Bullington and Stephen Long responded to the needs of the client while taking on the challenge of creating an innovative and sustainable building.

The house's owner, Christine Green, is a single mother with four children under six years of age. Christine desired space both inside and outside the house for her children to play, where they could be watched even while she was cooking, and a visual and physical connection to her mother's house nearby, which was also built by Rural Studio. The resulting 900-square-foot house went beyond her wishes. Though it is small, the two-bedroom house feels much larger because the living space opens to the north and south ends of the house, bringing in a large amount of light. At one end, a screened-in porch can be used as an extension of the living area for most of the year, allowing the children to play in a safe, enclosed area in the fresh air. Because the children often run back and forth between their mother's and grandmother's houses, a raised garden connects the two. The garden and lawn are protected by a concrete retaining wall that keeps cars away from the children's outdoor play space.

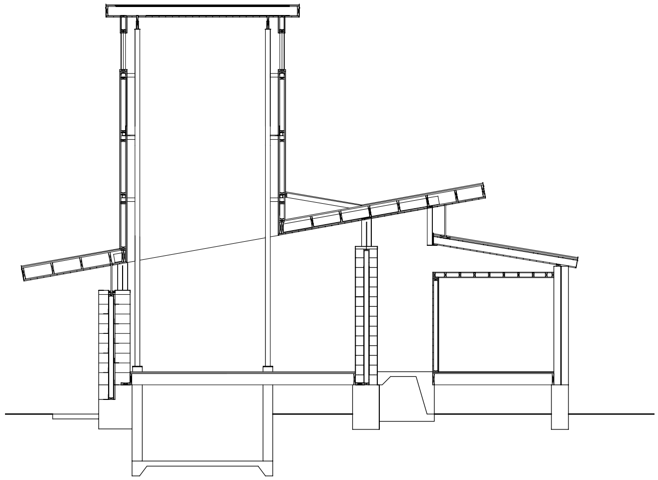
Two massive earth walls reinforce the idea that the garden is an extension of the interior spaces, and define the east and west facades of the house. For their thesis, the students experimented with ways of using the ubiquitous red clay as a building material. Their interest in recycling and alternative materials led them to develop a process that is a variation of hybrid adobe and fidobe, two techniques they learned from the alternative building website Hybridadobe.com. These techniques use paper fibers instead of straw to create the mud mix. Combining the two technologies, the students created earth blocks composed of 70 percent earth, 25 percent pulped newspaper, and 5 percent portland cement poured into cardboard boxes of various sizes and allowed to dry. While labor intensive, the technique requires no special skill or equipment, and the resulting mud bricks can produce a 12-inch-thick wall with an insulation value that is greater than in typical residential construction. Though massive, the non-load-bearing walls appear to be delicate. They are independent of the roof, and light that passes through windows above the wall decreases their visual weight.

Hovering over everything is a winglike roof supported by concrete columns. The roof was the first part of the house to be constructed in order to create a dry work space beneath. In the kitchen, a tower punctures the roof creating a grand, soaring space that also ventilates the house, catching breezes and drawing up hot air like a chimney. Floor vents work in conjunction with the tower to draw cool air up from the crawl space, which doubles as an underground storm shelter. The underbelly of the roof is made of cedar to match the interior walls of the house that are not mud brick. Cedar is also the material that clads the grandmother's house, further reinforcing its connection to Christine's.

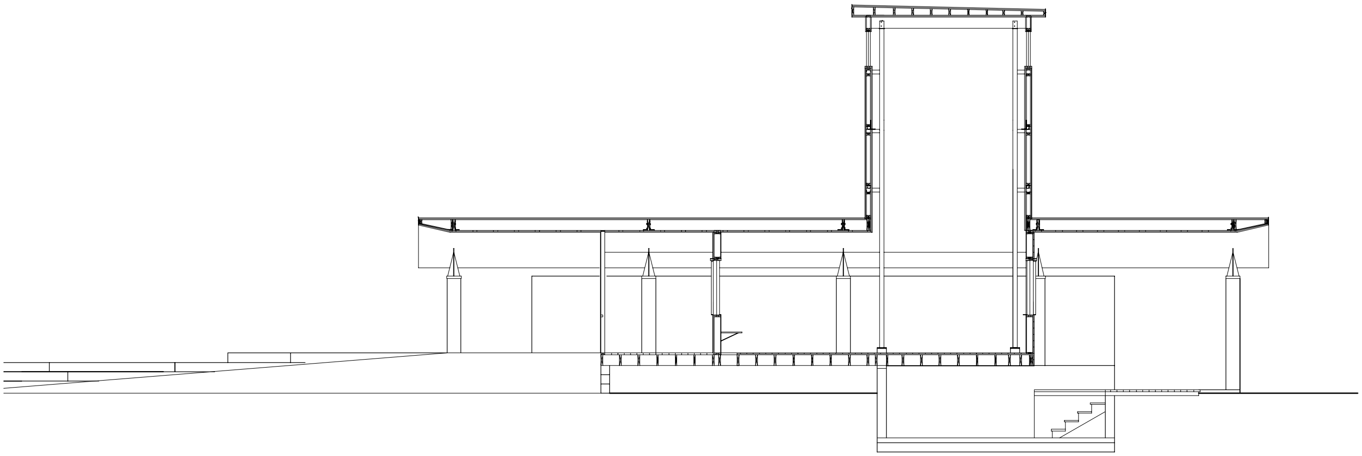
The roof hovers above the mud brick walls and extends out over the exterior spaces, making the interior of the house seem larger.



Floor plan



Section



Section

top: The tower over the kitchen ventilates the house, catching breezes and drawing hot air out of the house like a chimney.

bottom left: Christine Green and the youngest of her four children sit in the living room, which is enclosed by the massive mud brick wall behind her.

bottom right: A Rural Studio student with Christine's oldest child in the screened-in porch.

# 3—Compressed Earth Block

The compressed earth block was the first material to be used in the modern earth-building revolution, an entirely new building unit invented in the eighteenth century, when radical philosophies were emerging in Europe. François Cointeraux, a Lyonnaise architect who was impressed by the use of *pisé*, was so inspired by building with earth—which he saw as congruous with the emerging ideals of the French Revolution, being an inexpensive and readily available material for the common, hardworking man—that he sought to disseminate and improve upon the technology.[1] In 1803 Cointeraux developed a mechanical press to create a building module that he felt should be employed "throughout the realm, for the decency of villages and the honor of the nation."[2] Having learned of rammed earth in the wine-growing regions south of Lyon, his invention was based on the traditional wine press.[3] The rammed earth blocks produced by the press could be used to construct factories, fireproof buildings, and save wood.[4] He viewed the output of the press as a form of cast stone, or *pierres factices*—neither brick nor *pisé*, but *nouveau pisé*, as he called the entire process.[5] Thus, the modern compressed earth block (CEB) was born—a building component that had the versatility of a brick but the social, economic, and environmental potential of rammed earth.

Soon, improvements on the compressed earth block machine began to appear in other parts of the world. By the early twentieth century, manual and motor-driven mechanical presses with heavy iron lids that pressed the earth into molds were in use, mostly in developing countries. Probably one of the most important moments in the history of the compressed earth block was in 1952, when Colombian engineer Raul Ramirez—while working at the Centro Interamericano de Vivienda (CINVA), the Inter-American Housing Center in Bogotá—developed a manually operated machine that fabricates CEBs and tiles for the construction of low-cost housing. Popularly known as the Cinva-Ram, the device consists of a steel box whose base is filled with soil and a lever and compresses the soil. When the lever is released, the lid can be removed and the lower plate can be raised even further to extract the CEB. Using this process, a few workmen can produce up to five hundred blocks a day.[6] Portability and ease of use make this particular invention extremely attractive for the production of CEBs, and it is still commonly found in use throughout the world.

Today, the mechanisms created to produce CEBs are very advanced, and an entire industry has developed around them. Some devices are improvements on the manual press, while others have electric, diesel, or gasoline-powered engines that utilize hydraulic compression to produce thousands of blocks per day. These small factories, which can be towed by a truck, can cost upward of $50,000 and have equally expensive attachments that include earth-blending machines, hoppers, and loaders. The technological sophistication that allows for mass production at various scales makes CEB one of the few earth technologies that is also a viable commercial product.

Cointeraux's desire that earthen construction be an agent of societal reformation is still palpable in modern compressed earth block building culture. In the 1980s, the technology was disseminated throughout the developing world through aid agencies such as the Peace Corps and USAID. Mexico and other nations with growing populations in need of low-cost housing are some of the most booming markets for CEB machine sales.[7] While countries where aid organizations introduce the CEB often have their own well-established earth-building traditions, CEB is usually preferred because the machine-made product is perceived to suggest progress.

In a developing country, the perceived superiority of compressed earth block can be substantial. In Mali, for example, it is illegal to construct a school out of mud brick, but schools constructed of CEB are welcomed and often encouraged, even though the machine necessary to produce the blocks can be expensive and the tradition of mud brick is well established. Additionally, while CEBs can have higher compression strengths than mud brick, this often results in a block that is smaller, producing a building with less thermal mass, which results in classrooms that can be uncomfortably hot in the desert heat. Cement stabilizer is often an important ingredient in CEB production to ensure a standard product. The capital required to purchase portland cement and fossil-fuel-operated machinery is the great irony of using CEB in the developing world, particularly where traditional earth building thrives. Nevertheless, governmental, nongovernmental, and aid organizations, as well as local citizens, believe the machines' technological advancements often outweigh the capital needed to sustain them.

Nevertheless, there are advantages to using compressed earth blocks. Very little moisture is required to produce a CEB, so the blocks do not shrink and crack. The precision of shaping earth in a steel mold results in a standardized product, and its sharp edges

A detail of naturally compressed earth, called tepetate, which was carved from the ground.

and smooth surfaces allow a CEB to be left exposed as a finish material. In addition to the aesthetic quality of the block, its standardization can result in more accurate cost estimating. CEBs can also be used immediately out of the machine, whereas mud bricks take weeks to cure before they can be handled. They can also be stronger than mud brick or rammed earth, depending on the soil and compression strength of the machine, and a range of block sizes can be produced from a single machine. Some of the machines, such as those with a hydraulic press, require very little manual labor compared to that necessary to produce mud brick or rammed earth. The soil can also come directly from the site, saving transportation costs.

Like other earth-based technologies, the soil mixture used to produce a CEB can be quite varied. The recommended range of percentages for each component is 10–30 percent clay, 15–25 percent silt, 15–35 percent fine sand, 15–35 percent coarse sand, and 10–70 percent fine gravel.[8] No rock or coarse gravel can be present in the soil as it may disrupt the compaction or damage the machine. In CEB production it is necessary to include a stabilizer, such as portland cement, emulsified asphalt, or lime. Unlike rammed earth, which is compacted repeatedly, the blocks are compressed only once in the press, and the soil mixture does not bind completely, so the blocks must include this additional ingredient to reach a higher compressive strength than mud brick.[9]

After two hundred years of use in the industrialized world, compressed earth block still maintains its identity as a material of social transformation and expression. Architect Mauricio Rocha used traditional *tepetate*, blocks of earth that have been naturally compacted by geological forces, for a Center for the Blind, creating a thoughtful and responsive architecture while accommodating the project's strict construction budget. Heikkinen-Komonen Architects explored the architectural, economic, and contextual potential of CEB construction in their Villa Eila and Kahere Eila Poultry Farming School. D. Francis Kéré used it in a design for a school in his village where the construction of the school was itself part of the education. Expanding upon Cointeraux's beliefs, de Paor Architects commented on globalism, ecology, and the specifics of place with their installation of compressed peat blocks.

# Villa Eila

ARCHITECTURE FIRM

**Heikkinen-Komonen Architects**

LOCATION

**Mali, Guinea**

DATE

**1996**

Round mud brick buildings with thatched roofs are common throughout Guinea, but because traditional earthen structures have become associated with poverty, fired brick, produced in small kilns that consume large amounts of wood and are associated with progress and status, supplanted traditional earthen technologies. As a consequence of this practice, deforestation became an increasing problem in the forests of the Fouta Djallon region of Guinea. In addition, corrugated metal roofing, despite its extremely poor thermal and acoustical properties, especially during the hot and rainy seasons, began to replace traditional thatched roofs. Eila Kivekäs, the founder of the Finnish development association Indigo, was concerned about what was happening in the country and decided to construct a house that would exemplify economical and ecologically efficient building and promote local traditions through simple technological improvements. The Finnish firm Heikkinen-Komonen Architects was commissioned to create a prototype house to advance existing technologies and conserve resources particular to the local climate and economy.

opposite, top: South elevation

opposite, bottom: The west facade is open to views of the mountains

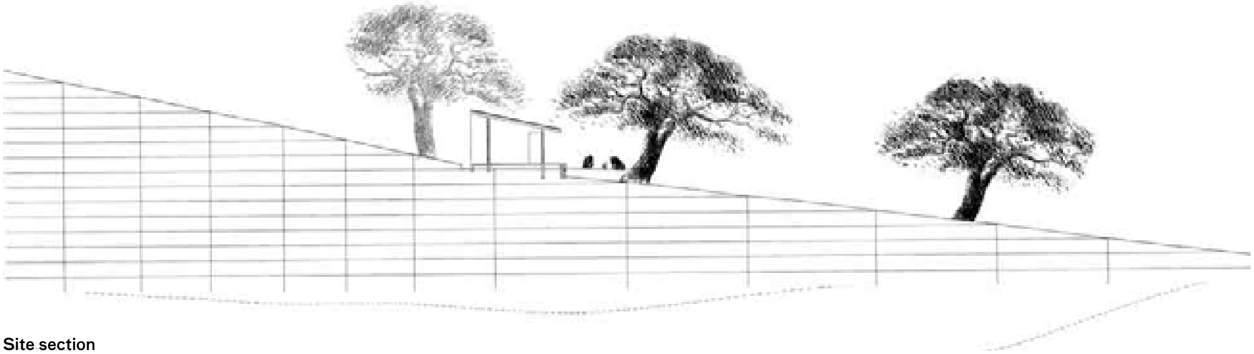
Villa Eila is a private residence located at the northeastern outskirts of the town of Mali, Guinea, at an elevation of 4,790 feet above sea level in the Fouta Djallon highlands—the origin of the Niger, Senegal, and Gambia rivers. Temperatures are mild, ranging from 62° Fahrenheit in the winter to 88° during the summer. For three months during the rainy season, precipitation is constant and the annual rainfall averages 20 inches.

The house is sited on a narrow terraced strip of land, on a west-facing slope with picturesque views of the surrounding peaks. A continuous roof structure, whose columns and beams are constructed of hard mahogany harvested from local forests and joined using simple steel fasteners, shades the indoor and outdoor living spaces beneath it. The slope of the roof is parallel to the slope of the site; and to protect against strong winds, thin steel rods are attached to the overhangs on the east and west sides of the roof, extending to the foundation, which anchor the roof to the ground. On the east side of the house, the rods support a woven bamboo screen that filters the morning sunlight and gives privacy to the outdoor toilet and bathing area.

