CHAPTER 6

Casa Arones

6.1 Summary

Located in the historic center of Cusco (Fig. 6.1), Casa Arones is a typical residential structure dating to the seventeenth century. Originally constructed as a single-family dwelling with ground floor commercial spaces, the building was later divided into multiple residential units. The structure is currently largely unoccupied; however, the owners, a non-governmental organization, plan to rehabilitate the house. The two-story 1100 m^2 building exhibits many of the design features and materials typical of residences from the Spanish Viceroyalty period, including moderately thick mud brick walls over a rubble stone masonry foundation, wood-framed gable roofs, and galleries with fired brick and stone masonry arcades surrounding a central patio (Fig. 6.2). The building has been enlarged and altered over the course of its history; however, many of these alterations date to the eighteenth and nineteenth centuries and may be considered historically significant in their own right. Casa Arones is in fair to poor condition overall. The preliminary findings indicate that most observed damages are the result of lack of maintenance. Although the building's structural systems are intact, many elements are unstable, particularly the masonry arcades. Casa Arones is vulnerable to future seismic events due to its unstable structural elements, the lack of transverse walls at the second floor, and the poor condition of the roof which has damaged the walls and thus the roof–wall connections. An emergency shoring system was recently installed to better protect the structure until a full conservation or rehabilitation project is undertaken.

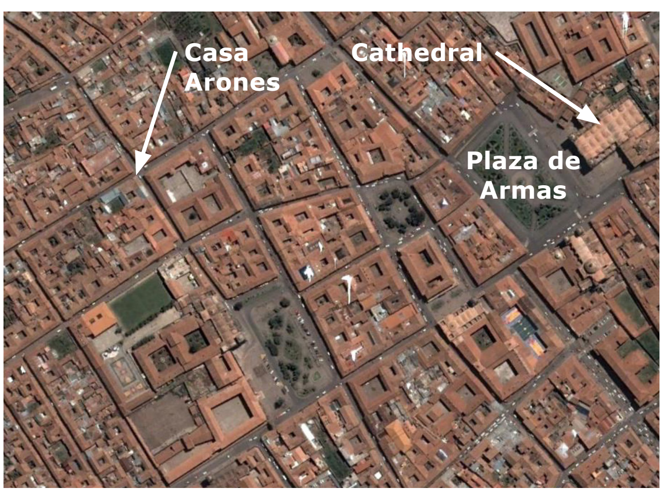

FIGURE 6.1
Satellite image showing the location of Casa Arones in relationship to Cusco's main square and cathedral.
Image: © 2012 DigitialGlobe, © 2012 Google.

FIGURE 6.2
View of Casa Arones, from the northeast.
Image: Sara Lardinois.

6.2 Historical Background, Context, and Significance

6.2.1 Historical background and context

The city of Cusco is located at 3,400 m above the sea level in the Peruvian Andes, near the Urubamba Valley. The city is the political capital of both the Cusco region and province. Cusco was also the capital of the Inca Empire and is today known as the Historic Capital of Peru.[1] As of 2007, the city had a population of 358,935; but, as a major tourist destination, it receives nearly 1.5 million visitors per year. Casa Arones is located in the historic center of Cusco in the Barrio de Nueva Alta, within the parish of San Pedro. During the Spanish colonial period, this place was known as *La Parroquia de Hospital de los Naturales* (Parish of the Hospital of the Indians), as it was home to the San Pedro Hospital. Prior to that it was known as *Chaguaytapra*.

The earliest known occupation of this area dates back more than 2,000 years. In 1941 the American archaeologist John Rowe found, in the adjacent neighborhood of Santa Ana, fifth to second century BCE pottery made by the Chanapata culture who had been living in the area since the eighth century BCE.

During the period of the Inca Empire, called Tahuantinsuyo by the Incans, Cusco was a complex urban center with distinct religious and administrative functions that were surrounded by clearly delineated areas for agricultural, artisanal and industrial production. The area where Casa Arones is located was used for agricultural purposes.[2] *Andenes* (agricultural terraces constructed with stone masonry walls), located on the Carmenca hill to the northwest, descended into the area where Casa Arones is currently located.[3] During the sixteenth century, this sector of Cusco was urbanized and the existing configuration of the andenes influenced the pattern of urban development.[4] At the time, this sector was called Picchu; and, it extended as far as the trail to Contisuyo, one of the four *suyos* or regions of the Inca Empire, located southwest of Cusco.[5] This trail later took the name of Calle Hospital. As the andenes became obsolete in this area, portions of the terrace walls were dismantled as needed and the stones were reused in the construction of new buildings. Other portions of these terrace walls still remain, and many of the houses that are built over the former terraces incorporate the stone walls into their foundations. In the case of Casa Arones, reused Inca stones are found in some areas of the foundation. In the sixteenth century, the area was considered a *huaca*, or sacred place, by the indigenous people;[6] and the *ayllus* living in the area called it Chacuaytapara.[7, 8]

In 1569 Don Francisco de Toledo arrived in Peru to organize the Viceroyalty. He traveled to Cusco, where he lived for two years (1570–1572), and began to organize the city, creating parishes and indigenous *reducciones* (villages). During that time, the city grew along the trail to the Contisuyo and thus extended its boundaries southwest;[9] however, the area of Picchu was not yet occupied by the Spaniards.

During the seventeenth century, the neighborhood where Casa Arones is located took the name of Barrio de la Calle Chawaytapra; and, it later took the name of Calle Nueva Alta, which is a name still used in reference to the street at the east side of Casa Arones today. During the first part of the seventeenth century, merchants and *criollos* (persons of pure Spanish descent born in the Viceroyalty) occupied Piccho (Picchu) and Chaguaytapra (Nueva Alta), as well as the neighborhoods of Matara, Pumancsaca (Umachata), and Quechua;[10] and they continued to do so until 1650 when a large earthquake destroyed many parts of the city.[11] After that time, Spaniards and mestizos lived in areas of Picchu, Chaguaytapra (Nueva Alta), Ayhuayco, Calle Hospital, and Calles Matará. During the eighteenth century, this sector was primarily residential in nature.

In 1840, following Peruvian independence, the definitive separation of the former territory of Alto Peru, or Bolivia, from Peru triggered a crisis in Cusco. The city lost a large part of its population and fell into a decline that continued until the first half of the twentieth century. During this period, houses were not well-maintained. Many houses were rented out or sold; and some of them, including Casa Arones, were subdivided and occupied by several families. According to an 1862 census, an average of four families, each with eight members, lived in each house in the Nueva Alta neighborhood.

The construction of Casa Arones is thought to date to the end of the sixteenth century or beginning of the seventeenth century, prior to the great earthquake of 1650. The earliest reference to the structure is in 1643, where it appears in *El Plano Mas Antiguo Del Cusco*.[12] In 1651, one year after the earthquake, the earliest known deed record shows that the house was sold to Pedro Carrasco, beginning a long chain of ownership for the house.[13] Sometime between 1672 and 1773 the house was sold to Don Cipriano Oblitas; and for this reason Casa Arones is sometimes referred to as Casa Oblitas in historic and current documents. The structure is currently unoccupied; however, a caretaker is on site several days a week to look after the building. The house is currently owned by a non-governmental organization, Guamán Poma de Ayala, which is planning to rehabilitate the house.

Casa Arones exemplifies many of the characteristics of a typical Cusco house, with two patios, a *zaguan* (entrance hall) providing access from the street to the main patio, and arcaded galleries surrounding the main patio which allowed for circulation between rooms and exterior spaces. This configuration is thought to be based upon the traditional residential architecture of the Mediterranean region; however, in Cusco, the Spaniards adapted the Mediterranean tradition to the existing Incan building typology—the *kancha*, which was a rectangular enclosure with three or more rectangular buildings placed symmetrically around a central open space.[15] Both the patio and kancha were similar in function; however, due to the symmetrical placement of buildings around the central space, the zaguan was not located in the center of the patio but rather at the side of it. This placement of the zaguan, while typical of Spanish structures in Cusco, is quite different from the prevailing patterns in Lima. In the case of Casa Arones, the house was not actually constructed over an earlier kancha, but rather earlier Incan andenes.

The house was originally constructed as a single family dwelling, with commercial spaces on the ground floor along Calle Arones to the east; and it was later converted to multiple residential units. The building has been enlarged and altered multiple times since its original construction. As a result, it incorporates a number of different architectural styles from different periods. The stone arcade at the gallery at the north side of the main patio is typical of late sixteenth and early seventeenth century constructions and is thought to be one of the oldest remaining parts of the house. The pavement in the main patio is also typical of sixteenth and seventeenth century building traditions. Remains of mural paintings, likely dating to the eighteenth century, have been found in the upper floor of the house. The main rooms in the house are covered with late nineteenth to early twentieth century wallpaper. At the exterior, the stone entrance portal reflects both Renaissance and Mannerist influences, while the wood door itself follows the Mudejar style. The second floor balconies likely date to a later period. Historic drawings indicate that the pattern of openings along the street façades has changed over time—a drawing prepared in 1776 shows a single door, corresponding the location of the current entrance portal, along Calle Arones. Two door openings are shown along Calle Nueva Alta; however, there are currently only windows at that façade.[15] The house has suffered from earthquake-related damages. In 1986, the staircase and second patio collapsed as a result of an earthquake.

6.2.2 Significance

Casa Arones is located within the boundaries of the City of Cuzco, which was inscribed on the UNESCO World Heritage list in 1983 (Fig. 6.3).[16] Casa Arones was registered as national monument on December 28, 1972, under Resolución Suprema R.S. No. 2900, which was published on January 23, 1973. It is important to note that in many records, including those of the former Instituto Nacional de Cultura, Casa Arones is listed under its alternative name of Casa Oblitas. The building is significant as a contributor to the historic urban landscape, located in a neighborhood comprised of earthen buildings of a similar age, size, design, and construction techniques, which was formerly an Incan agricultural sector. Casa Arones is also architecturally significant as a representative example of a typical seventeenth century residence in Cusco.

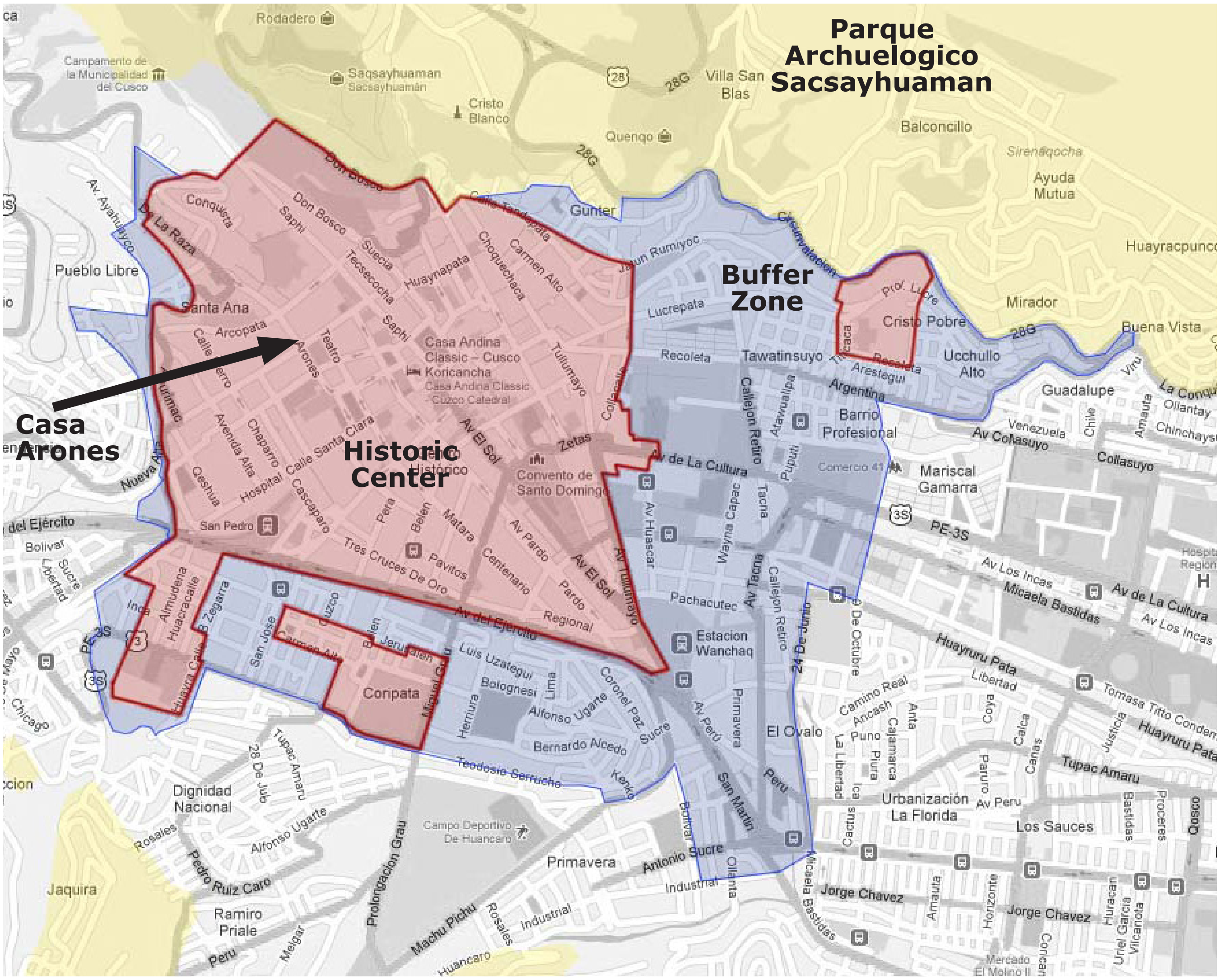

FIGURE 6.3
Plan showing the boundaries of the historic center of Cusco (red), buffer zone (blue), and archaeological zone (yellow).
Image: © 2013 Google, with additional annotations by GCI.

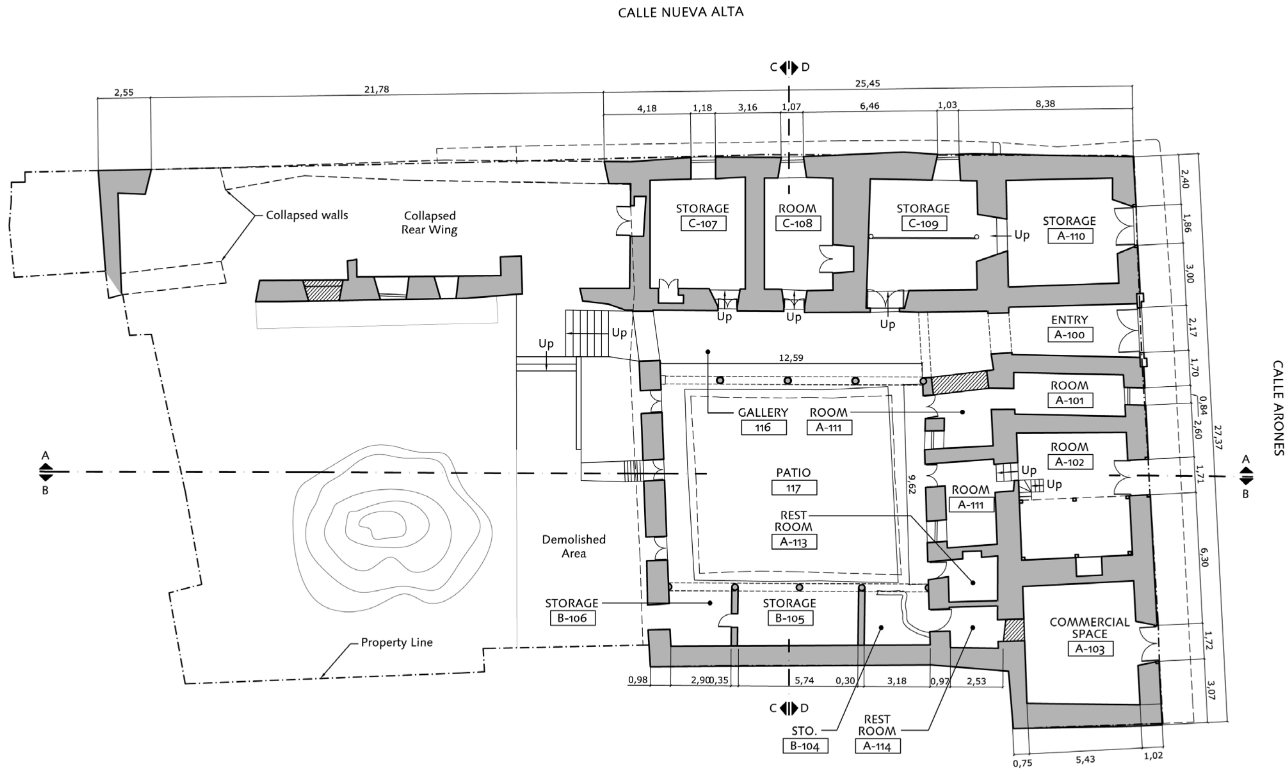

FIGURE 6.4
First floor plan, Casa Arones.
Drawing: Base drawing prepared by Enrique Estrada and edited by the GCI.

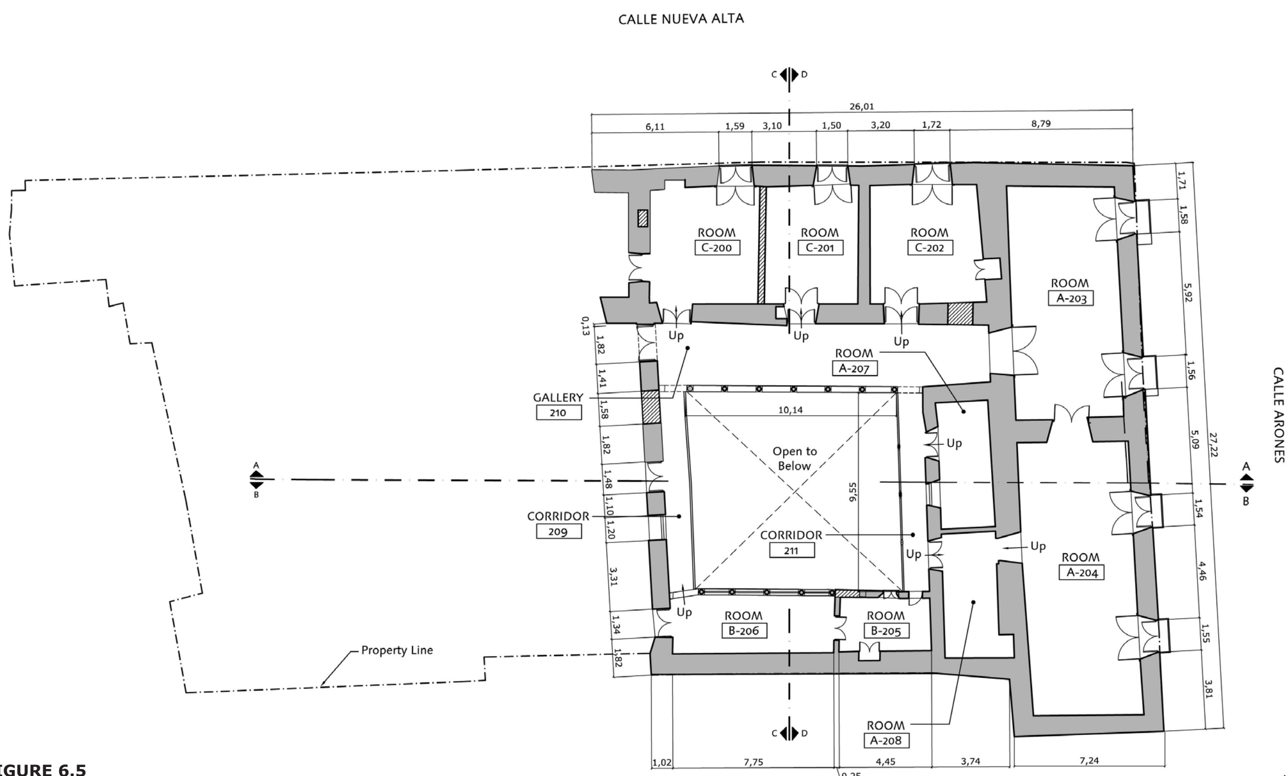

FIGURE 6.5
Second floor plan, Casa Arones.
Drawing: Base drawing prepared by Enrique Estrada and edited by the GCI.

6.3 Architectural Description

Located on an urban city block at the southwest corner of the intersection of Calle Arones and Calle Nueva Alta, the south and west exterior walls of Casa Arones immediately abut the historic two-story earthen structures on the adjacent properties. A narrow, stone paved sidewalk runs along the north and east facades of Casa Arones. The site gently slopes downward from the northwest to southeast, with an approximate change in grade of 1.90 m from west to east and also from north to south.