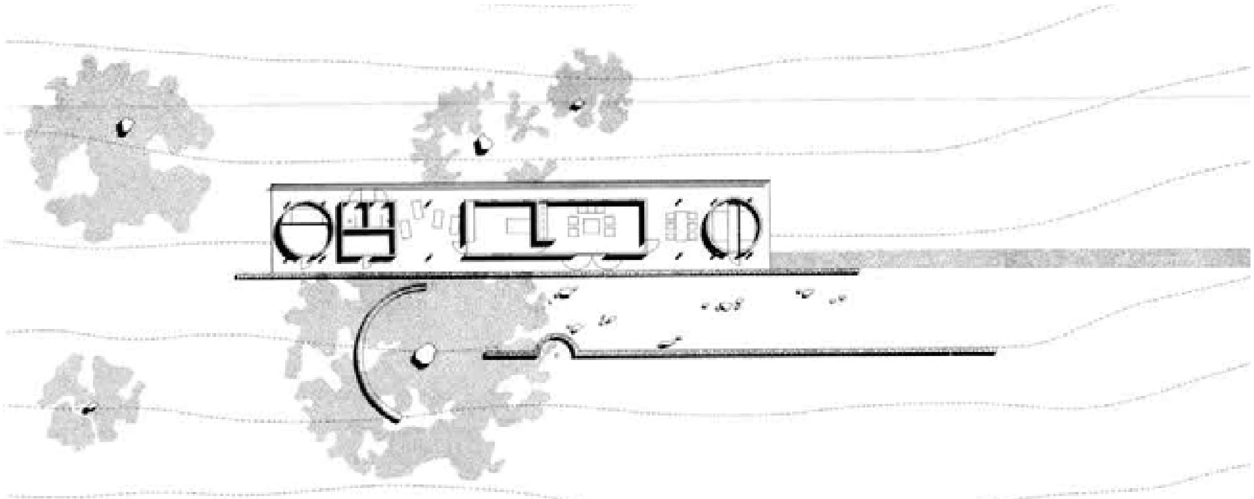
In the shade of the roof are several rooms of varying shapes. Round volumes at each end of the villa serve as guest rooms. A square room is used for storage and houses the bath and toilet facilities. Sleeping quarters are connected to the living room in the large rectangular space. Meals are also prepared in the living room, which has built-in cupboards and a counter. A gap between the ceiling and the roof allows cross ventilation to completely circulate around each independent volume.

Each of the rooms is constructed of a single thickness of stabilized compressed earth blocks measuring 10 by 10 by 20 inches and rendered with a cement stucco. Each compressed earth block is made of soil that contains approximately 12 percent moisture, mixed with 3 to 5 percent portland cement. In accordance with the aims of the architects and client, many of the building components were made by local villagers. The compressed earth blocks were made by hand using a press imported from Belgium that allowed a team of six workers to produce between 700 and 1,000 blocks a day.

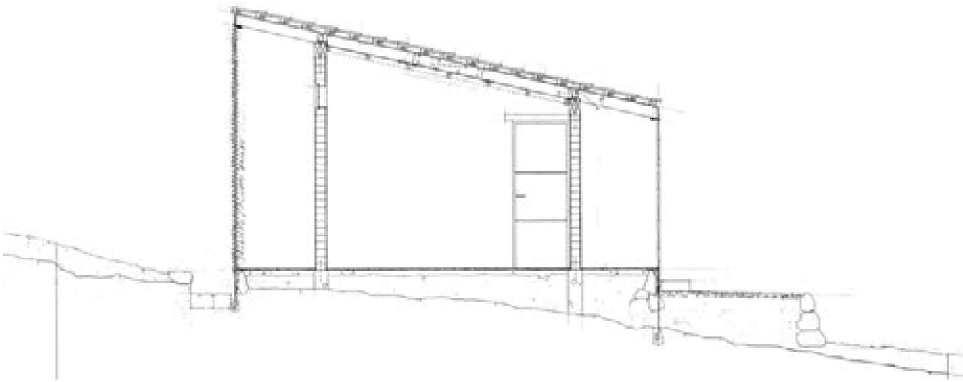
Floors are covered with glazed ceramic tiles handmade by women from the nearby village of Colci using molds built by a local carpenter. Outside, the terrace floor is covered with red gravel. The large ⅛-inch-thick roof tiles were made by hand on site from cement, fiberglass, and plant fiber, and are curved to interlock and overlap each other. Woven straw mats, another locally sourced craft, cover the ceilings in the northern guest room and the main living area and master bedroom.



Site section



Site plan



Section

top: The east facade is camouflaged by a woven bamboo screen that blends with the Fouta Djallon highlands in the background.

bottom left: A sublime effect is created by the alternating bands of light and shadow that pass through the woven bamboo screen.

bottom right: The ceramic floor tiles were made by local potters.

ARCHITECTURE FIRM

**Heikkinen-Komonen Architects**

LOCATION

**Koliagbe, Kindia, Guinea**

DATE

**1998**

In the early 1980s two Guinea natives, agronomist Alpha Diallo and his uncle, veterinarian Bachir Diallo, decided to help their country by creating a poultry farm to improve the Guinean diet, which lacked sufficient protein. Education, teaching others to raise and sell chickens, was to be the primary directive of the farm. Alpha had studied in Europe and was well known for his translation of the famous Finnish poem *The Kalevala* into his native language, Fulani. His work caught the attention of Eila Kivekäs, the founder of Indigo, a nongovernmental association dedicated to helping developing countries. Alpha eventually became Kivekäs's translator and told her of his and his uncle's poultry project. Although Alpha died in 1984, Kivekäs asked Bachir to begin the poultry farm with the support of Indigo, and in 1986, the poultry farm opened in the village of Koliagbe, becoming an immediate success.

Because of the rapid success and growth of the educational component of the poultry farm, classrooms and housing for students and teachers were needed. The poultry farm eventually was organized to educate five particular groups: illiterate farmers, farmers literate enough to receive advanced instruction, students from professional schools who might establish more poultry farms, professionals with academic backgrounds in fields such as veterinary studies, and university students preparing theses or final reports on topics of food and agriculture.

In 1998, Kivekäs commissioned Mikko Heikkinen and Markku Komonen, Finnish architects who had gained great experience in the region after completing several projects beginning with Villa Eila, to design a campus for the school. They continued their approach of improving upon regional building techniques by employing compressed earth block, rather than using crudely fired bricks, an inferior material whose production requires a tremendous amount of wood. They also avoided using corrugated metal roofs and instead designed a process in which the builders could make cement roof tiles by hand. The architects also imported their knowledge of wood construction techniques and developed a strategy for the campus based upon vernacular planning methods to create an Aga Khan Award–winning project whose history, philosophy, and architecture is a hybrid of Finnish and Guinean traditions.

Village compounds in Guinea typically consist of three types of buildings: larger communal structures for sleeping, smaller structures for cooking, and covered areas without walls for socializing. Buildings are usually grouped around an open space with a single tree, where activities take place in the shade and open air. The architects used this traditional organization as a precedent: the classroom, a dormitory that houses twelve students, and teachers' quarters define a courtyard with a tree in the center and a water tower marking the main entrance. A 4-foot grid on which the 3,660 square feet of buildings are arranged dictates the relationships between them and their proportions. The ramifications of this grid can also be seen in the details of the individual buildings. Glass is arranged in rows of fixed and operable windows that add diversity to the rigid layout and also allow for interiors that are bright and airy, reducing the massiveness of the earthen walls.

A double-layer load-bearing wall of stabilized compressed earth blocks resting upon a concrete foundation is the primary building enclosure used throughout the campus. This gives the buildings considerable thermal mass, keeping them comfortable throughout the year. Workers using a hand press were able to make up to a thousand blocks per day, on site, from locally sourced soil. The manual press

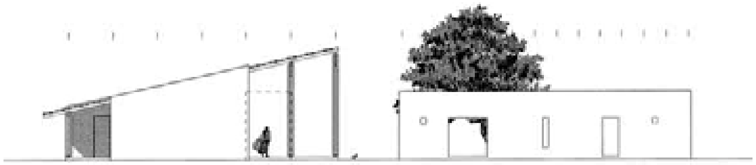
**opposite, top:** A water tower marks the entrance to the compressed earth block campus.

**opposite, bottom:** The thick walls are made of a double layer of stabilized compressed earth blocks exposed to the exterior, which rest upon a concrete foundation.

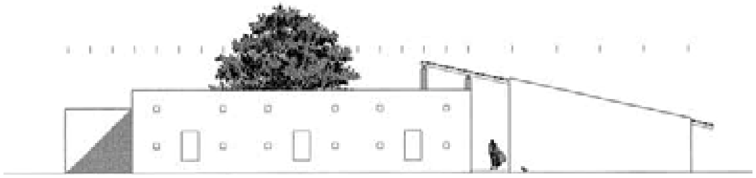
# Kahere Eila Poultry Farming School

produced blocks with a hard, smooth finish, so they were left exposed on the exterior of each building. To define the main entrances of the buildings, the compressed earth block of the facades was rendered smooth and painted to indicate the activities that take place within. The main classroom is painted indigo, the porches to the students' quarters are yellow, and the entry to the teachers' quarters is green. The interiors are rendered and painted a cream color, further creating a sense of lightness.

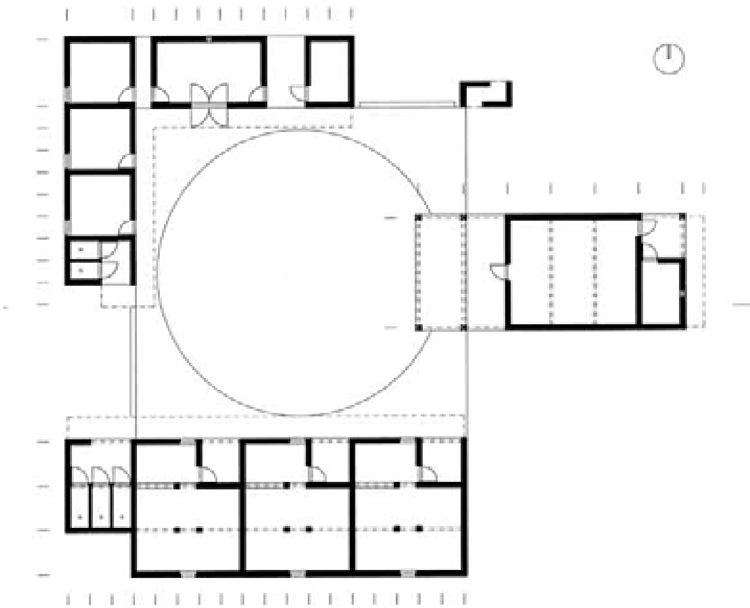
A Finnish sensibility of wood detailing, imported by the architects, appears throughout the campus. The wood trusses were designed so that large spans could be created using short pieces of the hardwood acajou and softer samba that are available locally. The roof is supported by elegant trusses made from these woods, which are connected with steel fasteners and a metal tension rod. Tall columns that support the entry porch to the classroom are also made of smaller pieces of wood spliced together using joinery reminiscent of modernist Finnish detailing. The poultry farming school also introduced compressed earth block skills to masons working on the project, resulting in a new trade in the region. After completing the school, the local builder who led the project started his own business and went on to use compressed earth block in the construction of a mosque and several private houses.



South elevations



North elevation



Floor plan

top: To illiterate farmers, the indigo painted facade indicates that the building is a classroom.

bottom left: Handmade roof tiles are supported by the trusses, and tall columns that are made of small-dimensioned, locally sourced lumber use steel fasteners and metal tension rods to create large spans.

bottom right: Cream-colored compressed earth block walls reflect light from the clerestory windows.

# $N^3$

ARCHITECTURE FIRM

**de Paor Architects**

LOCATION

**Venice, Italy**

DATE

**2000**

Peat bogs are one of Ireland's most characteristic features. They cover approximately one-sixth of the island (3 million acres) and provide fuel, fertilizer, and animal feed. Peat was so widely available during the seventeenth and eighteenth centuries that poor families constructed houses from dried blocks of it. Peat is a type of soil that is formed with organic matter. It is prevented from decomposing completely because of acidic or anaerobic conditions, takes thousands of years to form, and under the right conditions is the earliest phase of coal. Architect Tom de Paor believes that a significant portion of the bogs of Ireland will be exhausted before the middle of the twenty-first century, so when the Department of Foreign Affairs invited the Dubliner to represent Ireland at the architecture exhibition at the Venice Biennale in June 2000, he decided to use compressed peat as a way of speculating on the value of land and to create a precious gift for the city of Venice.

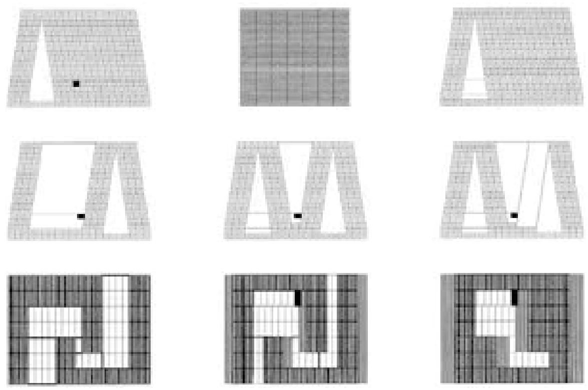
The 23 tons of bricks used for the installation were donated by Bord na Móna, an Irish company that harvests 1 million cubic yards of peat each year for fuel. The 40,224 compressed bricks, each measuring 16 by 12 by 10 inches, were bound with polypropylene straps into 1,676 individually numbered bales. The fuel value of this mass of peat was calculated to be 3,500 therm, and it contained 2,838 tons of native Irish water and 141 pounds of sulphur, statistics that also speak to the value of the installation. Bricks were corbeled, measured by a notch in the profile of the brick, creating a trapezoidal structure with a footprint of 7 by 21 bales resting on a layer of sand. Steel reinforcement bars and fiberglass mesh concealed within the courses of blocks provided additional strength for the corbeled structure.

The plan took on an N shape, and all bricks were oriented north/south so that the pavilion became a full-scale inhabitable cartographic N that accompanied north arrows, like those found on architectural drawings or maps—perhaps a gesture toward the general direction of the original home of the transplanted soil. The N shape also gave the pavilion its name and formed a labyrinth defined by two narrow and slanted passageways that led to a room open to the sky. Inside, rubber casts molded in the same profile as the bricks displayed nine cards that told the story of Venice's beloved saint, San Nicolo, whose remains are said to lie nearby in a church on the Lido that bears his name. This dark, damp labyrinthine monolith became a tomb or reliquary for Saint Nicholas, which inspired an alternative name for the installation—"Santa's Grotto." It also evoked the notion of the bogeyman, the etymology perhaps stems from the remains of humans found in the peat bogs thousands of years after their death, perfectly preserved because of the tanning properties of the acidic water.

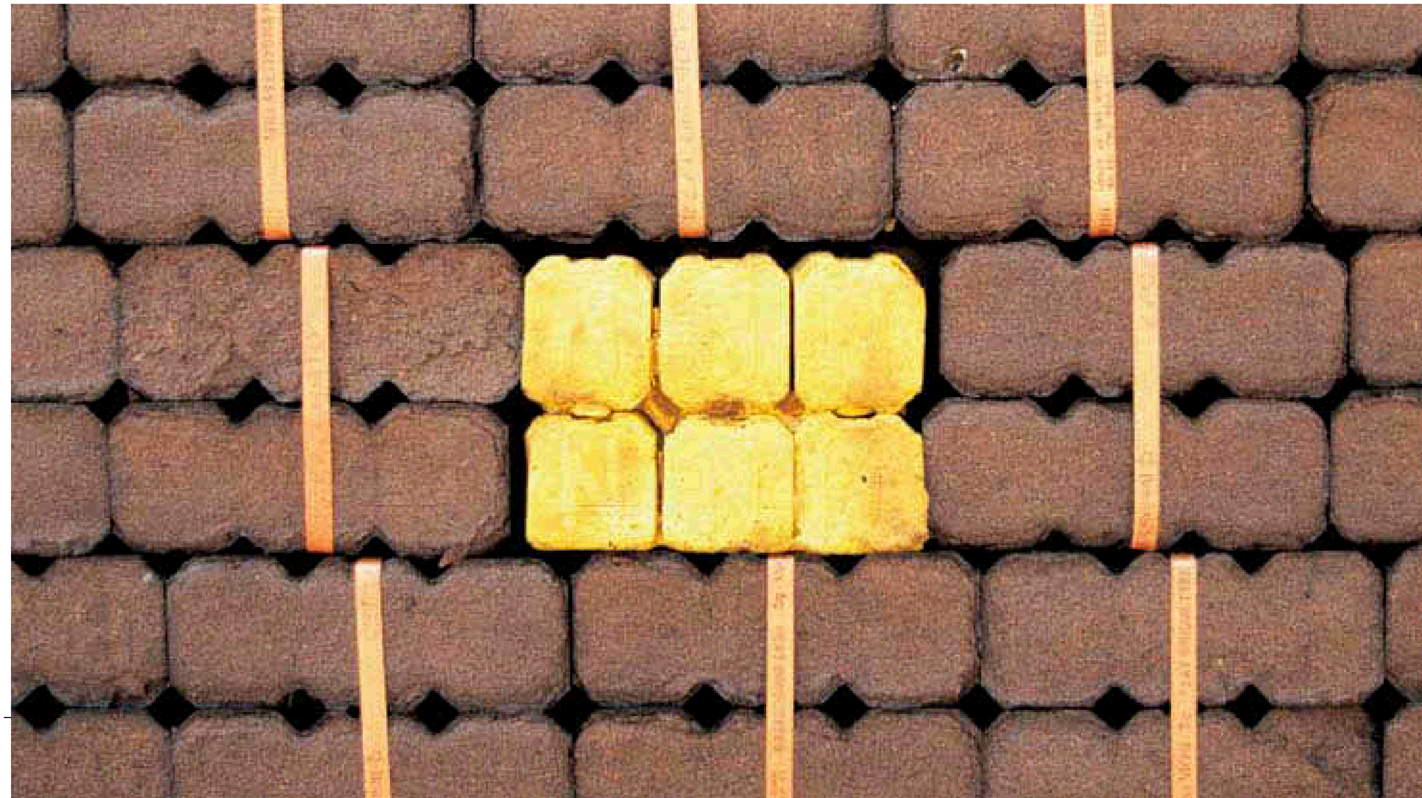
$N^3$ was also intended to bring attention to the fact that peat is a nonrenewable resource, so at the end of the Biennale, de Paor donated the 23 tons of imported Irish soil to Venice, a city where land is very scarce, in celebration of the Irish holiday Bloomsday, which celebrates James Joyce and his novel *Ulysses*. The bricks were decompressed and spread around a public garden where the rich nutrients taken from the island country contributed to the addition of land to the island city.