The two-story house consists of multiple narrow wings arranged around a central open-air patio (Figs. 6.4, 6.5), with a second patio and garden to the west which is not part of this construction assessment (Fig. 6.6).[17] The 1100 m^2 building is nearly square in plan, measuring approximately 25 m in the east–west direction (along Calle Nueva Alta) and 27 m in the north–south direction (along Calle Arones).[18] The main mass of the building is located in an L-shaped wing bordering the streets to the north and east. A smaller wing is situated to the south of the patio, and a mud brick wall separates the west side of the patio from the collapsing and demolished rear wing of the house to the west. Each wing is constructed of mud brick walls over stone masonry foundations and quincha is used for some of the interior partitions. The north and south sides of the patio are bordered by galleries with fired brick and stone masonry arcades. Each leg of the L-shaped wing is covered with a wood-framed gable roof, set perpendicular to the other, while the southern wing has a shed roof.

The exterior appearance of the house is largely defined by its planar wall surfaces, irregularly-spaced and shallowly-recessed window and door openings, and tiled gable roofs. The east façade is the primary façade and, thus, is more highly articulated than the north façade (Fig. 6.7). The main entrance portal consists of a monumental pair of Mudejar style wood doors framed by a stone entablature and rusticated Doric pilasters (Fig. 6.8).[19] This portal is not centered on the façade, rather it is located near the north end of the façade, so that it axially aligns with the interior gallery at the north side of the patio. A small window with decorative iron security bars is located at the left side of the entry portal. Three pairs of large doors provide separate access to each of the ground floor commercial spaces. At the second floor, there are four pairs of glazed doors with wood shutters, each providing access to small wood-framed balconies with decorative iron railings and wood skirting. Based upon the remnant sawn-off beam ends embedded in the wall, it appears that at one time there was a larger balcony wrapping around the northeast corner of the building (Fig. 6.9). At the north façade, the intersection of the two main gable roofs is visible, with the gable wall under the north–south ridge to the east and the eaves of the east–west ridge to the west. There are four small windows with iron security bars at the ground floor. At the second floor there are three pairs of glazed doors with wood shutters and decorative iron balconets, with a smaller window at the far west end (Figs. 6.10, 6.11). At the north and east façades, the second floor openings do not align with the ground floor openings. Both of the gable roofs have deep overhangs, with exposed wood framing at the open eaves. Exterior materials include exposed rubble and cut stone at the base course, plastered mud brick walls, and terra cotta roof tiles

At the interior of the building, each wing is typically one-room wide; and interior circulation occurs via the central patio and surrounding galleries and corridors (Figs. 6.12–6.14). Originally, there may have been a staircase in the north or east

FIGURE 6.6
Collapsing rear wing of house along Calle Nueva Alta (not part of construction assessment), with shoring and temporary roof in place.
Image: Amila Ferron.

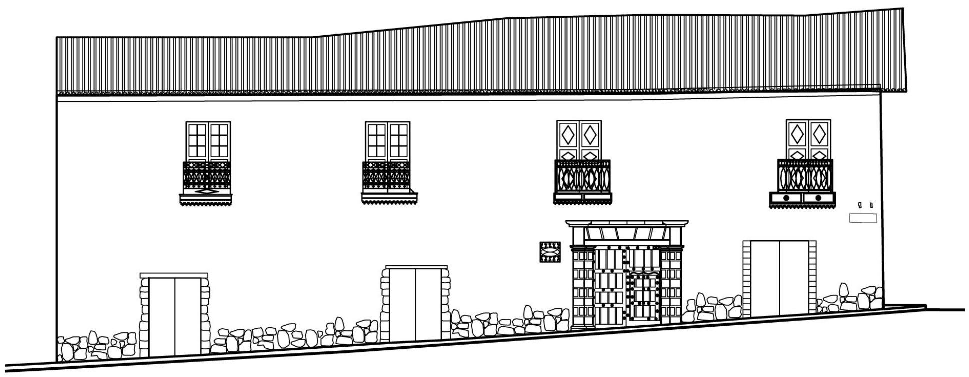

FIGURE 6.7
East façade, along Calle Arones.
Drawing: Base drawing prepared by Enrique Estrada and edited by the GCI.

FIGURE 6.8
Detail view of entrance portal at east façade.
Image: Sara Lardinois.

FIGURE 6.9
An example of an extant balcony at a nearby building on Calle Arones. The sawn-off beam ends at the northeast corner of Casa Arones suggest that it once had a similar balcony.
Image: Sara Lardinois.

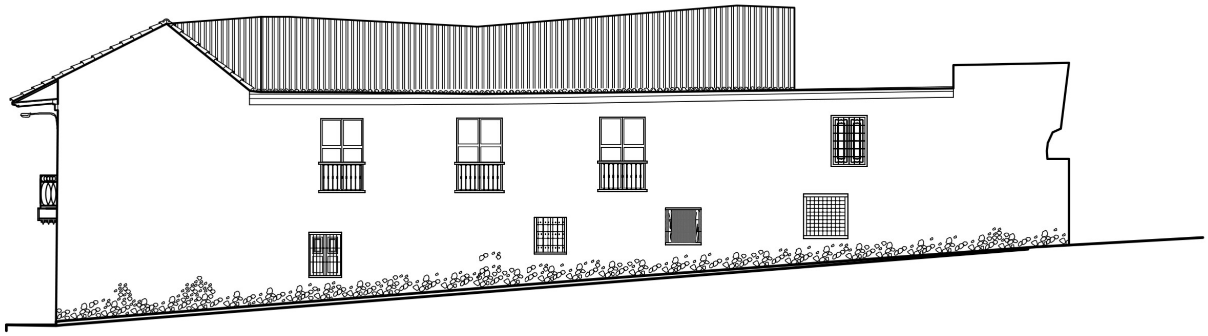

FIGURE 6.10
North façade, along Calle Nueva Alta. The far right end of the façade corresponds to the location of the collapsing rear wing.
Drawing: Base drawing prepared by Enrique Estrada and edited by the GCI.

FIGURE 6.11
Partial view of north façade, to the west of the gable wall.
Image: Sara Lardinois.

FIGURE 6.12
View of central patio, looking northwest.
Image: Claudia Cancino.

FIGURE 6.13
View of gallery arcade at north side of the patio.
Image: Amila Ferron.

FIGURE 6.14
View of cantilevered wood balcony at east side of patio.
Image: Sara Lardinois.

FIGURE 6.15
View of typical square-shaped room, C-201.
Image: Sara Lardinois.

FIGURE 6.16
View of room A-204—a long rectangular second-floor room along Calle Arones—looking south.
Image: Claudia Cancino.

wing; however, the most recent staircase appears to have been located in the now demolished rear wing. This staircase collapsed during an earthquake within the last 25 years, along with the rear west wing; and at the present time there is no means of vertical circulation between the two floor levels, other than a temporary wood ramp. The gallery arcades at the north and south sides of the square-shaped patio consist of stone columns supporting stone masonry arches at both the first and second floors. The second floor arches and columns are half the size of the first floor arches and rest on a stone masonry parapet wall. It is possible that there was once a similar arcaded gallery at the east side of the patio; however, it appears that it was filled in at some point to create as series of narrow rooms at both the first and second floors and a cantilevered wood balcony was constructed to allow for circulation. Most of the rooms at the first and second floors are small, with square-shaped floor plans (Fig. 6.15); however, there are two large rectangular rooms at the second floor of the east wing, which open up to the exterior balconies (Fig. 6.16). Interior finishes include stone paving in the entry hall, galleries, and patio; stone pavers, brick pavers, ceramic tiles, wood planks, and exposed earth flooring at the first and second floors; plastered walls with decorative painting at the mud brick walls bordering the galleries or wallpaper in some second floor rooms; and, exposed wood framing at the first floor ceilings and a combination of flat plastered false ceilings and exposed wood framing at the second floor.

6.4 Geological and Environmental Description

6.4.1 Geological description and seismic history

As previously noted, Casa Arones (lat 13°31'0.39" S; long 71°58'58.87" W) is built over the remains of Incan agricultural terraces with stone masonry walls. Several watercourses flow through the area.

The building is located in a level 2 seismic risk zone, as classified by the Peruvian Building Code, which is the middle level on a scale of 1 to 3.[20] As the house was constructed in the seventeenth century, it has been subject to a number of seismic events throughout its history, including the 1986 Cusco earthquake (M_W 5.3), the 1950 Cusco earthquake (M_W 6.0); the 1943 Yanaoca earthquake; the 1913 Abancay earthquake; and the 1650 Cusco earthquake. It is possible that the building was also subject to the 1746 Lima and 1687 Lima (M_W 8.5) earthquakes.[21]

6.4.2 Regional climate

Cusco's annual average maximum temperature is 22°C and the minimum is 3° C; however, in the winter, lows may drop below 0°C. As measured since 1976, the maximum average annual rainfall is 1125 mm and the minimum is 460 mm. It rains over 100 days each year.

6.5 Structural Description

The following sections describe the different structural materials, elements, and systems making up Casa Arones (Fig. 6.17). Their current condition and any irregularities, alterations, damages, and decay observed during the construction assessment survey are described in greater detail in section 6.6 that follows the structural description.

6.5.1 Survey sectors

For the purpose of conducting the construction assessment survey, the building was divided into four sectors, each encompassing two stories of the building (Fig. 6.18). The sectors were selected based upon differences in structural configuration, primarily related to the direction of the floor joists and roof rafters. The different sectors may also reflect the development of the building over time. The sectors are as follows:

- **Sectors A1 and B1**: The original two-story mud brick portion of the house along Calle Arones, with a gable roof oriented along a north–south axis. These sectors include multiple commercial spaces at the ground floor and two large rooms at the second floor.
- **Sectors A2 and B2**: The two-story mud brick portion of the house along Calle Nueva Alta, with a gable roof oriented along an east–west axis. These sectors are either original to the house or are an early addition. They include three rooms each at the first and second floors, as well as the gallery bordering the central patio with a fired brick arcade at the first floor and a stone masonry arcade at the second floor. The walls are typically of load-bearing mud brick construction; however, some of the second floor partitions are constructed of quincha.
- **Sectors A3 and B3**: Not used.

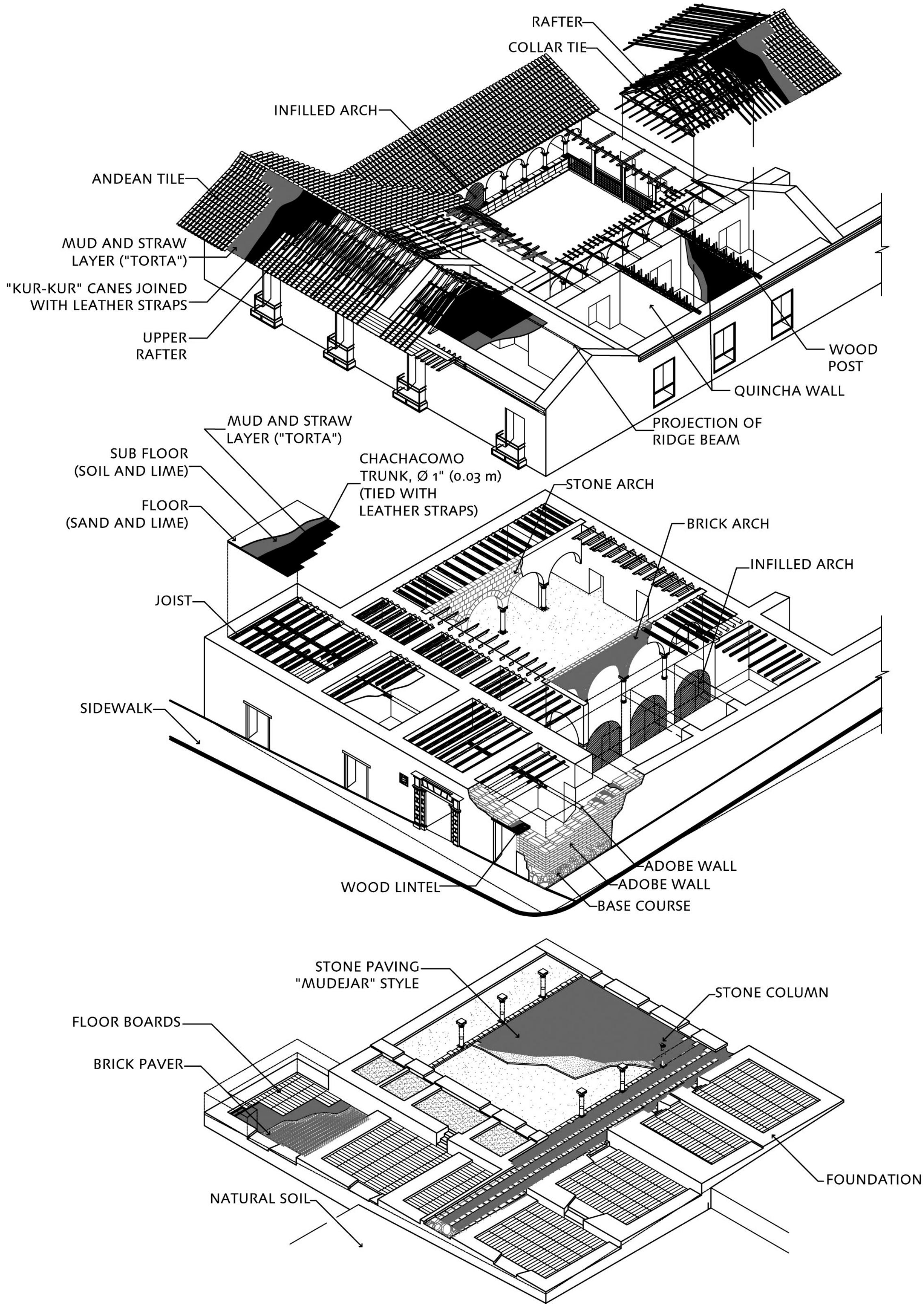

FIGURE 6.17
Overall structural scheme for Casa Arones.
Drawing: Mirna Soto, for the GCI.

- **Sectors A4 and B4**: A narrow, two-story mud brick portion of the house between Sectors A1/B1 and the patio. Originally, this area may have been a two-story gallery, similar to those at the north and south sides of the patio. Previous research has suggested that the gallery was infilled in the nineteenth century to create a series of small rooms.[22] The infill walls are primarily constructed out of mud bricks; however, quincha is used for some of the interior partitions. These sectors also include the cantilevered wood-framed exterior corridor at the second floor which links the north gallery (sector B2) with the south addition (sector B5). These sectors are covered by an extension of the western slope of the north-south gable roof.
- **Sectors A5 and B5**: A narrow, two-story mud brick portion of the house bordering the south side of the patio. It appears that this space was originally an open gallery, mirroring the design of the gallery at the north side of the patio (sectors A2 and B2). The design and configuration of the arcades at either side of the patio are similar; however, in these sectors both levels of the arcade are constructed in stone masonry. The south wall, abutting the adjacent property, is constructed with mud bricks. Previous research has suggested that the gallery was infilled in the nineteenth century to create a series of small rooms.[23] Mud brick and quincha are used for the interior partitions. These sectors are covered by a shed roof sloping downwards toward the patio.

Due to the presence of stored construction materials or other items in some rooms and locked doors at other rooms, it was not possible to fully inspect every room in each of the sectors during the construction assessment survey field campaigns.

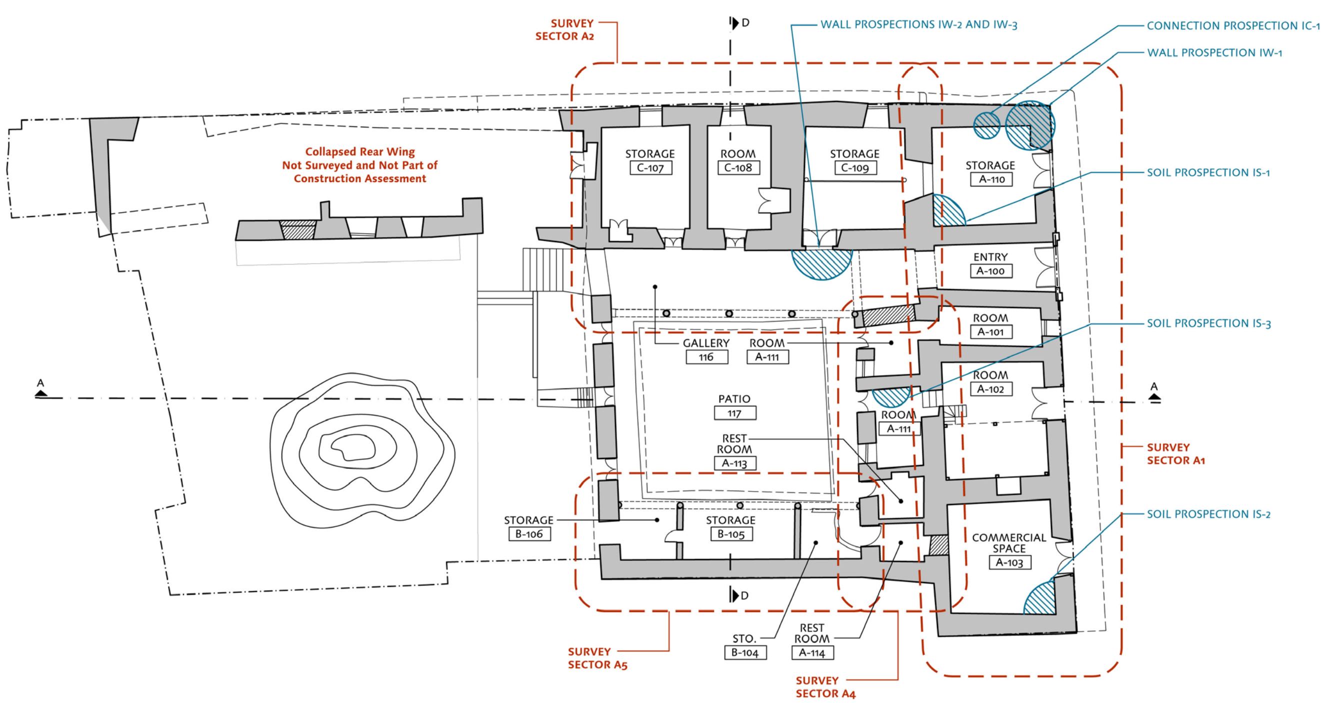

FIGURE 6.18
First floor plan, showing sector and prospection locations.
Drawing: Base drawing prepared by Enrique Estrada and edited by the GCI.

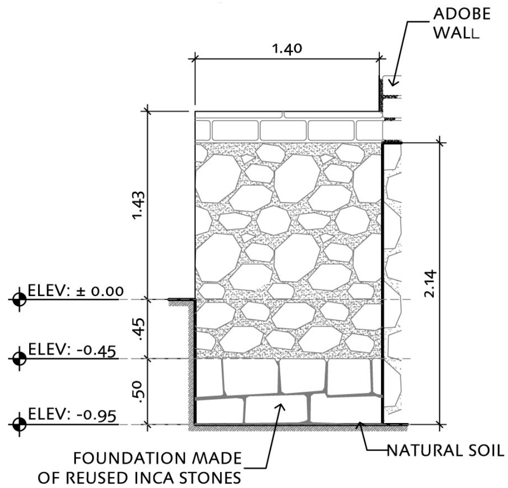

FIGURE 6.19
Prospection IS-2, illustrating the foundation configuration at the east façade wall at the southeast corner of the building, sector A1.
Drawing: Mirna Soto, for the GCI.

FIGURE 6.20
Prospection IS-2, photographic view of reused Inca stones.
Image: Mirna Soto, for the GCI.

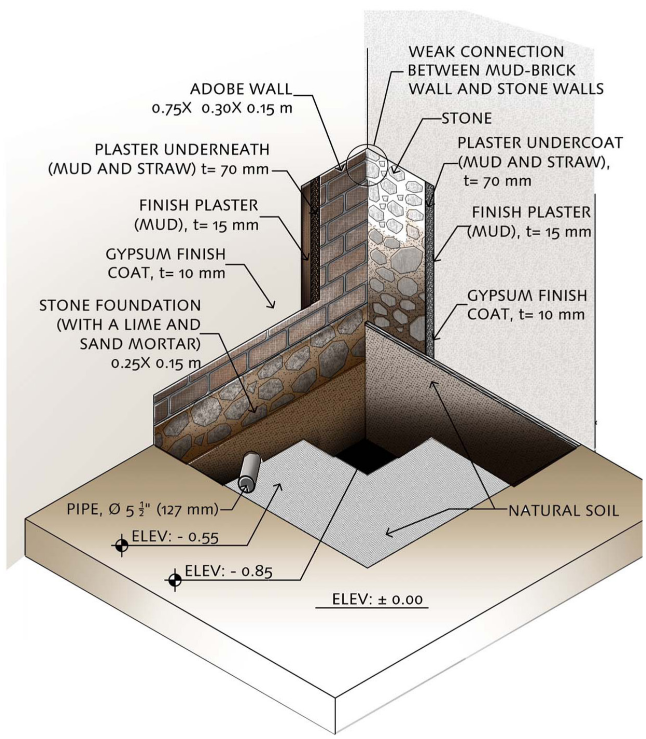

FIGURE 6.21
Prospection IS-1, showing the foundation and base course configuration at the southwest corner of room A-110, sector A1.
Rendering: Jabdiel Zapata, for the GCI.