**opposite, top: $N^3$ installed at the 2000 Venice Biennale**

**opposite, bottom: The 40,224 compressed peat bricks were strapped with polypropylene to form a stackable building module.**



**Elevations, sections, and floor-plan sections cut at various heights**



ARCHITECTURE FIRM

**Taller de Arquitectura Mauricio Rocha**

LOCATION

**Mexico City, Mexico**

DATE

**2000**

The Center for the Blind, designed by Mauricio Rocha, is a 150,700-square-foot complex that provides recreational and educational facilities for the blind and visually impaired. The campus is located in the Iztapalapa borough of Mexico City in a neighborhood with the city's highest concentration of persons with visual disabilities, on a site bounded on two sides by a busy intersection; the property was at one time used as a dumping ground for construction debris. A low budget for this project, which was funded by the Mexican government, necessitated that economical materials be used, so the architect decided to employ a traditional earth-building technique. Also, rather than considering the large amount of landfill on the site a problem, he took the potential to reuse the large amount of soil on the site as a departure point for the project and he created a strategy to reorganize the landfill to define orientation devices for the sightless.

The landfill was pushed to the perimeter of the site and compacted against a massive, 330-foot long "blind" retaining wall made of stone that had no fenestration and that separated the interior of the complex from the city. The grade was also shaped so that the center of the site was slightly elevated to underline the importance of the main public space at the center of the complex. This bold landscape move used 70 percent of the landfill found on the site to create the spatial and sensorial means by which the sightless navigate through the complex.

Four devices assist the blind in orienting themselves in the complex—two of which can be linked to moving the earth to the perimeter. The landfill pushed to the perimeter muffles noise from the busy streets outside the complex, creating a quiet campus that can be navigated using sound. A long narrow channel of water spans the length of the main plaza in the center of the complex, and at each bridge traversing the channel, leading to other parts of the complex, one can hear water bubbling against the stone. Smell is the second means by which one can orient oneself and navigate throughout the complex; aromatic plants such as jasmine, rosemary, and basil, and lemon trees were planted strategically throughout the earth berms that lie at the periphery, to allow people to navigate by scent. The fragrance of orange trees planted along side the water channel reinforces the multisensorial means by which one experiences the site. For the partially blind, passageways were created with stark contrasts between areas of light and shadow to define entryways; and the concrete and earth walls of the complex also have a navigational system that relies on touch. The textured walls that run the length of the building at the level of the hand serve as navigational devices for the blind. Rough, smooth, vertical, and horizontal bands cast in the concrete base help the occupants remember the location and function of the buildings.

The buildings of the center, which include a library, gymnasium, natatorium, auditorium, gallery of touch, and five studios dedicated to painting, sculpture, theater, and dance are constructed of compressed earth block that was made by an interesting traditional method. Called *tepetate* in Mexico, the secret of the

opposite, top: The narrow channel of water that runs the length of the main plaza allows users to navigate with the sound of bubbling water.

opposite, bottom: Textures cast into the walls aid in navigation. Students who can still perceive light but cannot make out details are guided by the stark contrasts between light and shadow in passageways.

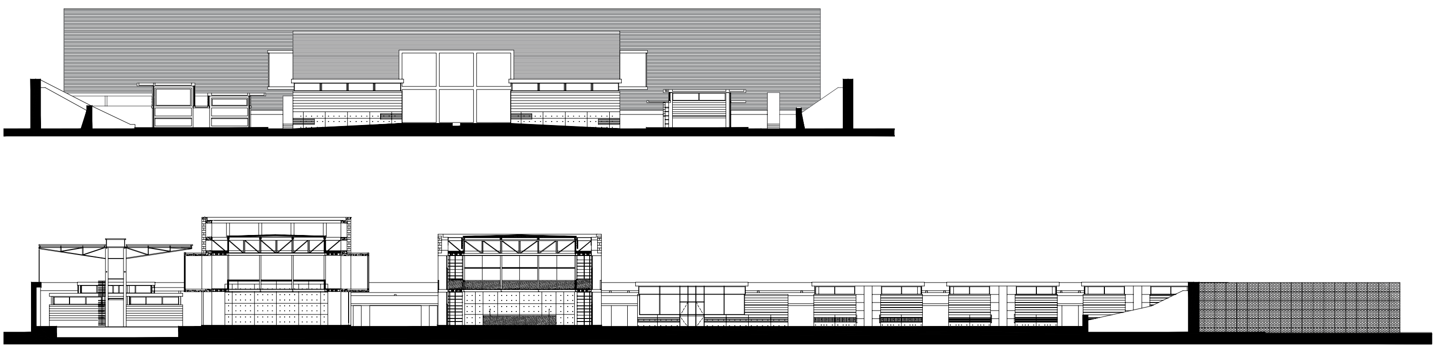
above: Tepetate infills a concrete structure, allowing for walls as high as 40 feet tall and interiors with large spans.

# Center for the Blind

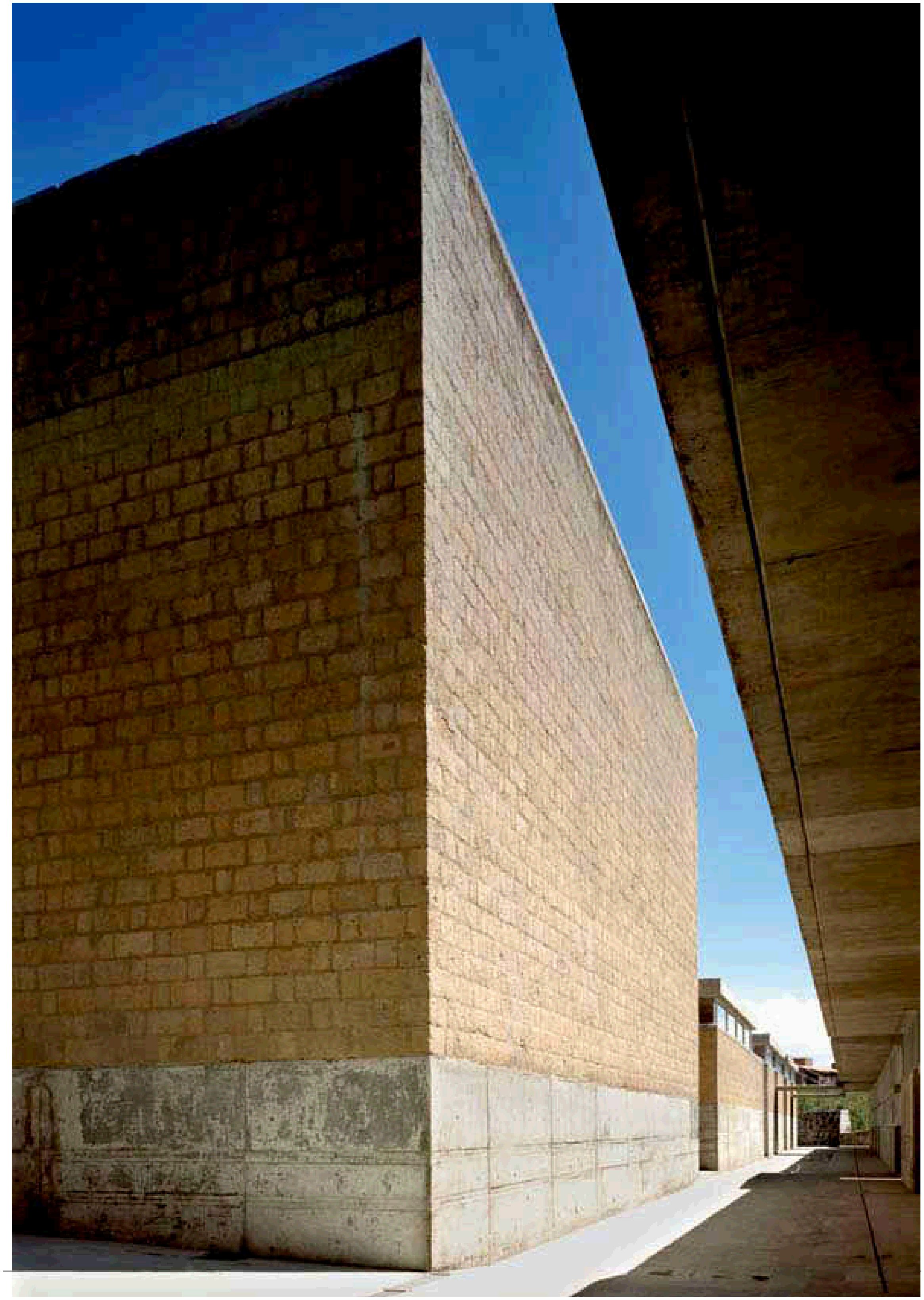
material is the soil used; naturally compressed caliche is the main component of this ochre-colored soil. Whereas modern compressed earth block is made by machine, tepetate is soil that was compressed over time though geological forces and cut from the earth in blocks. Unlike stone, tepetate is still friable and can be shaped easily. It was used in rural vernacular homes in the high plains of Mexico during the nineteenth century, but its use waned as it was replaced by industrial materials, despite the fact that they were not as economical as the traditional material. The architect decided to use tepetate because the average Mexican laborer is very familiar with this material, and it does not require precision, making it is easy to build with and inexpensive. Additionally, there is little maintenance associated with the material, and it ages very well.

In the past, it would have been difficult to use tepetate at the scale found at the Center for the Blind. But here the blocks are not load bearing; the tepetate serves as an infill "skin" that is supported by a concrete structure. In this way, Rocha was able to build walls as high as 40 feet tall and to have considerably large spans between them. The imprecision of the tepetate combined with refined concrete creates the sensorial atmosphere of the complex, where light and shadow, textures, smells, tradition, and modernity amount to the overall experience.

Site plan



Sections



The main buildings of the Center for the Blind are made of inexpensive, naturally compressed earth, called tepetate, which was carved from the ground.

ARCHITECTURE FIRM

**Diébédo Francis Kéré**

LOCATION

**Gando, Burkina Faso**

DATE

**2001**

There is a small school that is a marvel of ingenuity and community spirit on the southern plains of Burkina Faso, in the small village of Gando. It came into existence primarily because of a young architect's desire to build a school for the children of his village. Architect Diébédo Francis Kéré was the first person from Gando to be educated abroad, and believing that education was the primary vehicle for the advancement of his community, he decided to ensure that education be available in his village. While studying architecture in Berlin, Kéré and a group of friends created a fundraising association called Schulbausteine für Gando, Bricks for the Gando School, to promote the construction of a new school for the children of his town. He was also able to obtain the support of the government agency LOCOMAT of Burkina Faso, which helped train masons in the community to make bricks using compressed stabilized earth. Men, women, and children of the village were trained to construct stabilized compressed earth blocks, which were used for the walls and even the ceiling of the school.

The bricks used for the school have a small amount of cement mixed with the earth to increase their compressive strength and to protect them from the seasonal rains. Local villagers used a hand press, which allowed them to manufacture a large number of bricks each day, and construction of the walls was performed by them. Above each load-bearing wall is a concrete bond beam; metal rods spanning the space of each classroom are anchored to the bond beam and suspend a ceiling made of compressed earth block. This ceiling moderates indoor air temperature and creates an acoustical break between the classroom and the metal roof above.

The thick earth walls help keep the interior spaces of the school cool. The three earthen classrooms stand independent and disconnected from each other, and airflow around each classroom further assists in keeping interior temperatures down, which also helps students stay alert on hot days. The separation of classroom spaces also defines small outdoor spaces in the shade of the canopy, which are used as outdoor classrooms and break spaces.

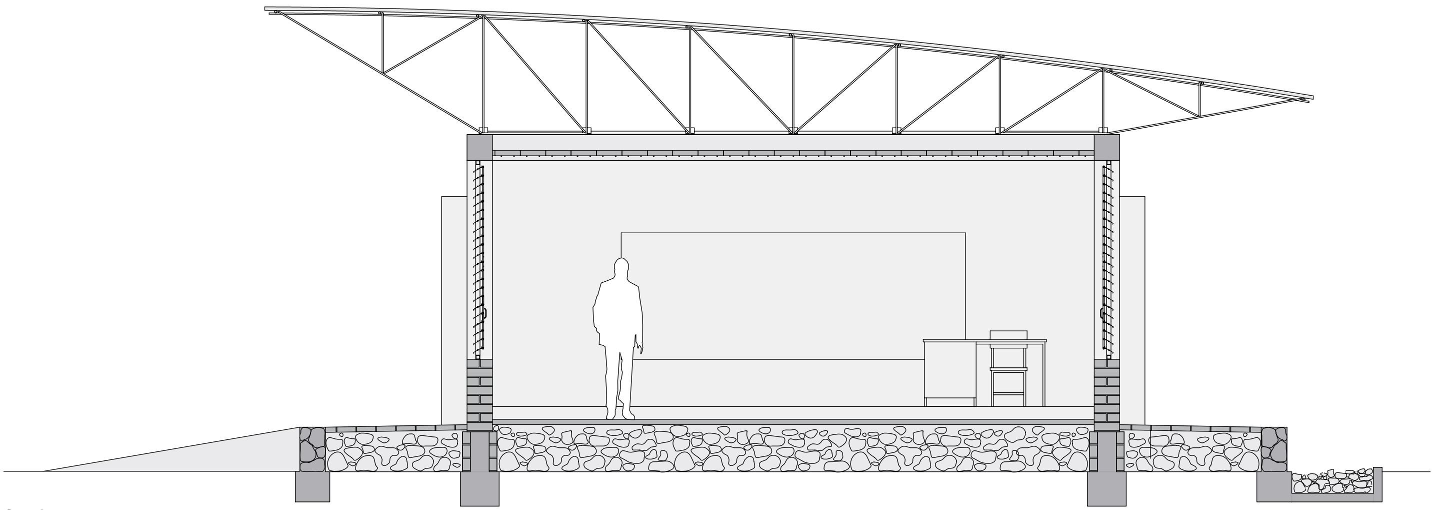
A soaring metal roof takes advantage of the skills and resources already available in Kéré's village. Traditional roofs in Burkina Faso are made of thatch, but increasingly, corrugated metal roofs are appearing in new construction. During rainstorms, however, they become very noisy due to rain pounding against the metal. Here, a metal roof was used, but an airspace between the earthen ceiling and the roof creates an acoustical buffer. Welding was already a well-established local skill in the community and Kéré took advantage of the fact when designing the ingenious truss system that supports the lofty metal roof. Each lightweight metal truss was built to be lifted onto the structure without the use of cranes and was fabricated using simple tools—reinforcement bar, a hacksaw, and a small welding machine. The school's east-west orientation ensures that very little of the wall surface of the school is heated by the direct rays of the rising and setting sun, and during midday the roof keeps the entire building in shade.

Gando's Primary School is a model for client-village activism and many near-by villages have followed its lead by forming organizations to construct their own schools. Furthermore, the skills that villagers learned in the construction of the school have attracted the attention of local authorities, who now hire them to construct municipal projects in the region.

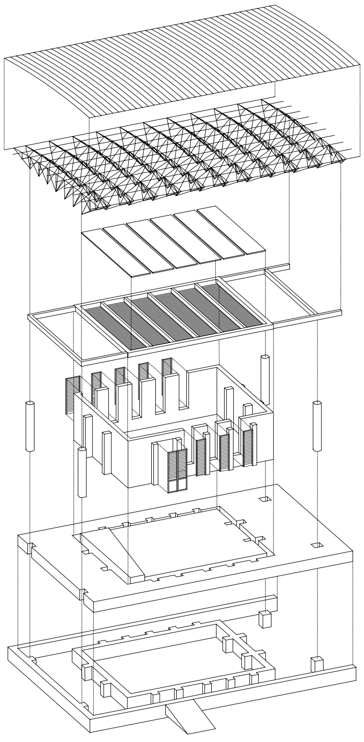
opposite, top: South elevation

opposite, bottom: The walls, floors, and ceiling of each classroom are constructed of earth.

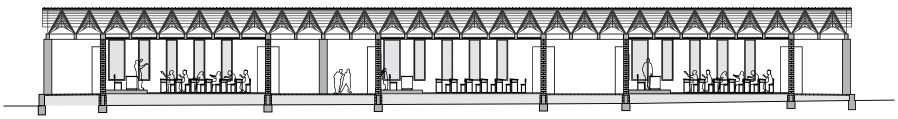
# Primary School



Section



Exploded axonometric drawing



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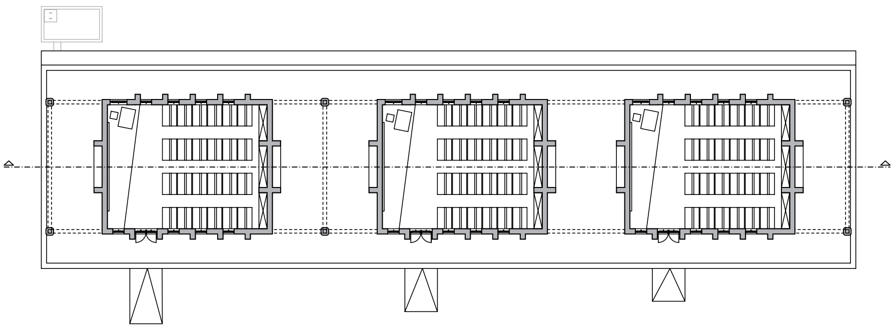


Floor plan

top left: The metal truss system is made of a reinforcing steel rod and was built by villagers using only a hacksaw and a small welding machine.

top right: Students tend to the herbs and vegetables growing in the school garden.

bottom: Alternating enclosed and open-air spaces beneath the canopy create small, shaded outdoor areas.

# 4—Molded Earth

The availability of suitable soils for building has resulted in rich and diverse traditions of earth architecture across the globe. According to some estimates, there are approximately twenty techniques of earth building on the planet.[1] Architects are beginning to rethink traditional forms of earthen construction and modify them in response to the needs of a changing world. Natural disasters, the need for low-cost housing, cultural preservation, and sustainability are some of the forces that push architects to reinterpret past earth-building traditions, creating new kinds of architecture and updated versions of ancient techniques. To follow are a handful of important building traditions that architects have creatively transformed into perhaps some of the most radically experimental works of contemporary earthen architecture.

### Wattle and Daub

The oldest of earth-building technologies, and perhaps of all building technologies, may be wattle and daub.[2] Before mankind began to create societies based on farming, hunter-gatherer societies needed portable shelter or shelter that could be made with the materials on hand that accommodated a nomadic lifestyle. Branches could be carried or found and used to build a structural framework, and plastering mud onto this matrix of woven branches created protection from the sun and wind. This technique, called wattle and daub, was used by the earliest people of every inhabitable continent.[3] In excavations of the oldest known settlements, like Jericho and Çatalhöyük, wattle and daub structures predate the more permanent structures constructed of mud brick or rammed earth.

As the name suggests, wattle and daub comprises two components. A wattle is a woven structure of small plant elements held together in a stiff frame. Reeds, bamboo, branches, and twigs are common materials used to construct the lattice. Mud, or daub, adheres to the irregularities and overhangs of the organic matrix. The mud mixture is similar to that used for mud brick, but with smaller aggregate, and dung is often the organic binder. The daub is then smeared on to the wattle by hand until the entire surface is covered. When dry, the finish surface can either be a smooth final coat of daub, or it can be whitewashed with lime.

Unlike other earth-building systems that are extremely massive, wattle and daub can be quite thin, but it does not have the same thermal mass properties of rammed earth or mud brick. However, because the woven structure is extremely flexible, it is highly earthquake resistant—one reason for its use in the seismic zones throughout the world, evidenced by the wealth of wattle and daub structures in South America and Indonesia. But seismic zones are not the only environments where wattle and daub can be found. Many of the Native American cultures of North America employed wattle and daub as a primary means of construction, and the United Kingdom is still home to a sophisticated array of examples of the technique. Indigenous and European Australians, too, used wattle and daub; and it also flourishes throughout Europe and Asia.

Even though wattle and daub is still widely used throughout the globe, the technique is quickly being replaced by industrial systems and the materials that accompany them. Where branches and mud were once common, expanded metal lath and cement stucco have taken over. Nevertheless, many cultures throughout the world still practice traditional wattle and daub techniques and some architects, like Chileans Smiljan Radic and Marcelo Cortés, have given the ancient technology new life by reexamining and reinterpreting it in an era when it is often thought to be unsuited to contemporary society. Radic's unique architectural installation, *Extension for the Charcoal Burner's Hut*, expressed and revealed both the formal and traditional aspects of earthen construction by exposing a process that typically is partially buried; and Marcelo Cortés's *quincha metálica* used steel to create a system that is a hybrid of traditional and industrial technologies.

### Cob

Cob is the simplest of all earth-building techniques. It requires very few tools and no formwork or internal structure, and consists of piling and molding mud to create walls. The cob mix is similar to that of mud brick, but much stiffer and with a somewhat higher straw content, which helps the mud hold its form as it is piled. Mud is shaped by hand or trowel and set in place directly on top of a foundation to an average height of approximately 18 inches around the perimeter of the building footprint. This is done with a pitchfork or a cob fork, a traditional tool found in the United Kingdom, similar to a pitchfork but designed specifically for use in cob construction.[4] Each 18-inch layer is called a lift, and it must be left to dry sufficiently before the next one is applied. Openings for windows and doors are shaped as the wall grows, and wood or stone lintels are added to span the openings only after the wall has cured. Because of the nature of the process, cob structures can be highly sculptural. A straight line is not the norm in a cob construction, but window and door openings and walls can be leveled using a paring iron to create cleaner edges and walls.

The simplicity of the system has allowed the technique to flourish throughout the world. Native Americans piled mud to create large multistory dwellings. The ruins of Casa Grande, built of cob between 1200 and 1450 by the Hohokam culture near Phoenix, Arizona, became the first prehistoric cultural site to be protected in the United States.[5] The multistory Taos Pueblo in New Mexico, which was constructed of cob between 1000 and 1450 and is the oldest continuously occupied dwelling in North America, is still a thriving village. In northern Yemen, *zabur*, as cob is called there, is a sophisticated tradition; multistory dwellings and fortifications of piled mud are still being constructed today by Bedouin cultures. In the United Kingdom, where the word *cob* originated, building with piled mud flourished from the thirteenth to the nineteenth century. In Ireland, Scotland, Wales, Northern Ireland, and England, many typologies, from humble farmhouses to stately manors, as well as the birthplace of sixteenth-century writer and explorer Sir Walter Raleigh (founder of the first English colony in the Americas) were constructed of cob. With British colonization the use of cob spread to Australia, New Zealand, and North America. In New Zealand, English colonists constructed over 8,000 cob houses.[6]

Today, cob is very much alive thoughout the world. In the United Kingdom the long, curving cob wall in Associated Architects' Cobtun House demonstrates how well suited this simple technique is to combining high and low technologies in an ecological design. In Heringer and Roswag's design for a children's school in Bangladesh, the sculptural potential of cob is explored in the caves carved out of the wall where students can study, play, or sleep.

### Poured Earth

Pouring earth into formwork and allowing it to dry is a technology that contains elements of wattle and daub, rammed earth, mud brick, and cob. When wattle is used on an exterior wall and an interior wall, the resulting gap is filled with mud. While rammed earth construction requires laborious tamping, here, when the mud is dry, the resulting shape is achieved. Depending on the tradition, the formwork might be left, becoming the primary structural support for the building, or the formwork is wattle, embedding further reinforcement in the wall; in other cases, the shuttering is removed, and the wall is allowed to dry as if it were one giant mud brick.

The Juana Briones House, built in 1845 near San Francisco, California, is a unique example of this type of construction, which is called *encajonado*, a Spanish term that describes stuffing mud into a framework of lath.[7] In the United Kingdom, many houses were built during the late eighteenth and early nineteenth centuries by combining straw, chalk, and soil and pouring the mix into formwork. Once the material dried, the formwork was removed to expose the brilliant white walls.[8] This is similar to Marwan Al-Sayed's use of gypsum in a poured earth wall in Phoenix, Arizona; the color helps bring a quality of lightness to the massive poured earth walls while reflecting the desert sun. Nader Khalili's superadobe, in which flexible sacks of earth are stacked to create quick, low-cost disaster housing, is a radical take on poured earth traditions.

### Extruded Earth

Pushing a soil mixture through a die to create precise profiles is common in the brick- and terracotta-making industry. The process begins with mechanically mixing precise amounts of shale, clay, and other soils with water. This results in building units that benefit from a high degree of quality control as the soil mixture is homogeneous for each batch and profiles are equal in dimension, with flat faces that were formed by steel molds. As profiles are extruded, the soft, moist clay is cut with a series of wires to the correct length, after which it is air dried for several days. Following this, traditional bricks are fired in a kiln to the point of vitrification. Those bricks not entering the kiln are called "green bricks," and increasingly, architects are considering these as building modules because the precision inherent in the process makes the production of large quantities of high-quality earthen building units possible. The soil content for green bricks must have a lower clay content than those headed for the kiln, but the precision of the process also allows for this as well as for more accurate cost estimation than is possible in traditional mud brick manufacturing. Also, customized shapes and lengths can be created by changing the profile of the die or the distance of the wire cutters. Not using the kiln also saves on fossil fuels; many brick plants maintain constant high temperatures in kilns by using natural gas and propane. Architect Gernot Minke took advantage of this process in his design for a kindergarten at Sorsum. Thanks to the precision of the extruding process the bricks making up the the school's domes could be left exposed as the finish surface, and each brick had a customized profile that improved acoustics.

ARCHITECTURE FIRM

**Nader Khalili**

LOCATION

**Baninajar Refugee Camp, Khuzestan**

DATE

**1995**

Iranian-born architect Nader Khalili has long been interested in the earthen architecture of his home country. Since founding the California Institute of Earth Art and Architecture (Cal-Earth) in 1991, he has expanded upon the traditional earth-building techniques of Iran, inventing unique and useful earth-building processes in response to important global issues. Early on, Khalili experimented with creating waterproof ceramic houses by setting fire to entire earthen structures, similar to firing a clay pot in a kiln. Later, Cal-Earth collaborated with NASA to explore construction techniques for building on the Moon and Mars, using the soil of those celestial bodies. Khalili's attempts to vitrify soil with fire eventually led to experiments where he constructed buildings with small plastic bags that were to be filled with lunar or Martian soil and affixed together with Velcro. Khalili's exhaustive, hands-on research has evolved into an innovative technique that uses local soils to respond to human housing crises anywhere in the world—a technique he calls superadobe.

Superadobe was developed as a system for building small stand-alone structures that could be clustered together to serve larger programmatic needs without the use of extensive skilled labor. It was also designed to be used in cases where both temporary and permanent shelter was needed in areas that lacked access to building materials, particularly wood. What resulted is an ecologically and economically appropriate tactic to house the millions of people displaced by natural and human disasters.

In 1995 Khalili partnered with the United Nations Development Programme and the United Nations Refugee Agency to build emergency shelters for Iraqi refugees displaced by the Persian Gulf War, using the superadobe technique. The refugees themselves constructed fifteen shelters in the Baninajar Refugee Camp in Khuzestan, Iran, at the cost of $20,000, $3000 less than the budget allocated for the project.

The superadobe technique is simple: polypropylene sandbags 14- to 18-inches in diameter, which can be up to a mile in length, are filled with dirt, sand, or clay and optionally mixed with a small amount of a locally sourced stabilizer, such as lime or cement. Because the bags can be filled by hand, the structures can be built by anyone—men, women, the elderly, and the young. As the bags are filled, they are stacked and wound in increasingly smaller circular patterns to form domed structures.

As each course is layered, barbed wire is placed between the bags. The barbed wire keeps the bags from slipping and gives the structure a tensile strength that is complementary to the compressive strength of the earth. When the structure is complete it is plastered with local soil that also might be mixed with lime for increased water resistance.

Since superadobe was extensively developed and tested in earthquake-prone California, it meets stringent building codes. The flexibility of the structure, curved forms, and barbed wire reinforcement give a superadobe structure surprising resistance to seismic forces. This makes it an ideal building system for housing victims of earthquake disasters or for housing in places with active faults. Superadobe is an ideal housing solution to other natural and man-made disasters as well, and, ironically, Khalili has made the materials associated with earthquakes, floods, and wars—sandbags and barbed wire—into an elegant and useful housing solution.