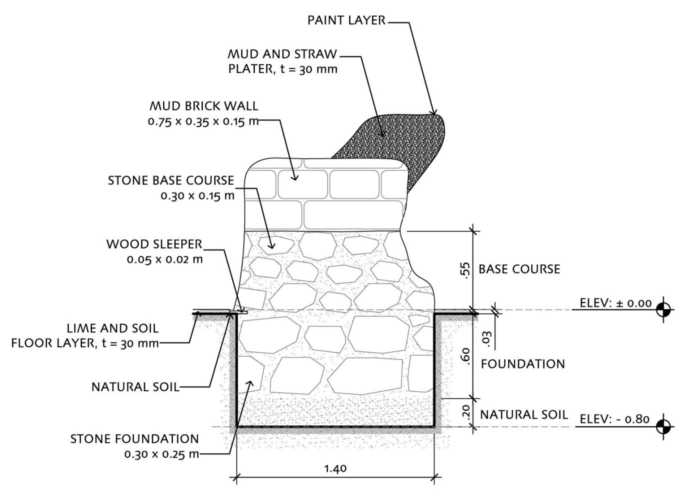

FIGURE 6.22
Prospection IS-3, illustrating foundation configuration at north wall of room A-111, sector A4.
Drawing: Mirna Soto, for the GCI.

6.5.2 Foundations and base course

The building foundation typically consists of a manmade rubble stone masonry base course and foundation bearing on the natural soil; however, the configuration varies throughout the building. Prospections carried out during the construction assessment survey field campaigns identified the following foundation configurations:

- **Sector A1**: At the southwest corner of room A-110, soil prospection IS-1 revealed two different foundation configurations. Along the south wall, there is a 0.47 m high rubble stone masonry foundation, which extends approximately 0.25 m above the floor level. The west wall marks a change in floor level between room A-110 and room C-109 to the west that is related to the natural upward slope of the site from east to west. In this location, the bottom of the rubble stone masonry foundation corresponds to the floor level in room A-110 and extends upwards to a height of at least 1.42 m; and it is possible that the stone construction extends across the whole height of the wall at the first floor. The average face size of the foundation stones is 0.25 × 0.15 m. A sand and lime mortar is used (Fig. 6.21).
- **Sector A1**: At the southeast corner of sector A1, in room A-103, soil prospection IS-2 revealed a 2.0 m high rubble stone masonry foundation with a mud and lime mortar, extending approximately 1.2 m above the floor level. At the base of the foundation along Calle Arones, two courses of large cut stone blocks are present, which are likely reused stones from the Inca period. This reused stonework is approximately 0.5 m high and extends approximately 0.5 m beyond the face of the rubble stone foundation above. The reused Inca stones are also set in what appears to be a mud and lime mortar (Figs. 6.19, 6.20).
- **Sector A4**: Soil prospection IS-3 revealed a 0.55 m high rubble stone masonry base course over a 0.60 m deep foundation. The typical face dimensions of the base course stones are 0.30 × 0.15 m, and the foundation stones typically measure 0.30 × 0.25 m. The stones are bonded with a lime mortar (Fig. 6.22).

As observed in several other locations in the building, the base course typically ranges in height from 0.55 to 1.50 m above the floor level. At Calle Nueva Alta, the rubble stone base course is exposed at the exterior and projects beyond the face of the wall above to form a sloped base. Although typically constructed of rubble stone masonry, the exterior face of the base course along Calle Arones is finished with cut stones having a smooth face.

6.5.3 Walls

6.5.3.1 Load-bearing mud brick masonry walls

Most walls at Casa Arones are of load-bearing mud brick construction, with the exception of the arcades surrounding the patio and several interior partitions. The mud brick walls typically have a plaster finish at both the interior and exterior faces. The walls can be classified as moderately thick in relationship to their height, with a slenderness ratio between 6 and 8.[24] In sectors 1, 2, and 5, the walls generally vary in thickness from 0.90 to 1.10 m; however, the primary north–south wall separating sector A1 from A2 and A4 is somewhat thicker at 1.20 m, presumably because it serves as a retaining wall against the natural slope of the site. The north

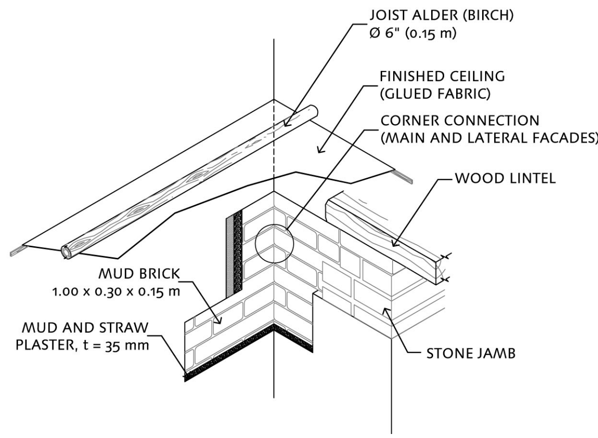

FIGURE 6.23
Prospection IW-1, isometric view showing mud brick corner connection between the east and north façades. Drawing: Mirna Soto, for the GCI.

end of this wall is in part constructed with stone masonry (see prospection IS-1, Fig. 6.21). The walls in sector 1 are approximately 5 m high at the first floor;[25] and at the second floor, the walls measure approximately 4 m to the eaves and 5.5 m to the top of the gable. Sectors 2 and 5 have similar height walls; although, due to the natural slope of the site, the first floor walls are somewhat shorter at 4 m. The infill walls in sector 3 are somewhat thinner, ranging in thickness from 0.60 to 0.90 m.

The mud bricks are set in an English bond pattern, with alternating courses of header and stretcher bricks.[26] A typical mud brick measures 0.75 m long × 0.30–0.35 m deep × 0.15 m high and is reinforced with straw. The bricks are laid in a mud and straw mortar, with both horizontal and vertical mortar joints ranging in thickness from 20 to 25 mm. At both the first and second floors of sectors 1 and 2, the corners of the mud brick walls are connected through overlapping bricks (Fig. 6.23).

Due to the plan configuration and lack of transverse walls in some locations, there are several relatively long spans of unrestrained mud brick construction. In sector 1, there are two large rooms at the second floor, measuring 5.2 m wide × 11.2 m long (room A-203) and 5.2 m wide × 13.2 m long (room A-204). The 27.2 m long east façade at the east side of these rooms is braced only by the gable end walls and one interior transverse wall. Similarly, in sector 2, there are three small rooms at the second floor; and, the overall span between the mud brick walls at either end of the sector is 15.7 m. Rooms C-200 and C-201 are divided by a quincha partition, and rooms C-202 and C-203 are divided by a thin mud brick wall. Neither of these partitions is properly connected to the north façade. In sector 5, the 13.5 m long south perimeter wall, which abuts the adjacent property, was originally constructed without intermediate bracing. At both the first and second floors of sector 5 only a few thin mud brick or quincha partitions are set perpendicular to the south perimeter wall. There has been some attempt to reinforce the south perimeter wall in this sector, through the installation of threaded steel bar anchors with wood plates, connecting it to the wall of the adjacent building (see section 6.6 for further description).

The first and second floor openings do not necessarily align in plan. There are significant lengths of continuous, uninterrupted vertical wall panels at the east façade along Calle Arones, which has three shop doors and a large double entry door at the ground floor and four openings providing access to exterior balconies at the second floor. At the north façade along Calle Nueva Alta, there are no openings in the sector 1 gable wall. In sector 2, there are three small openings at the first floor and three larger openings at the second floor. The first and second floor openings at sector 2 do not align, thus reducing the width of uninterrupted mud brick panels at the façades. As sector 4 is divided into a number of small rooms, there are a significant number of door openings within the mud brick walls. Sector 5 abuts an adjacent mud brick building, and thus there are no openings within the south wall. In all sectors, closely-spaced wood lintels are typically used to span the openings. The ratio of openings to the vertical surface area of the façades is provided in Table 6.1.

Both the exterior and interior sides of the mud brick walls are finished with a mud and straw plaster. Cement plaster has been applied around the exterior side of the door opening to room A-102 along Calles Arones. The exterior plaster has a non-decorative painted white finish. The interior rendering typically consists of one 20 to 30 mm thick layer of a mud and straw plaster and one layer of 2 mm thick gypsum; however, the thickness is greater where later plaster coats have been applied over the original coat.

Table 6.1: Ratio of openings to total vertical surface area of façades

Façade	Area of Openings*/Total Vertical Surface Area of Façade
East façade, along Calle Arones	13%
North façade, sector 1, along Calle Nueva Alta	0%
North façade, sector 2, along Called Nueva Alta	15%
Exterior façade average	**9.3%**
North patio façade (fired brick and mud brick wall), sector 2	18%
East patio façade (mud brick wall), sector 4	24%
South patio façade (mud brick wall), sector 5	0%
Patio façade average	**14%**

* Does not include any infilled openings at the patio façades.

FIGURE 6.24 (LEFT)
First floor arcade at the north side of the patio, with stone columns and fired brick arches (covered with plaster).
Image: Sara Lardinois.

FIGURE 6.25 (RIGHT)
Second floor arcade at north side of patio, with stone columns at stone masonry arches.
Image: Claudia Cancino.

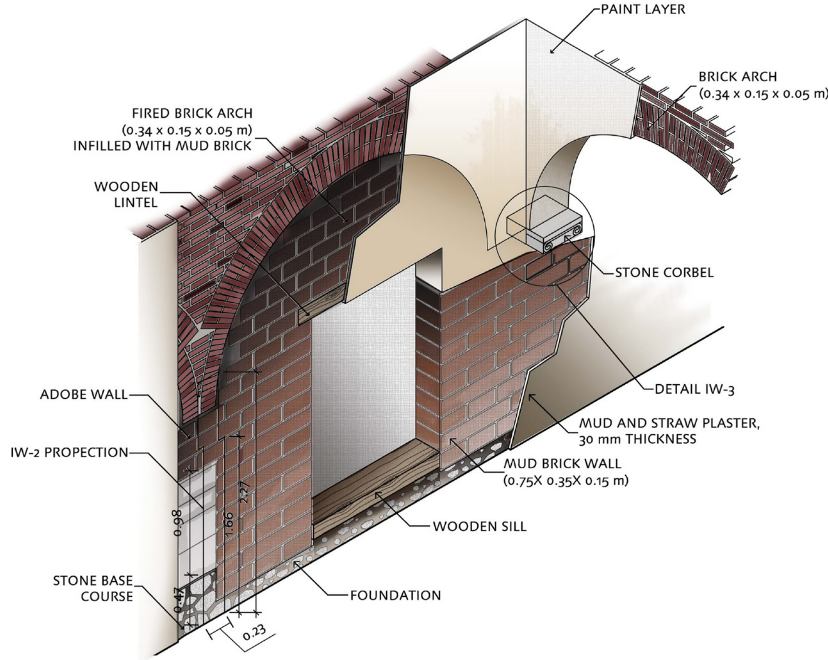

FIGURE 6.26
Prospection IW-2, showing fired brick arch with adobe infill at the north side of gallery 116. The door opening provides access to storage C-109.
Rendering: Jabdiel Zapata, for the GCI.