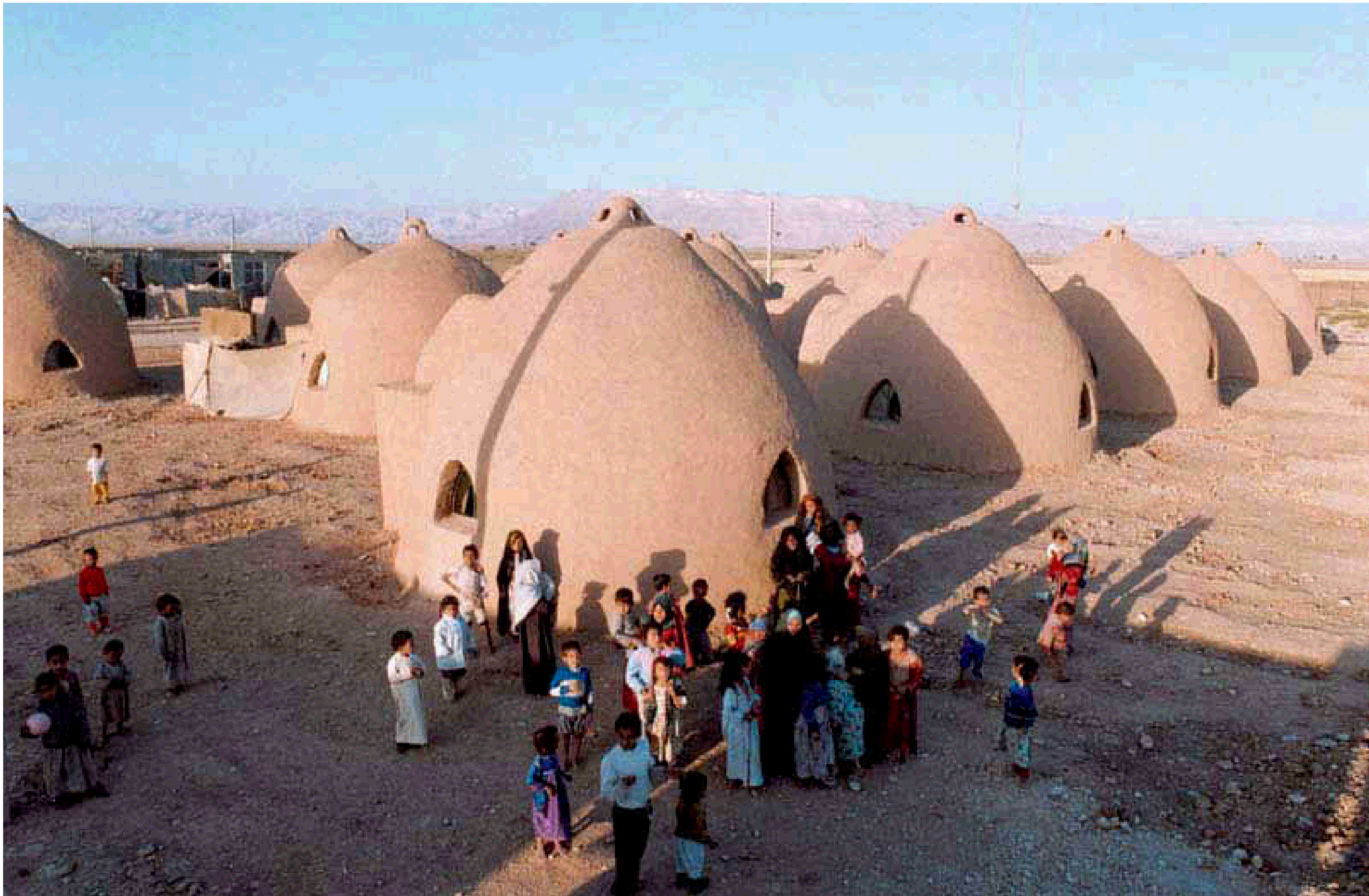
opposite, top left: Polypropylene sandbags were filled with dirt, sand, or clay mixed with a small amount of lime or cement and wound into domes.

opposite, top right: Superadobe structure under construction

opposite, bottom: The Baninajar Refugee Camp is a grouping of fifteen superadobe shelters built by the refugees themselves.

# Baninajar Refugee Camp Housing





# Waldorf Kindergarten

ARCHITECTURE FIRM

**Planungsbüro für Ökologisches Bauen Kassel**

LOCATION

**Sorsum, Germany**

DATE

**1996**

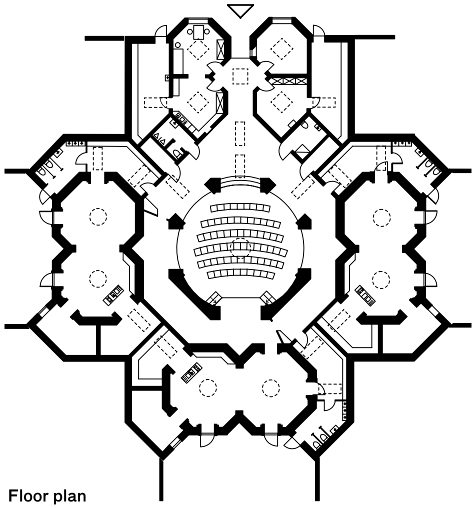
Waldorf schools, which aim to educate through multidisciplinary developmental approaches that address the needs of the growing child, are well known around the world for their unique architecture. Rudolf Steiner, an architect who developed this educational philosophy in 1919, believed that in an industrial age, the handmade, the curvilinear, and the organic had an important value in a culture increasingly moving toward the machine-made and the rectilinear. Steiner promoted the use of natural materials, exposed woods, and biological forms in his buildings, a reflection of a philosophical movement he developed called anthroposophy, which promoted sustainable thinking and biomorphism long before trends in sustainability and blobitecture emerged. The aesthetic, material, and environmental philosophy driving the design of the Waldorf schools is evident in the design for a Waldorf kindergarten by German architect Gernot Minke.

The kindergarten is located in Sorsum, Germany, a small village of 3000 people in the district of Hildesheim in northern Germany. Its 6,400 square feet of space are devoted to three group, gathering areas, restrooms, food preparation areas, offices, and a large centrally located assembly space. The majority of the building is buried underground, and the rest emerges from the ground like a fairy-tale dwelling. Domes define the topography of the roofscape of the kindergarten, on which wild grasses are planted in a 6-inch-thick layer of earth that covers the building, creating a seamless connection with the surrounding landscape. At the peaks of each hill, a skylight suggests that there is something hidden below.

A large dome defines the main space within. Reaching almost 23 feet in height, the shell that defines this assembly space spans a distance of 33 feet and is constructed of 12-inch-thick bricks. The dome rests atop a ring of fired brick columns, creating a series of arched openings that allow children and visitors in and out of the space. At the center of the dome, an oculus illuminates the vast space, creating a rhythm of light and shadow that is enhanced by the specially formed bricks that define the dome. Surrounding the larger dome are three smaller domed group areas. Rooms and corridors adjacent to these gathering spaces are constructed of heavy timber with experimental earth infill that consists of various types of earth plasters, earth bricks, and oddly shaped clay-filled cotton hoses that look like mud sausages.

Unfired bricks were used to construct the domes. A similar mixture of soils used to make fired brick, but with a smaller percentage of clay to reduce shrinkage, was mixed in a brick factory, extruded through a mold, and wire cut. Each of the custom-made bricks was set in place with the assistance of a rotational guide developed by researchers at the University of Kassel. The device precisely located the best position for each brick in order to optimize the geometry of the dome, ensuring that the structural load is efficiently directed to the foundations of the building.

Each of the bricks has a special rounded surface specifically designed to absorb sound. This makes the large gathering space at the center ideal for the kinds of alternative educational activities offered by the kindergarten. The corbeled structure of the dome and the sod roof are responsible for creating a warm space with marvelous acoustics, making it ideal for the lectures and musical performances they host.



Floor plan

top left: Wild grasses grow in the layer of earth covering the building, creating a seamless integration with the surroundings.

top right: Corridors within the school exhibit various earth finishes invented by the architect.

bottom left: Each brick has a rounded surface designed specifically to improve the acoustics of the domed spaces.

bottom right: The central dome encloses the large assembly area and rests on top of fired brick columns.

ARCHITECTURE FIRM

**Marwan Al-Sayed Architects Ltd.**

LOCATION

**Phoenix, Arizona**

DATE

**1998**

The desert is characterized by oppositions. The heat of the day contrasts with the cool of the night. Light and shadow, wet and dry are some of the polarities that are part of desert life. The exploration of these dichotomies, along with those of heavy and light, mass and space, earth and sky were the driving force behind the House of Earth and Light. Both the immediate site and the larger context provided opportunities to create and explore space and use materials that respond to those contrasts.

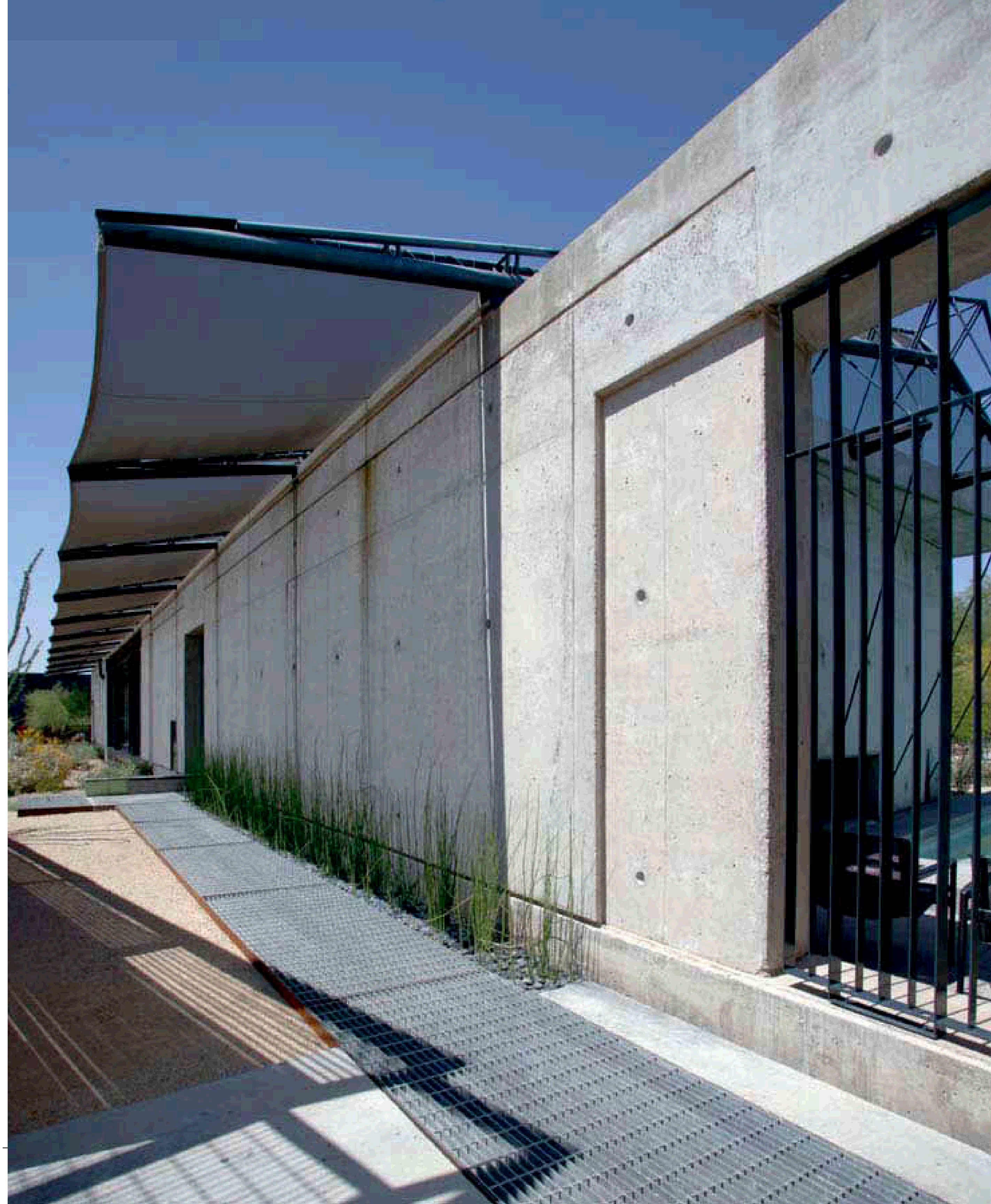
In the desert, dry ephemeral riverbeds through which the scarce seasonal rain is channeled are called wash basins. The presence of moisture in these basins attracts an abundance of flora and fauna, and subtle breezes flow through the natural depression. This particular suburban desert site is bisected by a wash basin, making architect Marwan Al-Sayed's vision for a long narrow house, a common type in the desert, seem difficult. But Al-Sayed took advantage of the unique microclimate of the dividing wash and separated the 2,500-square-foot house into three parts. The central component is a steel-and-glass bridge containing the living and dining room, which floats over the ravine. Large panes of low-emissivity glass block ultraviolet and infrared solar energy, and operable windows take advantage of the cool breezes, vegetation, and the shade of the wash basin.

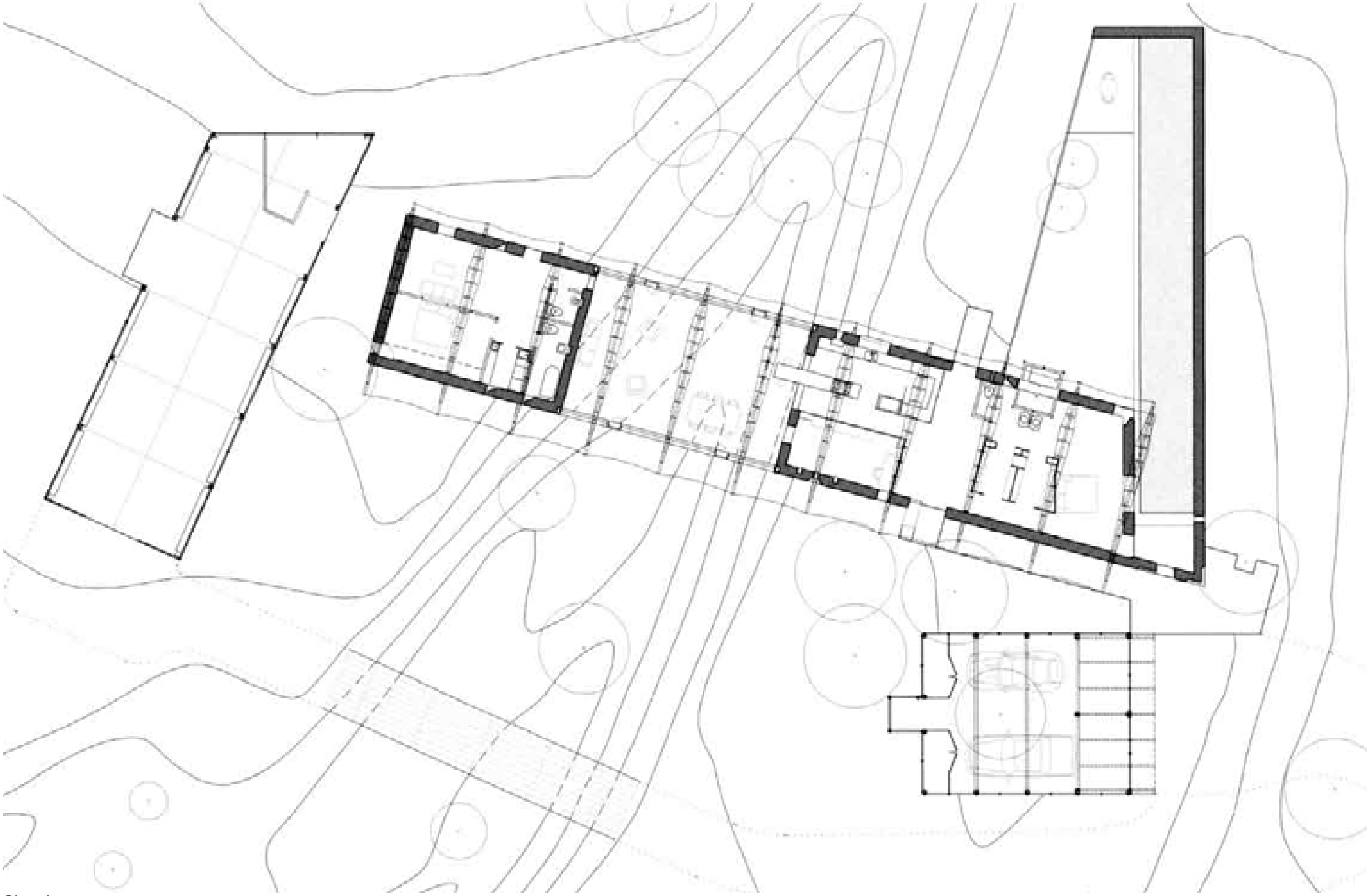
In contrast to this lofty transparent bridge spanning the natural depression, the house is grounded on both sides by massive opaque earthen volumes with 18-inch-thick walls. Originally, the walls were to be rammed earth, which is an increasingly popular material in the Phoenix area. Ultimately, the architect and contractors developed an innovative mix of stabilized gypsum soil that was poured into concrete forms and allowed to dry in place. The heavy walls buffer the desert sun and contain the more private areas of the house: the entry, study, kitchen, bedrooms, and bathrooms. In each room there are custom glass elements that reflect light and are trasnsparent and colorful in contrast to the heavy, opaque, matte walls. Custom glass floor tiles define the entry, and the bathroom sinks are cast glass. An 8-foot-long cast-glass desk located in the study reflects light from its magenta surface. Outside, water and earth are juxtaposed; an illuminated lap pool extends away from the house, reflecting light that is captured by the colorless walls. Most striking is the way the walls capture the subtleties of the desert light transmitted through the translucent fabric roof that hovers like a cloud overhead.

The roof, reminiscent of the Bedouin tents found in Morocco, the architect's childhood home, is the most innovative feature of the earthen dwelling. Held in tension, three layers of fabric are attached to eleven custom lightweight steel trusses that were fabricated by the client, a part-time metal worker. The top layer of fabric, perforated to allow some light in and to help the fabric system breathe, is coated with PVC (polyvinyl chloride), and designed to protect the layers below from the harsh sun. It also creates a 6-foot shaded overhang on the south facade that shelters the walls from the sun and from the occasional rainstorm. The second layer is a PVDF (polyvinylidene fluoride) fabric that serves as a waterproof membrane and allows light transmission. The final layer, an unwoven fabric that resists solvents and acids, developed for aerospace application, is suspended 6 inches below the previous one, creating an insulative air space and thermal transmission barrier as well as a final layer of translucency that constantly captures the ever-changing qualities of desert light.

**opposite: The walls are an innovative mix of raw gypsum, soil, and portland cement.**

# House of Earth and Light





Site plan

The House of Earth and Light is the first modern residential building with a tensile fabric roof structure.

top: View from the steel-and-glass living room toward the more private spaces, which are made of poured earth

bottom left: An 8-foot-long magenta cast-glass desk contrasts with the thick earth walls.

bottom right: The lap pool and long earthen wall extend out into the landscape.

# Extension for the Charcoal Burner's Hut

ARCHITECTURE FIRM

**Smiljan Radic**

LOCATION

**Culiprán, Chile**

DATE

**1999**

Along the coast of Chile in the region surrounding Culiprán, there exists a tradition of making charcoal that involves the construction of *hornos de barro*, mud ovens that convert ubiquitous thorn wood into fuel. Chilean architect Smiljan Radic was inspired by these charcoal furnaces and the constructions that surround the life of a *carbonero*, or charcoal maker, and his interest led him to demonstrate the process of charcoal making in his installation *Extension for the Charcoal Burner's Hut.*

There is a dying tradition of nomadic charcoal makers who possess the knowledge of constructing traditional charcoal furnaces in Chile. The furnaces are made by digging a cylindrical hole in the ground that is approximately 47 inches deep and 118 inches in diameter. The hole is then filled with a stack of chopped thorn wood to form a dome that protrudes above the surface of the earth.

To amplify the process and traditional construction technique, Radic executed this entire process above ground. To do this, a wire cage in the shape of a bowl was constructed to serve as the above-ground version of the exhumed pit in which the wood is placed. The wire cage had a secondary purpose: helping hold the mud to the underside of the container. The bowl was then filled with thorn wood, which was stacked to create a sphere.

This dome-shaped pile of wood was then covered with a 3-inch layer of mud mixed with straw, which was shaped around the wood by tamping it with a short stick, forming a large smooth clay mound. A series of perforations created around the exterior of the mound served as flues to regulate the rate at which the fire inside the mud shell burned. The furnace was then left to air dry for one month, much like a piece of pottery, after which the wood was ignited and allowed to burn very slowly for four days. After the furnace cooled, the charcoal was removed from its mud cocoon through a small opening at the base, leaving a self-supporting dome—the mud layer having been baked hard by the internal fire from the charcoal-making process. Like the traditional furnaces, the Extension for the Charcoal Burner's Hut will eventually melt back into the earth, leaving no record or memory.

left to right: A wattle made of metal lath gave structure to the lower hemisphere of the mud oven; the mud-plastered bottom half of the sphere, which would typically be buried in the ground, was instead exposed; the lower half was filled with wood to form a sphere; the wood was encased in a mud cocoon.

opposite: Smoke emerges from small openings in the charcoal furnace.

ARCHITECTURE FIRM

**Associated Architects**

LOCATION

**Worcester, United Kingdom**

DATE

**2003**

For thousands of years cob builders, with the help of oxen trampling a mixture of straw, water, and clay, have built countless homes in the bitter climate of coastal Britain by piling this mix atop a stone foundation in courses molded in place by hand. After each layer of cob was set, it was allowed to dry for two weeks, and then another course was placed atop the previous, with doors and window openings being shaped as the walls grew. Today, these charming historic homes, many 500 years old or more, continue to be occupied and fetch high market prices; and because of recent increases in lumber prices and a growing interest in ecological building practices, cob construction in Great Britain and throughout the world is once again gaining popularity. Whereas most new cob houses reflect traditional styles, the Cobtun House is representative of more contemporary sensibilities.

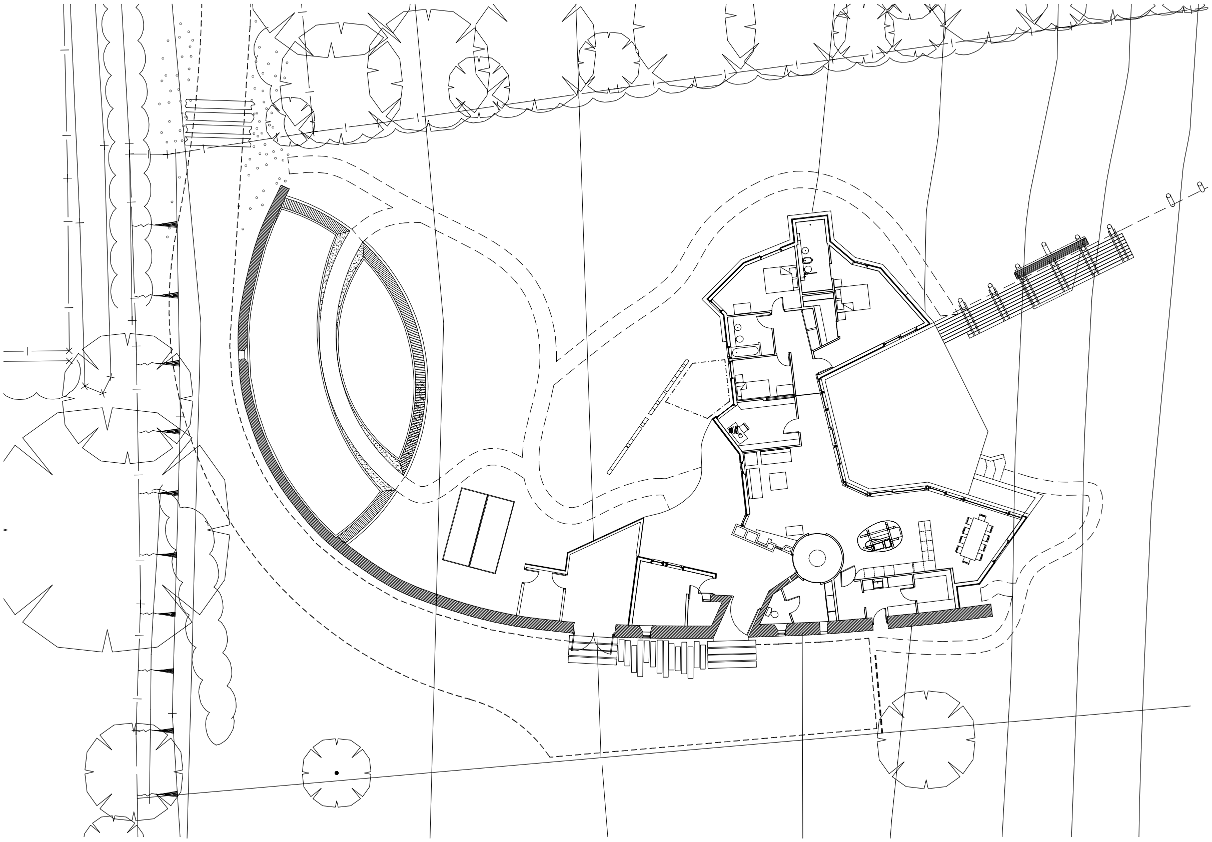
The Cobtun House's name comes from the combination of the Anglo-Saxon words *cob*, the building material made from straw and mud, and *tun*, a large vessel. It contains four bedrooms, three bathrooms, a study, a modern kitchen with pantry, wine storage, and an open-plan living space. Designed by the Birmingham-based firm Associated Architects, the project was the winner of the Royal Institute of British Architects' Sustainable Building of the Year award in 2005 for its innovative use of an ancient building material in a modern way, as well as for reducing impact on the environment through a number of ecological features that were employed in the design of the house.

Most of the soil used to construct the walls was taken from the excavation of the site. Because the soil had a low clay content, additional soil with a higher clay content from a nearby construction site, originally destined for a landfill, made up 25 percent of the final mix. Using pitchforks, the mixture was piled atop a stone and recycled-brick foundation. Because the walls were formed by hand, not with formwork as in rammed earth construction, the walls have a subtle organic quality. The sand, clay, silt, and gravel from the two sites, when mixed with water and straw, created a building material that possesses a high compressive strength, dries with minimal shrinkage, resists cracking and erosion, and is 100 percent recyclable. The high straw content used as a binder in the cob gives the walls their rough texture and high insulation value, which is supplemented by recycled newspaper embedded within the wall. At 3 feet thick, the walls create a sensuous enclosure that keeps the house comfortably cool in the summer and warm in the winter.

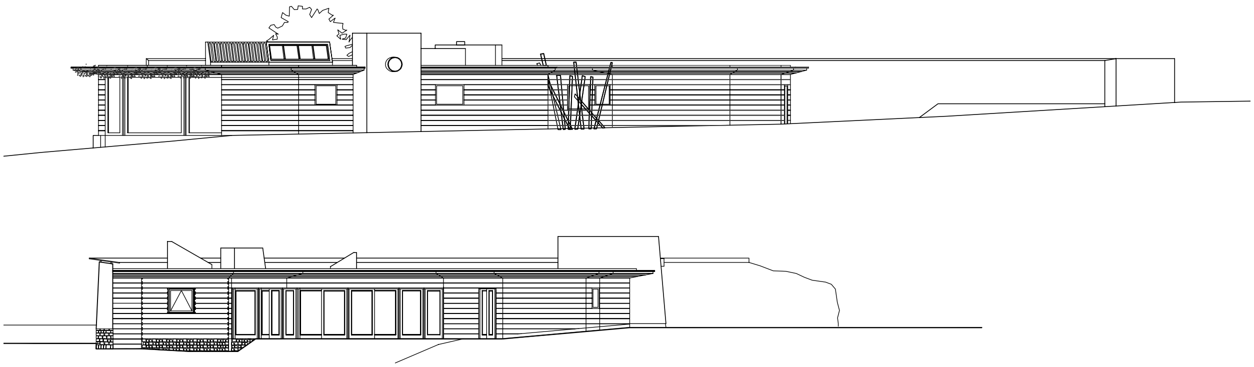
A corrugated metal roof caps the earth walls, protecting them from the rains common to the climate. The roof also collects rainwater, which is stored in a tank to irrigate the organic vegetable garden and to supply the water-efficient washing machine and low-flush toilets. A large overhang on the roof also shields the walls from the summer sun. On the south side, a 6-foot-long trellis of grape vines cantilevers from the roof to create a seasonal solar shade for the large glass opening that looks out upon the vast landscape sited against the River Avon. In the summer, the shade of the broad grape leaves prevents solar gain through the glass, and the reverse occurs when the leaves disappear and the low winter sun penetrates the glass, warming the concrete floor and massive earthen walls. In combination with other solar features, such as a solar hot water heating system and heat-retaining window blinds, these elements make the Cobtun House much less expensive to operate than a conventional house.

# Cobtun House

The long, south-facing cob wall of
the Cobtun House



Site plan



Elevations

top: A trellis hangs over the terrace to help keep the large glass wall shaded and the interior cool; a solar water heating system is also visible on the roof.

bottom: Inside, the house is cool, white, smooth, and highly refined, in contrast to the textured cob exterior.

ARCHITECTURE FIRM

**Sur Tierra Arquitectura**

LOCATION

**Peñalolén, Chile**

DATE

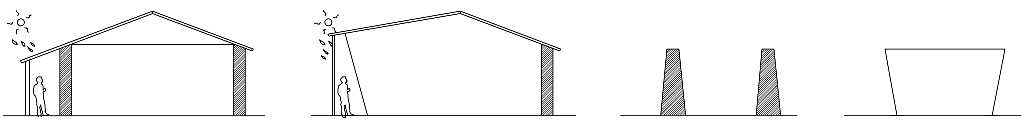
**2005**

Wattle and daub, called *quincha* in Chile, is a traditional building technology that has existed in South America for at least 8,000 years and continues to be widely used today. Traditionally, a quincha structure is constructed by creating a framework, or wattle, of interwoven pieces of wood, cane, or bamboo. This matrix of vertical and horizontal members is then covered on both sides with a mixture of mud and straw, or daub, and finished with a thin lime plaster to create a weathertight building envelope in the form of wall or ceiling panels. The system results in a lightweight flexible structure that is inherently earthquake resistant.

For several years, Chilean architect Marcelo Cortés has been developing a technologically advanced version of this ancient building method. Instead of using bamboo or cane to create a matrix to hold mud, which is extremely labor intensive and only allows for short spans, he used steel and welded wire mesh—a *quincha metálica*. Cortés arrived at the idea to use metal from observations of traditional houses in the historic center of Santiago that are constructed of mud brick set in a wood frame with metal wire holding the mud bricks in place during earthquakes. On the matrix he applies a technologically sophisticated mixture of mud—a *tecno-barro* that includes lime to control the volumetric expansion of clay and increase water impermeability. The spans and sculptural potential of steel allow him to create forms and spaces that were not previously possible with earthen construction, such as the canted walls that defy the logic of traditional quincha.

The Peñalolén House is a 1,075-square-foot private residence built in Peñalolén, Chile, a community on the outskirts of Santiago concerned with ecological issues. The community was settled by a group of people who were looking for an alternative way of life that was in harmony with the environment and began to incorporate ecological ideas into the construction of their houses. Local mud brick traditions and the abundance of clay in Peñalolén made quincha the obvious choice for the construction of the house, and an opportunity for Cortés to experiment with his new invention. The imposing views of the colorful Andes Mountains with their violets, browns, and snow-capped whites against the sky and landscape were a driving force in the design for the house, and the sculptural possibilities of quincha metálica allowed Cortés to create a form that gestures toward the incredible vistas. Formally and structurally, the house is also a response to the geological and climatic forces of the region.

The framework is constructed of steel clad with a welded wire mesh and coated with an asphalt emulsion, applied to the steel to prevent corrosion caused by the lime-stabilized techno-mud. Earth and steel have very different thermal expansion ratios, and the earth prevents the overheating of the metal, making the underlying chassis stable despite fluctuations in outdoor temperature. The form of the building is also a reinterpretation of the way traditional houses in Chile's central valley respond to the sun and rain. Instead of the continuous porch that rings the typical house, here the walls are canted to respond to the angle of the sun and wind-driven rain, protecting the earthen walls from solar gain and erosion. Like traditional quincha, the structural framework of welded steel creates an inherently earthquake-resistant structure. The thin mud skin is lightweight and the steel frame is flexible, and unlike the historic structures in Santiago, the Peñalolén House has no heavy mud bricks that would make it susceptible to collapse in an earthquake.



Shading and rain diagram used to derive the form of the house

# Peñalolén House

top: Thin earthen walls envelop the uniquely sculptural form.

bottom left: Creating a framework of steel and woven wire mesh was the first step in constructing this quincha metálica structure.

bottom center: The wire mesh was then covered with a mud mixture called tecno-barro.

bottom right: The inclined walls gesture toward the mountains and protect the walls from sun and rain.

ARCHITECTURE FIRM

**Heringer-Roswag Cooperation**

LOCATION

**Rudrapur, Dinajpur District, Bangladesh**

DATE

**2005**

Because of high levels of rain and a lack of clay in the extremely fertile soil, Bangledashi cob construction suffers from such high levels of erosion that buildings often must be reconstructed each year. Furthermore, a binder such as straw is not typically available, and stone for use in foundations can not be found, as much of the landscape rests on rich deep soil. When the German-Austrian architecture team of Anna Heringer and Eike Roswag were posed with the challenge of designing a school there, they sought to improve the traditional cob culture by addressing these problems directly and using the construction of the school as a vehicle for educating builders and laypeople in ways to construct lasting, beautiful structures.