6.5.3.2 Load-bearing fired brick and stone masonry walls

The arcades at the north and south sides of the patio are typically constructed with cut stone masonry with lime mortar; however, fired brick masonry is used for the first floor arches at the north side of the patio. Each arcade consists of four stone or fired brick arches at the first floor and eight smaller stone arches over a low stone parapet at the second floor (Figs. 6.24, 6.25). The arches are supported by stone columns or end brackets embedded in the adjacent mud brick construction. Most of the stone and fired brick is covered with a painted mud plaster; however, the stone columns are exposed. Fired brick arches were also observed within the mud brick wall construction at the north, east, south and west sides of the north gallery (room 116). The arches of the north side were originally open and later infilled with mud bricks (Fig. 6.26).

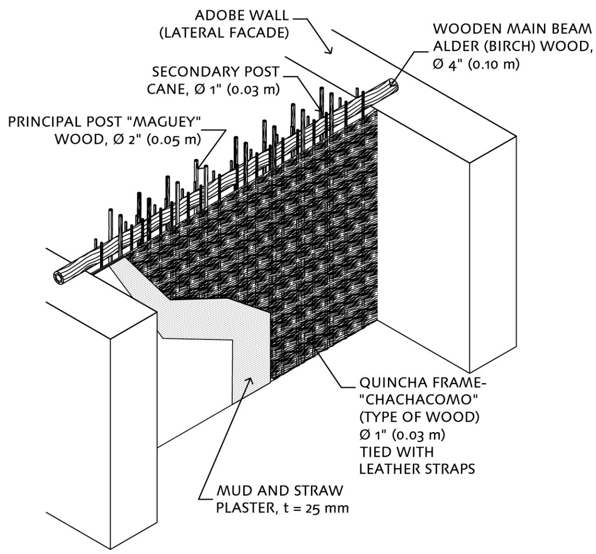

FIGURE 6.27 (LEFT)
Prospection IIW-3, illustrating the quincha wall construction.
Image: Mirna Soto, for the GCI.

FIGURE 6.28 (RIGHT)
Prospection IIW-3, photographic view of 1" (0.025 m) diameter wood trunks below the mud and straw plaster.
Image: Mirna Soto, for the GCI.

6.5.3.3 Quincha partitions

Quincha is used for interior partitions at the second floor of sectors B2, B4, and B5. The partitions are approximately 0.30 m thick and consist of two adjacent quincha frames. The tops of the frame posts are supported by the wood tie beams at the roof above (Fig. 6.27, 6.28). The primary quincha posts are made of maguey wood, 2” (0.05 m) in diameter, and are spaced at 0.75 m on center. The secondary posts are made of 1” (0.03 m) diameter canes. One-inch diameter, horizontal local *Chachacomo* tree trunks or branches are attached to the posts with leather straps and are covered with a mud and straw plaster. The frames themselves are not structurally connected to the lateral mud brick walls, except for the fact that the tops of the posts are attached to a roof tie beam with ends that are embedded in the walls.

6.5.4 Floors

Constructed on grade, the first floor is finished with a number of different materials installed directly over the ground or fill. The second floor construction is comprised of a 0.04 m thick layer of lime, sand, and gypsum mortar, followed by a 0.03 m thick layer of straw with some mud in it, over 1” (0.025 m) diameter *Chachacomo* tree trunks or branches, supported by 6” (0.15 m) diameter wood joists spaced approximately 0.50 m on center and pocketed into the mud brick walls. The *Chachacomo* trunks are tied to one another and the floor joists with leather straps (Figs. 6.29, 6.30). At rooms having a long span between the lateral walls, such as in sector B1, overlapping joist ends with an east–west orientation are supported by 8” (0.20 m) diameter wood beams or girders with a north–south orientation (Fig. 6.31). These beam or girder ends are pocketed into the mud brick walls. The underside of the framing and canes is finished with thin coat of gypsum plaster. Second floor finishes include the exposed lime and sand mortar finish coat, stone pavers, ceramic tiles, and wood planks. Cantilevered corridors and balconies are constructed using 0.03 m thick wood planks over wood framing and 0.07 × 0.17 m hand-sawn wood posts support the roof framing above (Fig. 6.32).

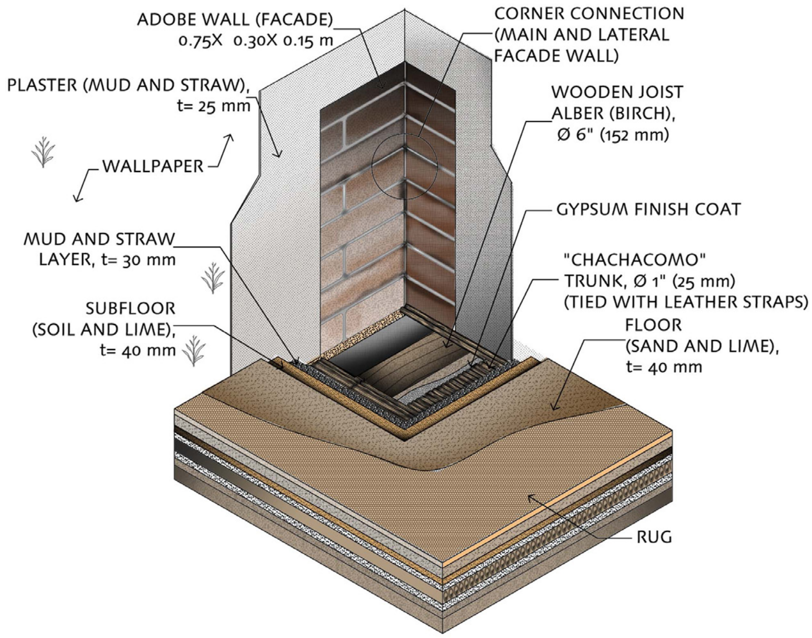

FIGURE 6.29
Prospection IIW-2, showing the second floor construction at the southeast corner of room A-204.
Rendering: Jabdiel Zapata, for the GCI.

FIGURE 6.30
Prospection IIW-1, photographic view of floor construction at the northeast corner of room A-203.
Image: Claudia Cancino.

FIGURE 6.31 (LEFT)
View of room C-109 ceiling, showing wood beam or girder, running in the east–west direction and supporting the floor joists above.
Image: Sara Lardinois.

FIGURE 6.32 (RIGHT)
View of wood framing at cantilevered balcony at east side of patio.
Image: Sara Lardinois.

6.5.5 Roof

Sectors 1 and 2 of Casa Arones are covered with gable roofs set at right angles to one another and each having an approximate slope of 4:12. The galleries in sectors 2 and 4 are covered by extensions of the main gable roof slopes. Sector 5 is covered by a shed roof that slopes downward towards the patio. Each of the different roofs is constructed with wood framing and covered with *Kur Kur* canes,[27] a mud and straw layer (*torta de barro*), and Spanish style terra cotta roof tiles.[28] Where the roof framing is exposed, such as at the galleries surrounding the patio, the underside of the framing is covered with a gypsum finish coat.

The framing at the gable roofs consists of wood *pares y nudillos* framing, which are trusses composed of two rafters and a collar tie connected with leather straps, spaced at 1.1–1.2 m on center. Two intermediate rafters typically occur between each pares y nudillos truss, and a 4” (0.10 m) diameter tie beam occurs approximately every 3.50 m (Figs. 6.33, 6.34). The tie beam and rafters extend into the mud brick wall construction approximately 0.15 m. A short joist, or lookout, is tied to the end of the tie beam and projects beyond the exterior wall to form the eaves. The ends of the rafters sit on discontinuous wood plates embedded within the mud brick walls. Wall plates were observed in room C-200 of sector B2; however, prospections IIC-1 and IIC-2, carried out in room A-204 of sector B1 did not reveal the presence of wall plates (Fig. 6.35). The rafters are strapped to a wood ridge beam which is supported by the gable end walls. The finished flat ceiling in Sectors 1 and 2 is either directly attached to the underside of the tie beams or is hung from a secondary wood framing system. The roof over the galleries and in Sector 5 utilizes a similar framing system to that of the gable roof, but without a collar tie (Figs. 6.36–6.38). Wood keys are used where the roof tie beams intersect with the stone masonry gallery arcades (Fig. 6.39). A wood key was also observed at the north wall of gallery 210.

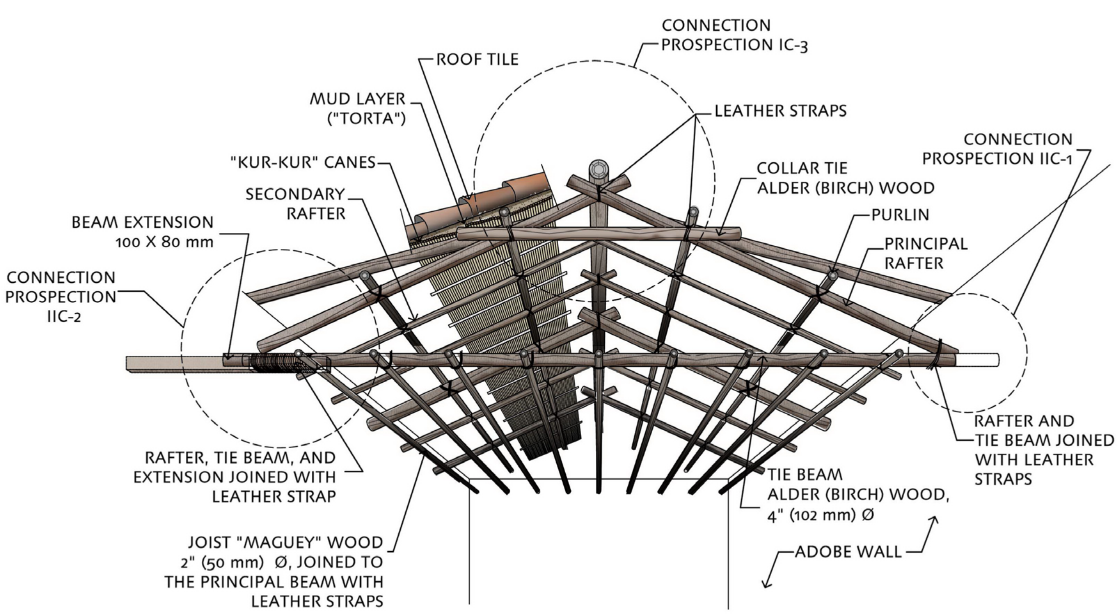

FIGURE 6.33
Prospections IIC-1, IIC-2, and IIC-3, showing the roof structure over sector B1, with rafters, collar ties, and tie beams. Rendering: Jabdiel Zapata, for the GCI.

FIGURE 6.34 (LEFT)
Prospection IIC-2, photographic view of tie beam end at mud brick wall (at left), with ceiling joist below.
Image: Mirna Soto, for the GCI.

FIGURE 6.35 (RIGHT)
View of wall plate below roof rafters, room C-200.
Image: Sara Lardinois.

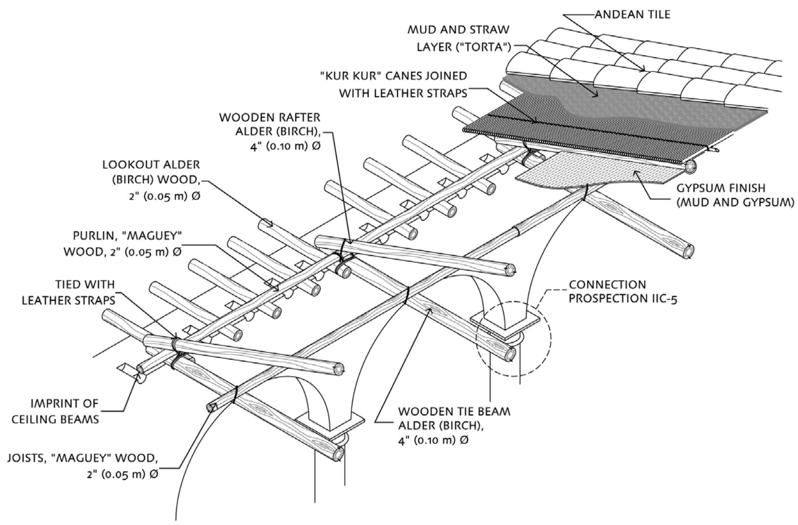

FIGURE 6.36
Prospection IIC-6, illustrating roof framing over the north gallery 210, sector B2.
Drawing: Mirna Soto, for the GCI.

FIGURE 6.37
Exposed rafters at ceiling of gallery 210
Image: Sara Lardinois.

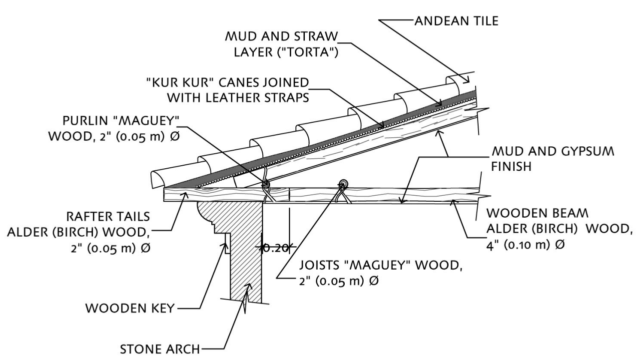

FIGURE 6.38
Prospection IIC-4, illustrating roof framing over the cantilevered wood balcony, sector B4.
Drawing: Mirna Soto, for the GCI.

FIGURE 6.39
Wood key at intersection of tie beam and arcade wall, north side of patio.
Image: Carina Fonseca.

6.6 Irregularities, Alterations, Damages, and Decay

The following sections describe the current condition of the different structural materials, elements, and systems making up the Casa Arones and any irregularities, alterations, damages, and decay that were visually observed during the construction assessment survey.

6.6.1 Foundations and base course

Overall, the foundation and base course are in fair condition and generally cohesive. Humidity in the soil and foundations and rising damp have led to moisture damage, detachment and loss of plasters, and basal erosion at some of the mud brick walls above. At the north façade (sector A2) there has been severe erosion and loss of the base course stones in an area corresponding to room C-109. The damage is most severe below the window in that room (Figs. 6.40, 6.41). This damage may be the result of falling water from the roof above, as the location corresponds to the valley at the intersection of the two main gable roofs. Surface water runoff along the adjacent sloping sidewalk, which is finished with smooth impermeable stone paving, may also contribute to the problem; however, this is an unlikely source as the damage is localized and is not as severe in other parts of the north elevation.

6.6.2 Walls

6.6.2.1 Load-bearing mud brick masonry walls

Due to the plan configuration and lack of transverse walls in some locations, there are several relatively long spans of unrestrained mud brick construction at the second floor, which increases the vulnerability of the walls to out-of-plane failure mechanisms. Where transverse walls are more prevalent, such as in sector B2, they are not properly connected to the north façade wall; and as a result they do not effectively improve the out-of-plane behavior of the north façade. Vertical cracks

FIGURE 6.40
Erosion and loss of base course stones outside room C-109, north façade. Image: Claudia Cancino.

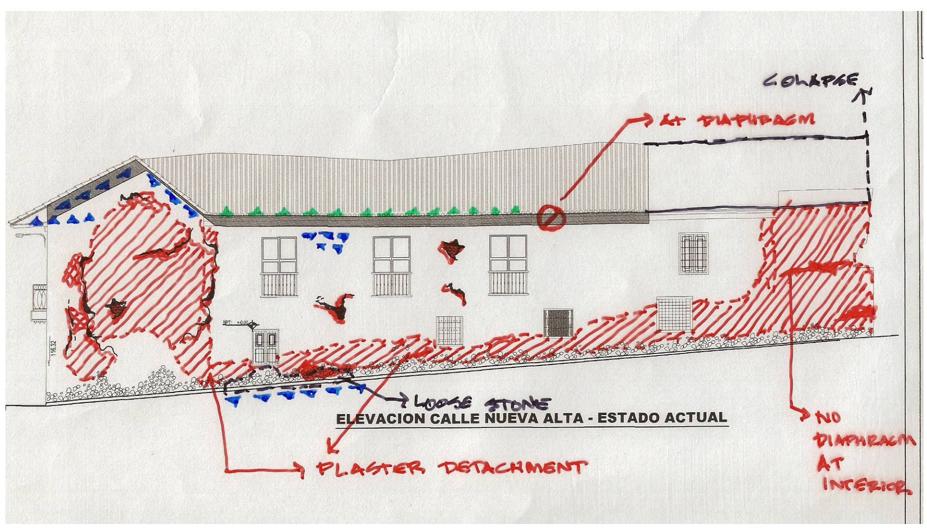

FIGURE 6.41
Graphic condition survey of north façade, indicating areas of loose and lost base course stones (in black) and plaster detachment (in red). Areas of moisture damage are indicated with the blue triangles, and green triangles mark areas where vegetation is present. Drawing: Claudia Cancino.

were observed in the transverse walls, suggesting some out-of-plane displacement in the lateral perimeter walls in both sectors B1 and B2 (Fig. 6.42). In room 204 of sector B1, a significant diagonal crack was observed through prospection IIW-2, indicating some disconnection between the façade at Calle Arones and the south perimeter wall (Fig. 6.43). In sector B5, At the south wall, five 5/8” (16 mm) diameter threaded steel rods with steel plates and wood blocking have been installed at the second floor, tying the south wall to the adjacent building wall; however, this is not a good solution because stress concentrations produce cracking around the rod (Fig. 6.44).

The mud brick walls are in fair condition overall. Rising damp and a leaking roof have led to detachment and loss of the interior wall plasters and erosion of the mud brick construction at the base and tops of many walls. The basal erosion is most significant at the southwest corner of sector A1. Although the walls do not appear to be unstable as a result, the erosion has led to failure of some of the connections between the roof framing and walls. The basal erosion may compromise the structural performance of the mud brick walls in future seismic events.

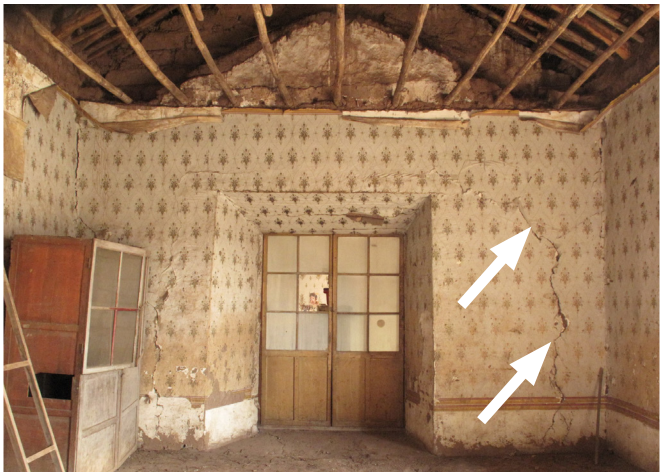

FIGURE 6.42
Vertical crack in transverse wall between rooms A-203 and A-204, adjacent to the east façade.
Image: Claudia Cancino.

FIGURE 6.43 (LEFT)
Crack in second floor mud brick wall at southeast corner of building, indicating a disconnection between the façade at Calle Arones and the south perimeter wall.
Image: Claudia Cancino.

FIGURE 6.44 (RIGHT)
Threaded steel rod, plate, and wood blocking at south perimeter wall (room B-206).
Image: Sara Lardinois.

Due to lack of maintenance, the exterior plaster covering has been partially lost, leaving the mud bricks exposed in many locations. The loss is most severe along the north façade (Fig. 6.41). At the interior, the plaster remains intact; although there are areas of plaster detachment and loss at the base and top of walls, resulting from the rising damp and moisture damage previously described.

6.6.2.2 Load-bearing fired brick and stone masonry walls

The fired brick and stone masonry arcades are in poor condition and unstable (Fig. 6.45). While the stones themselves are in good condition, there is significant loss of mortar. The arcade walls have long spans, which are poorly restrained. As a result, they exhibit some outward displacement and the arches themselves were in danger of collapse prior to the installation of a temporary shoring system. The west ends of both the north and south arcade walls appear to be the most unstable, with cracking and separation between the stones (Fig. 6.46). This may also be the result of displacement in the adjacent mud brick wall at the west side of the patio, brought on by the collapse and demolition of the adjacent construction. Portions of the second floor arcade at the south side of the patio have been infilled with mud bricks (Fig. 6.47).

6.6.2.3 Quincha partitions

The quincha panels are in good condition.