This Aga Khan Award–winning project was commissioned by the Bangladeshi Modern Education and Training Institute, an organization that promotes the individual interests and learning speeds of children, and it was realized with the cooperation of the Bengali development agency Dipshikha, the Shanti Bangladesh Partnership Association, and the Papal Children's Mission. The Handmade School employs the traditions of earthen construction and adapts them using local resources to increase the longevity and structural stability of the building. Cows were used to mix the earth and water together and rice-straw was introduced into the mixture to serve as a binder and help the walls dry evenly. The entire project was, as its name suggests, built without the need for any machinery. The mud mixture was piled into layers, compacted by hand, and allowed to dry—after which additional layers of mud were added to increase the height of the wall.

Because the construction of the school involved many techniques that were unfamiliar to local workers, twenty-five laborers had to be trained to take part in the construction. School children and teachers were also trained and participated in the construction process—shaping the door and window surrounds—which instilled community pride and a sense of ownership of the school. Each door also bears the name of the Bengali children who attend the school, which forms a tradition that will grow with each new school year.

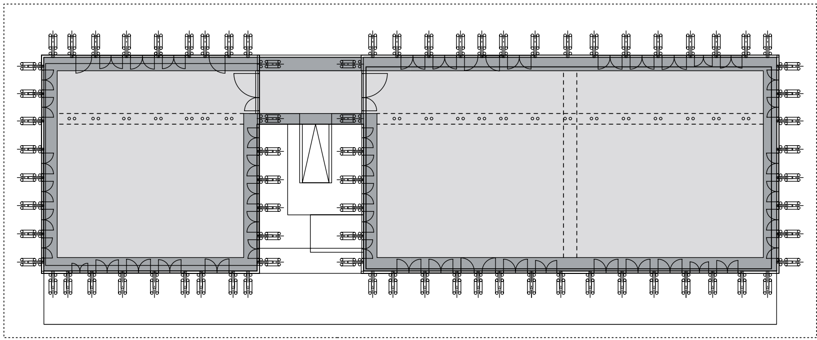
While some new traditions were formed, others were transformed. Traditionally, earth buildings in Bangladesh are built directly on the ground without any means of preventing moisture from creeping into the walls. Called rising damp, this problem was prevented in the construction of the school by building a brick foundation that forms a buffer between the damp soil and the earthen walls, which are solid enough to prevent animals from burrowing in. When the walls were dry, a sharp spade was used to shape them into relatively flat planes. The walls were left exposed on the outside, and the interior was plastered with a light-colored clay and lime wash to brighten the spaces of the school. The plastic nature of the cob allowed the architects to design playful "cave spaces" at the rear of each ground-floor classroom. Inside these intimate, organic, haptic spaces, children can study, meet in small groups, nap, or play.

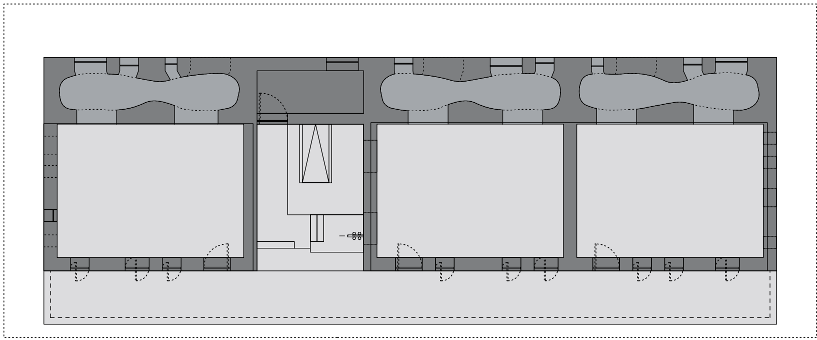
Whereas the first story has thick walls and secret caves, the second story of the building is constructed of a light bamboo framework containing two large rooms with expansive views and abundant space, with a facade that is clad with bamboo strips on wooden frames and anchored to the earthen walls below. Views from these rooms extend above the treetops and past the village pond. The bamboo floor is covered with a layer of mud, creating an earthen floor surface that references the spaces below. Diaphanous walls are constructed of bamboo strips on wooden frames that create a play of shadows across the earthen floor. A ceiling, covered with strips of colorful, locally woven fabric, is hung from a triple layer of thick bamboo beams. These sturdy rafters are part of the roof structure, which is clad with corrugated metal and provides large eaves that protect the mud walls from the heavy rainfall. An outdoor platform extends into the trees from the second story of the school, overlooking the village of predominantly small earthen dwellings.

opposite, top: Colorful doors create welcoming entrances on the south elevation.

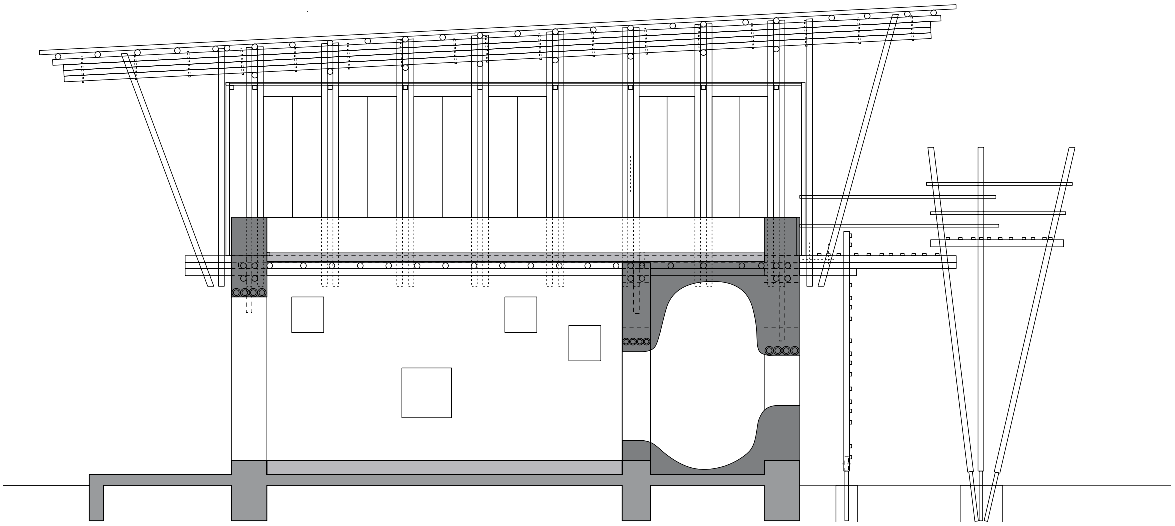
opposite, bottom: The second story of the building was constructed of a light bamboo framework clad with bamboo strips on wooden frames.

# Handmade School



Floor plans



Section

left top: The interior was plastered with a light-colored clay-and-lime wash to brighten the spaces of the school.

left bottom: Cave spaces for studying, playing, or napping

right: Detail of bamboo structure embedded in the cob wall

The adaptations of earth-building techniques to meet the demands of an industrial society are often quite ingenious. Hybridizing building systems in response to external forces such as building codes or earthquakes, calibrating soils, and preserving traditions against encroaching technologies are some of the ways earthen architecture is surviving, flourishing, and advancing in a modern era. But what does the future of earth architecture look like?

As the world's developing nations become industrialized they abandon their strong earth-building traditions. Meanwhile, post-Fordian societies are attempting to correct the errors of a wasteful, polluting, and consumptive legacy. Ecological and sustainability issues are increasingly at the forefront of discussions on first-world development, and earth, in the context of architecture, is the most "earth friendly" material that exists. While the use of earth as a building material in the industrial age has never been widely seen to represent progress, that is beginning to change. As evidenced by the projects in this book, the efforts of Cointeraux, Fathy, Wright, Le Corbusier, and countless other architects, engineers, builders, organizations, and laypeople have not been in vain, and the inherent beauty and versatility of humankind's oldest building material will likely gain greater mainstream acceptance in the near future. Evidence of this lies in the recent updates to international and national building codes that include specifications on earthen construction. As of this writing, the American Society for Testing and Materials is updating its earthen-building guidelines, and the Getty Conservation Institute is supporting an international survey of existing earthen-building standards worldwide. The State of New Mexico Building Code, which at one time made it illegal to continue its thousand-year-old tradition, now includes provisions for stabilized and unstabilized mud brick, rammed earth, and compressed earth block. Whereas many earth-building guidelines have been restrictive and often prevented the construction of traditional earthen architecture, many codes around the world now recognize the performance of traditional elements such as wooden bond beams, earthen mortars, and earthen plasters, and they also include guidelines for hybridizing earthen architecture with concrete for use in foundations, lintels and bond beams.

The fact that industrial societies and developing countries are entering the digital era at the same time has also helped spur interest in earthen architecture in contemporary culture. Digital media is creating a new paradigm that is empowering the culture of earthen architecture: the internet has allowed both developed and developing countries to disseminate and share earth-building technologies via online discussion forums and informational websites in many languages that are translatable digitally on the web. This book itself was inspired by my blog, Eartharchitecture.org, and two of the best groups for discussing earthen architecture are the Yahoo adobe group, http://groups.yahoo.com/group/adobe/, moderated by Quentin Wilson; and the Spanish-language group Arqui-Terra, http://www.elistas.net/lista/arqui-terra, moderated by José María Sastre Martín.

The digital era is also giving birth to entire new methods for creating earthen architecture. Perhaps one of the most interesting advancements of the technology is a process called Contour Crafting. Developed by Professor Behrokh Khoshnevis of the Information Sciences Institute at the University of Southern California, Contour Crafting is modeled after rapid additive prototyping methods such as 3-D printing; the technology can take a 3-dimensional model from a computer and with a computer-controlled gantry translate it into a physical object using a method of layered manufacturing that can employ a variety of different materials to build full-scale structures. The speed and efficiency of the technology could be used to build low-cost housing quickly during natural disasters, and the technology has also attracted much interest from the architectural avant-garde. Khoshnevis, who grew up in Iran, home to many wonders of the earth-built world, believes that straw and mud are an excellent admixture for use in Contour Crafting, and he has studied using uncured clay in the fabrication of structures. The housing prototypes he has hypothesized take traditional earthen architecture techniques, such as the Nubian vault to create unsupported earth roofs, or more recently developed technologies, such as Nadar Khalili's superadobe, as precedents. Because designs can be directly constructed from 3-D models, extremely complex geometries can be created, opening the possibility of using earth in radically new ways. Nadar Khalili and Behrokh Khoshnevis are also conceiving of ways that lunar and Martian soil can be used to construct the architecture of future interplanetary colonization. When their vision becomes a reality the question will emerge: Can the medium for man's oldest building achievements still be called Earth architecture?

## Acknowledgments

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I am very grateful for the cooperation and interest of the staff of all the participating architecture firms and organizations, and the individuals and photographers who provided me with images, drawings, information, and contacts. I would like to extend my appreciation to the Aga Kahn Trust for Culture, Eva Madshus, senior curator of collections and exhibitions; and Vidar Ibenfeldt, fotoarkivar / photo archivist at the National Museum of Art, Architecture, and Design in Oslo; David Winchester at Casa Grande Ruins National Park; and Stacy Jed at Architecture for Humanity for helping me locate and providing me with difficult to find photos.

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The lives of my entire extended family and ancestors are the inspiration for this book, as they knew the true meaning of living in buildings made of earth. I am greatly appreciative of the San Fratello and Turner families for their continual support and interest.

None of this would have been possible without the support of my wife, traveling partner, and colleague, Virginia San Fratello, who in addition to inspiring me, also fearlessly accompanied me to the Middle East, South America, Mexico, Europe, Africa, and throughout the United States, and who continually read drafts, copyedited, offered a critical eye to the selection of images, and was invaluable to the organization and assembling of the manuscript.

## Notes

### Introduction

**1.** Many academics, authors, builders, writers, and architects have noted that between one-third and one-half of the population of the planet lives in buildings constructed of earth, although none have cited the origin of this number directly. See, for example, Jean Dethier, *Down to Earth: Adobe Architecture, An Old Idea, A New Future*, trans. Ruth Eaton (New York: Facts on File, 1983), 8; Elizabeth Lynne and Cassandra Adams, eds., *Alternative Construction: Contemaporary Natural Building Methods* (Hoboken, NJ: John Wiley & Sons, Inc., 2000), 88–89; Paul Graham McHenry Jr., *Adobe and Rammed Earth Buildings* (New York: John Wiley & Sons, Inc., 1984), vii.

**2.** Paul Oliver, "Earth as a Building Material Today," *Oxford Art Journal* 5, no. 2, Architecture (1983): 35. Oliver points out that "while no one knows how many earth buildings are currently in use," estimates run as high as 80 million. Lynne and Adams, eds., *Alternative Construction*, 89. This number reflects rammed earth and mud brick combined.

**3.** David Easton, *The Rammed Earth House* (White River Junction, VT: Chelsea Green Publishing Company, 1996), 5. Paul G. McHenry Jr., *The Adobe Story* (Albuquerque: Univeristy of New Mexico Press, 2000), 37.

**4.** Orlando Romero and David Larkin, *Adobe, Building and Living with Earth* (New York: Houghton Mifflin, 1994), 8. The Paul Revere House is constructed of timber frame with a mud brick infill, which was a common technique at the time—as noted via telephone interview with Patrick Leehey, research director at the Paul Revere House. Rancho del Cielo, the former Western White House of former president Ronald Reagan, where he spent more than a full year of his eight years in office, was first named Rancho de los Picos after Spanish settler José Jesus Pico, who moved north from Mexico and built the original adobe house in 1871. Chairman Mao was born on December 26, 1893, in Shaoshan, Hunan Province, China, in a simple thirteen-room mud brick house. Saddam Hussein was born in Tikrit, Iraq, on April 28, 1937, and grew up in the town of Al Dawr, a mud brick town on the banks of the Tigris River.

**5.** Brigitte Huck, *Donald Judd Architecture* (Vienna: Hatje Cantz, 1991), 35. It is interesting to note that, according to Marianne Stockebrand, director of the Chinati Foundation, Judd originally intended to use mud brick for his concrete box sculptures on permanent display in Marfa.

**6.** The density of New York City is approximately 41 people per acre based on population data from 2000.

**7.** Jean Dethier, *Down to Earth*, 8.

**8.** Vitruvius, *Ten Books of Architecture*, trans. Ingrid D. Rowland (Cambridge: Cambridge University Press, 1999), 10.

**9.** Ibid., 36. Air pockets present in pumice enable this volcanic rock to float.

**10.** Ibid., 40

**11.** Kenneth Frampton, *A History of Modern Architecture*, 3rd ed (London: Thames and Hudson, 1992), 8.

**12** Kenneth Frampton, *Studies in Tectonic Culture: The Poetics of Construction in Ninetheeth and Twentieth Century Architecture*, ed. John Cava (Cambridge: Massachusetts Institute of Technology Press, 2001), 4–5.

**13.** Peter Collins, *Concrete: The Vision of a New Architecture* (Montreal: McGill-Queen's University Press, 2004), 20–21.

**14.** Easton, *The Rammed Earth House*, 10.

**15.** Martin Meade and Jean-Claude Garcias, "Return to Earth," *Architectural Review,* October 1985, 67.

**16.** Paula Lee, "Cointeraux and the School of "Agritecture" in Eighteenth-Century France," *Journal of Architectural Education* 60, no. 4 (May 2007): 44.

**17.** Meade and Garcias, "Return to Earth," 67.

**18.** Thomas Jefferson, *The Writings of Thomas Jefferson* (New York: G.P. Putnam's Sons, 1895), 135.

**19.** Jean Dethier "A Back-to-the-Earth Approach to Housing," *UNESCO Courier,* March 1985.

**20.** See Georgi Georgiev, "The Renaissance of Rammed Earth," *Aspects Magazine*, January 2001, http://gaiapolis.hit.bg/rammedearth.html; and Gijs Van Hensbergen *Gaudí: A Biography* (New York: Perennial, 2003), 71–72.

**21.** Ruth Eaton, "Mud: An Examination of Earth Architecture," *Architectural Review*, October 1981, 228.

**22.** Reyner Banham, *A Critic Writes* (London: University of California Press, 1996), 142.

**23.** Frank Lloyd Wright, *Frank Lloyd Wright: An Autobiography* (San Francisco: Pomegranate, 2005), 168.

**24.** Brendan Gill, *Many Masks: A Life of Frank Lloyd Wright* (Cambridge: Da Capo Press, 1998), 18.

**25.** Easton, *The Rammed Earth House*, 16–17.

**26.** Robert Twombly, *Frank Lloyd Wright: His Life and His Architecture* (New York: John Wiley & Sons, 1979), 263.

**27.** Berdeana Aguar and Charles Aguar, *Wrightscapes: Frank Lloyd Wright's Landscape Designs* (New York: McGraw-Hill Professional, 2002), 249.

**28.** Charles Jencks, *Le Corbusier and the Continual Revolution in Architecture* (New York: Monacelli Press, 2000), 243.

**29.** Reyner Banham, *A Critic Writes: Selected Essays by Reyner Banham* (Berkeley: University of California Press, 1999), 53.

**30.** Willy Boesiger, *Le Corbusier: Oeuvre Complète 1938–1946* (Zürich: Artemis-Aidc, 1971), 94–99.

**31.** Le Corbusier, Willy Boesiger, Hans Girberger, *Le Corbusier, 1910–65* (Zürich: Verlag für Architektur, 1991), 254, notes that La Sainte-Baume was to be constructed of rammed earth. Sarah Menin, *Nature and Space: Aalto and Le Corbusier* (New York: Routledge 2003), 152, points out that La Sainte-Baume was only one of a series of prototypes developed out of Corbusier's Radiant City ideal.

**32.** Simone Swan, "Elegant Solutions," *Saudi Aramco World* 50, no. 4 (1999): 16–27.

**33.** James Steele, *An Architecture for the People: The Complete Works of Hassan Fathy* (London: Thames & Hudson, 1997), 147.

**34.** Ibid.

**35.** Swan, "Elegant Solutions," 25.

**36.** An interview with James Steele, Abdel Wahed El-Wakil, and Hasan-Uddin Khan, "Legacy of Hassan Fathy," *Saudi Aramco World* 50, no. 4 (1999): 54–63.

**37.** A. Berle Clemensen, *Casa Grande Ruins National Monument, Arizona: A Centennial History of the First Prehistoric Reserve 1882–1992* (United States Department of the Interior/National Park Service, 1992), 38.

**38.** Ibid, 51

**39.** Ibid, 79.

**40.** Robert Smithson, the American artist famous for creating modern sculpture through the manipulation of earth, is quoted naming Olmsted "America's first 'earthwork artist.'" See Niall Kirkwood, *Manufactured Sites: Rethinking the Post-industrial* (Oxford: Taylor & Francis, 2001), 128.

**41.** Clemensen, *Casa Grande Ruins*, 80–81.

**42.** The fatalities were reported by BBC News on Friday, December 26, 2003. See http://news.bbc.co.uk/1/hi/world/middle_east/3348613.stm.

**43.** For more information on organizations that offer workshops and other educational opportunities, visit: http://www.eartharchitecture.org and click the "organizations" link.

**44.** For excellent essays on the politics of building with earth, see Jean-Louis Bourgeois and Carollee Pelos, *Spectacular Vernacular, The Adobe Tradition* (New York: Aperture, 1996).

### Chapter 1—Rammed Earth

**1.** Anne P. Underhill et al., “Systematic, Regional Survey in SE Shandong Province, China,” *Journal of Field Archaeology* (1998): 453.
**2.** Gaius Plinius Secundus, ed. John F. Healy, *Natural History: A Selection* (London: Penguin, 1991), 338. Healy translates Pliny’s description of the walls as “compacted because they are made by packing earth down between two sets of shuttering, so that the material is stuffed in rather than raised up.”
**3.** Hugo Houben and Hubert Guillard, *Earth Construction: A Comprehensive Guide* (Rugby, UK: Practical Action, 1994), 14.
**4.** Kathleen Deagan and José María Cruxent, *Archaeology at La Isabela: America’s First European Town* (New Haven, CT: Yale University Press, 2002), 98.
**5.** See, for example, Paul Graham McHenry Jr., *Adobe and Rammed Earth Buildings: Design and Construction* (Tucson: University of Arizona Press, 1984), 98. David Easton, *The Rammed Earth House* (White River Junction, VT: Chelsea Green Publishing Company, 1996), 30.
**6.** Stephen L. Sass, *The Substance of Civilization: Materials and Human History from the Stone Age to the Age of Silicon* (New York: Arcade Publishing, 1998), 126.
**7.** Further proof that the process has achieved an industrial status is well-known California-based architect, author, and builder David Easton’s acronym for an earth-building technique he invented: P.I.S.E. (pneumatically impacted structural earth), a play on the French term *pisé.*

### Chapter 2—Mud Brick

**1.** Hugh Chisholm, *The Encyclopædia Britannica* (Cambridge, England, and New York: Cambridge University Press, 1910–11), 2:382.
**2.** Michael Balter *The Goddess and the Bull: Catalhöyük: An Archaeological Journey to the Dawn of Civilization* (New York: Simon and Schuster, 2005), 1–3.
**3.** Banister Fletcher et al., *Sir Banister Fletcher’s A History of Architecture* (Oxford, UK: Architectural Press, 1996), 31.
**4.** According to *Webster’s New Collegiate Dictionary*, 1974 edition, The Germanic prefix, ur- means “prot(o)-,” “first,” “oldest,” and “original,” making the speculation of the link between the proto-city Ur and the word *urban* even more intriguing.
**5.** Hugo Houben and Hubert Guillard, *Earth Construction: A Comprehensive Guide* (Rugby, UK: Practical Action, 1994), 13.
**6.** Bruce Bower, “Ancient Birth Brick Emerges in Egypt” *Science News* 162, no. 7 (2002): 110.
**7.** T. Granier et al., “The Nubian Vault: Earth Roofs in the Sahel,” (paper presented at the Living in Hot Deserts Conference, Ghardaia, Algeria, December 9, 2006), 1. http://www.lavoutenubienne.org/IMG/AVN_paper_Ghardaia_vs2-lite.pdf
**8.** James Talboys Wheeler, *The Geography of Herodotus* (London: Longman, Brown, Green, 1854), 414–15.
**9.** Douglass Bailey, *Prehistoric Figurines: Representation and Corporeality in the Neolithic* (New York: Routledge, 2005), 168.
**10.** Vitruvius, *Ten Books on Architecture*, trans. Ingrid D. Rowland (Cambridge: Cambridge University Press, 1999), 36.
**11.** Houben and Guillard, *Earth Construction*, 9.
**12.** Peter I. Bogucki, *The Origins of Human Society: The Blackwell History of the World* (Malden, MA: Blackwell Publishers, 1999), 351.
**13.** Peter N. Peregrine and Melvin Ember, *Encyclopedia of Prehistory* (New York: Kluwer Academic/Plenum Publishers, 2001), 20.
**14.** Roberta M. Delson, “Planners and Reformers: Urban Architects of Late Eighteenth-Century Brazil,” *Eighteenth-Century Studies* 10, no. 1 (1976): 41.
**15.** *The American Heritage® Dictionary of the English Language, Fourth Edition*, s.v. “Adobe,” http://dictionary.reference.com/browse/adobe (accessed: August 27, 2007)
**16.** Telephone interview with Patrick Leehey, research director at the Paul Revere House, July 2007.
**17.** Norval Morris and David J. Rothman, eds., *The Oxford History of the Prison: The Practice of Punishment in Western Society* (Oxford: Oxford University Press, 1995), 76.
**18.** Paul Graham McHenry Jr., *Adobe and Rammed Earth Buildings* (Tucson: University of Arizona Press 1984), 48.
**19.** The range of values for the soil percentages were derived from mud brick soil composition values by McHenry Jr., *Adobe and Rammed Earth Buildings*, 50; and from Gernot Minke, *Building with Earth: Design and Technology of a Sustainable Architecture* (Basel: Birkhäuser, 2006), 65.
**20.** Stated by Mel Medina, owner of the Adobe Factory, the largest mud brick production site in the world.
**21.** McHenry Jr., *Adobe and Rammed Earth Buildings*, 4.
**22.** www.adobefactory.com.

### Chapter 3—Compressed Earth Block

**1.** David Easton, *The Rammed Earth House* (White River Junction, VT: Chelsea Green Publishing Company, 1996), 10.
**2.** Ibid.
**3.** Hubert Guillard, Thierry Joffroy, and Pascal Odul, *Compressed Earth: Manual of Design and Construction Volume II* (Brunswick, Germany: Friedr. Vieweg & Sohn Verlagsgesellscahft mbH, 1985), 10.
**4.** Easton, *The Rammed Earth House*, 10.
**5.** Jean Dethier, *Down to Earth: Adobe Architecture, An Old Idea, A New Future*, trans. Ruth Eaton (New York: Facts on File, 1983), 8.
**6.** Laurence Keefe, *Earth Building, Methods and Materials, Repair and Conservation* (London: Taylor & Francis, 2005), 67.
**7.** Ibid., 94.
**8.** Energy and Resources Institute, Institut Catalá d’Energia, and Asia Urbs Programme, *Sustainable Building Design Manual* (New Delhi: Energy and Resources Institute, 2004), 119.
**9.** Gernot Minke, *Building with Earth: Design and Technology of a Sustainable Architecture* (Basel: Birkhäuser, 2006), 64.

### Chapter 4—Molded Earth

**1.** Jean Dethier, *Down to Earth: Adobe Architecture, An Old Idea, A New Future*, trans. Ruth Eaton (New York: Facts on File, 1983), 8.
**2.** “wattle and daub,” *Encyclopædia Britannica Online*, http://www.britannica.com/eb/article-9076299 (September 11, 2007).
**3.** David Easton, *The Rammed Earth House* (White River Junction, VT: Chelsea Green Publishing Company, 1996), 9.
**4.** Joseph F. Kennedy, Catherine Wanek, and Michael Smith, *The Art of Natural Building: Design, Construction, Resources* (Gabriola Island, Canada: New Society Publishers, 2002), 132.
**5.** A. Berle Clemensen, *Casa Grande Ruins National Monument, Arizona: A Centennial History of the First Prehistoric Reserve 1882–1992* (United States Department of the Interior/National Park Service, 1992), 38.
**6.** Kennedy, et al., *The Art of Natural Building Design*, 133.
**7.** More information about the Juana Briones House, which is currently in danger of being destroyed, can be found at http://www.brioneshouse.org.
**8.** Laurence Keefe, *Earth Building, Methods and Materials, Repair and Conservation* (London: Taylor & Francis, 2005), 13.

## Design Credits

### Chapter 1—Rammed Earth

Rammed Earth Houses
Designers: Francoise Jourda, Gilles Perraudin
Bowali Visitor Information Centre
Designers: Glenn Murcutt, Phil Harris, Adrian Welke
Low Compound
Designers: Eddie Jones, Neal Jones, Doyle Hostetler, Harold Williams
Ooi House
Designers: Kerry Hill, Rowena Hockin, Albano Daminato, Robert Allan
Palmer-Rose House
Designer: Rick Joy
Poll House, Margaret River
Designers: Gary Marinko, Jill Marinko
Thurgoona Campus of Charles Sturt University
Designer: Marci Webster-Mannison
Chapel of Reconciliation
Designers: Rudolf Reitermann, Peter Sassenroth
Mason's Bend Community Center
Designers: Forrest Fulton, Adam Gerndt, Dale Rush, Jon Shumann
National Wine Centre
Designers: Richard Desgrand, Philip Cox, Steve Grieve
Eden Project Visitor Centre
Designers: Nicholas Grimshaw, Andrew Whalley, Jolyon Brewis, Vincent Chang, David Kirkland, Michael Pawlyn, Jason Ahmed, Vanessa Bartulovic, Dean Boston, Chris Brieger, Antje Bulthaup, Amanda Davis, Florian Eckardt, Alex Haw, Perry Hooper, Bill Horgan, Oliver Konrath, Angelika Kovacic, Quintin Lake, Richard Morrell, Tim Narey, Monica Niggemeyer, Killian O'Sullivan, Debra Penn, Martin Pirnie, Juan Porral-Hermida, Mustafa Salman, Tan Su Ling
Sihlhölzli Sports Facility Storage Sheds and Chronometry Tower
Designer: Roger Boltshauser
Split House
Designer: Yung Ho Chang
Cemetery Extension and Chapel of Rest
Designers: Stefan Marte, Bernhard Marte
Center of Gravity Foundation Hall
Designers: John Frane, Hadrian Predock
Residence at Meteor Vineyards
Designers: James Cutler, Bruce Anderson
Vineyard Residence
Designers: John Wardle, Andrew Wong, Fiona Dunin, Grant Roberts, Aimee Goodwin, Tarryn Deeble, Zoe Geyer, Fiona Lynch
Rosie Joe House
Designers: Natalie Baker-Wadsworth. Larry Curtis, Kristofer Larsen, Mitch McComb, Clio Miller, Jimmy Nielsen, Aaron Raymond, Scott Woodruff
Zousei Architecture
Designers: Manabu Sawase, Takehiko Nez
Amankora Bhutan Resorts
Designer: Kerry Hill
Red Hill Residence
Designers: Chris Botterill, Christopher Harty, Rhonda Mentiplay
Back 40 House
Designers: Andy Powell, Jason Gallo
Nk'Mip Desert Interpretive Centre
Designers: Bruce Haden, Brady Dunlop, Norm Hotson, Stephanie Forsythe, Tina Hubert, Julie Bogdanowicz
Residence 1
Designers: Mary Hardin, John Folan

### Chapter 2—Mud Brick

La Luz Community
Designer: Antoine Predock
Matthews Residence
Designer: William Bruder
The Eco House
Designer: Sverre Fehn
Camacho Residence
Designer: Simone Swan
Arrillhjere Demonstration House
Designer: Brendan Meney
Druk White Lotus School
Designers: Sean Macintosh, Roland Reinardy, Caroline Sohie, Jonathan Rose, Ian Hazard, James Fleming, Masato Minami, Martin Self, Davina Rooney, Omar Diallo, Rory McGowan, Francesca Galeazzi, Dorothee Richter, Marek Monczakowski, Ian Grace, Leslie Dep, Jess Siddhu, Neil Marlow, Vicky Coy
Bodega en Los Robles
Designers: José Cruz Ovalle, Hernán Cruz, Ana Turell
Cocuy Pecayero Distillery
Designer: Rafael Mattar Neri
Casa Corralones
Designers: Mathias Klotz, Magdalena Bernstein
*Prada Marfa*
Designers: Michael Elmgreen, Ingar Dragset, Ronald Rael, Virginia San Fratello, Joerg Boettger
Christine's House
Designers: Amy Green Bullington, Stephen Long

### Chapter 3—Compressed Earth Block

Villa Eila
Designers: Mikko Heikkinen, Markku Komonen
Kahere Eila Poultry Farming School
Designers: Mikko Heikkinen, Markku Komonen
$N^3$
Designer: Tom de Paor
Center for the Blind
Designer: Mauricio Rocha
Primary School
Designers: Diébédo Francis Kéré

### Chapter 4—Moulded Earth

Baninajar Refugee Camp Housing
Designer: Nader Khalili
Waldorf Kindergarten
Designer: Gernot Minke
House of Earth and Light
Designer: Marwan Al-Sayed
Extension for the Charcoal Burner's Hut
Designers: Smiljan Radic, Marcela Correa
Cobtun House
Designers: Martin Bull, John Christophers, Simon Jesson, Richard Slawson, Adam Wardle
Peñalolén House
Designer: Marcelo Cortés
Handmade School
Designers: Anna Heringer, Eike Roswag

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