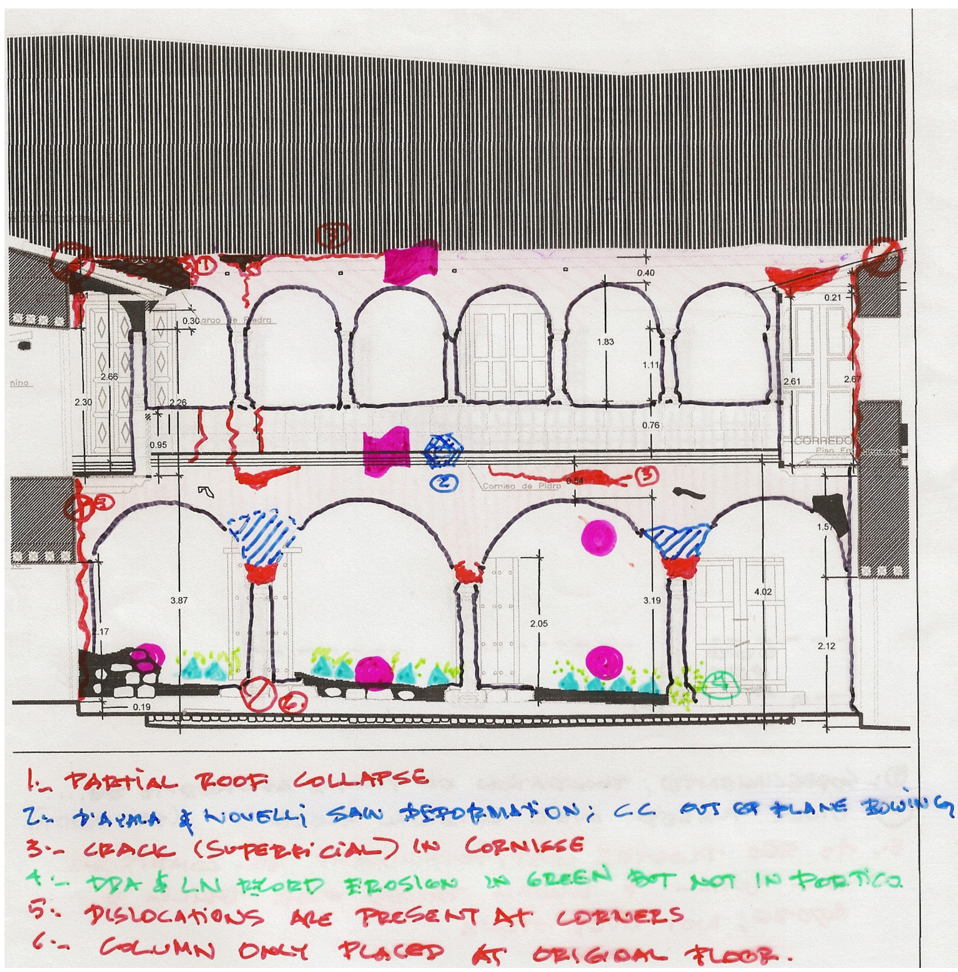

FIGURE 6.45

Graphic condition survey of fired brick and stone masonry arcade wall at the north side of patio. Drawing: Claudia Cancino.

FIGURE 6.46
West end of stone masonry parapet wall at south arcade, as viewed from room B-206.
Image: Sara Lardinois.

FIGURE 6.47
View of infilled arcade at south side of patio.
Image: Sara Lardinois.

6.6.3 Floors

The floors have been subject to a number of alterations including:

- It appears that there was once an exterior balcony wrapping the northeast corner of the building; however, this was removed and some point and only the remnant sawn-off beam ends embedded in the wall remain.
- A wood-framed second floor corridor was constructed at the east and west sides of patio, linking the north gallery (sector A2) with south addition (sector A5).
- A wood-framed mezzanine was constructed within commercial space A-102 (sector A1).

The second floor finishes and framing are in fair to poor condition. A leaking roof has led to uneven settlement, significant loss of the mortar layer in some locations, and rot and deformation of wood floor joists and beams below. This damage is most pronounced at the far south end of sector A1 and in sector A5, corresponding the area of greatest roof damage above. In areas where the gypsum plaster at the underside of the wood floor joists and beams has been lost, beetle damage was observed.

6.6.4 Roof

The roof covering has been replaced at least once in the building's history; however, it appears that only damaged wood rafters and trusses have been replaced as needed, with some of the original framing remaining.

The roof is in poor condition. The following decay and damages were observed:

- There are several large areas of missing roof tiles, which have been patched with corrugated metal sheets.
- Water infiltration through the roof has led to detachment and loss of interior wall plasters, erosion at the tops of the mud brick walls, and damage to the second floor ceiling finishes and framing below:

FIGURE 6.48
View of broken collar ties.
Image: Sara Lardinois.

  - As a result, a large percentage of the second floor ceiling joists and plaster finish has collapsed or been intentionally removed due to its poor condition.
  - The gypsum plaster ceiling finish at the underside of the roof rafters in sector B5 and other second floor galleries and porches is in poor condition, with large areas of loss.
  - In some cases, the depth of erosion at the top of the mud brick walls is so great that the ends of the roof rafters and tie beams are no longer supported by the walls.

- Wood rot and beetle damage were observed in some of the wall plates and wood framing.
- At several pares y nudillos trusses, the connection between the collar ties and rafters has failed, and the collar ties are deformed or broken (Fig. 6.48).

As a result of these conditions, the roof is unable to fully resist thrust actions and is partially collapsed. The degree of collapse is greatest at the south end of sector B1 and the west end of sector B2. The deformation and collapse has given the roof an irregular profile.

6.6.5 System-wide irregularities, alterations, damages, and decay

Casa Arones has been subject to a number of system-wide alterations; however, the extent and chronology of these alterations is still unclear after review of the extant historic research and numerous investigative prospections. Possible and known alterations include:

- Originally, there may have been a gallery at the east side of the patio (sectors A4 and B4), which was later infilled with earthen construction to create multiple small rooms that currently exist at the first and second floors between the patio and original construction along Calle Arones. Presumably, the wood-framed second floor corridor at the east side of the patio was constructed at the same time. Alternatively, all of sectors A4 and A5 may represent a later addition to the building.
- The house is thought to have originally had a staircase near the northeast corner of the house; however, the most recent staircase at the west side of the patio has collapsed or been dismantled due to damages. At the pres-

ent time, a temporary wood plank ramp in the garden is the only means of access between the first and second floors.

Casa Arones has also been subject to a number of system-wide damages and decay, including:

- A wood shoring system has been installed throughout the building as an emergency intervention to support the stone masonry arcades surrounding the patio and the failing floor and roof framing elements.
- The rear western wing (not part of this construction assessment), surrounding the second patio, has collapsed.

6.7 Preliminary Findings

The following preliminary findings on the structural behavior of Casa Arones are based upon qualitative methods, including historical research and direct observations made by the investigative team during surveys carried out in 2010. The investigative team utilized their past experience with historic earthen construction to interpret that data collected through research and observation and develop preliminary ideas on the possible structural behavior of the building. These preliminary findings will be explored further in the next phases of the project through quantitative methods, including static and dynamic testing and numerical modeling analyses. Following the quantitative testing and analyses, the preliminary findings will be revised as necessary and expanded upon to provide a complete diagnosis and safety evaluation.

The preliminary findings are:

- Casa Arones is in fair to poor condition overall. Most observed damages are the result of lack of maintenance.
- The structural performance of the building is compromised by several unstable elements, including the fired brick and stone masonry arcades and the roof structure.
    - The arcade arches are unstable due to the fact that there is not any bracing for the columns that support the arches. The low resistance of the lime mortar used in the masonry further contributes to the instability of the arcades.
- The leaking roof has damaged the tops of the walls and the connections between the roof and the walls. This damage has a negative impact on the out-of-plane bracing that is provided by the tie beams.
- Basal erosion in the walls is the result of a leaking roof, the lack of an efficient drainage system, and humidity in the soil.
- There are relatively few transverse walls at the second floor; and, where present, there is often a disconnection between transverse and lateral walls. This has led to outward displacement and vertical cracking.
- The shear cracking, including the cracks the corners of openings, is a result of the low resistance of mud brick construction to tensile stresses.

Notes

1 Cusco was declared the Historical Capital of Peru in the Peruvian constitution of 1993.

2 Rostworowski de Diez Canseco 1962, 132. According to Rostworowski de Diez Canseco, this sector of Cusco was devoted to the cultivation of potatoes, corn and "quinua."

3 The historian and author Garcilaso de la Durand José Vega (1539–1616) wrote of the andenes in this area, "La tierra que araban era un andén hermosísimo que esta encima de donde esta fundado el convento del señor de San Francisco, La casa cual digo que es el cuerpo de la iglesia, labro a su costa el dicho Juan Rodríguez y Villalobos a devoción del señor de San Lázaro cuyo devotísimo fueron los frailes franciscanos." Quoted in Vega 1959, 218.

4 Calle del Hospital, Calle Nueva Alta, and Calle Nueva Baja were laid out according to the pre-existing pattern of the andenes walls.

5 The Picchu sector of Cusco included the neighborhoods of Carmenca and Quillapata. Vega noted "Yendo con el mismo cerco, yendo al poniente hacia el norte había otro barrio llamado Picchu. También estaba fuera de la ciudad. Delante de este siguiendo el mismo cerco, esta el gran barrio llamado Carmenca, nombre propio y no de la lengua general. Por él sale el camino real que va al Chinchaysuyo." Quoted in Vega 1959, 42–46.

6 It was considered the fifth *huaca* (sacred place or monument) in the ninth *ceque* (line or pathways connecting shrines), towards the Chinchaysuyo, which was the northern region of the Tahuantinsuyo (Rowe 1981). Tahuantinsuyo, a Quechua word meaning the *four quarters* or *portions,* was the name used by the Incas for their territory and that is presdentlly referred to as the Inca Empire. The Chinchaysuyo included the western part of Cusco and the current Peruvian province of Caravaeli in the Arequipa region along the coast and extended north to Pasto (in present day Colombia), including all the territories in present day Ecuador.

7 The origin and meaning of the Incan name Chacuaytapara is unknown.

8 An *ayllu* is an extended family group that formed the basic political and social units of pre-Inca and Inca life in the Andes

9 According to historian and author Garcilaso de la Durand José Vega, at the beginning of the seventeenth century, the city of Cusco extended as far as Chaquillchaca (Vega 1959).

10 Esquivel Coronado 2001, 35.

11 In the side chapel of the Cathedral of Cusco, a famous painting by Alonso Cortés de Monroy, known as the Monroy Panorama, depicts the city of Cusco immediately following the 1650 earthquake.

12 In this map, *El Plano Mas Antiguo Del Cusco, Dos parroquias de la ciudad vistas en 1643*, which is located in the Archivo Arzobispal de Lima, the notes surrounding Casa Arones read: "Panadería del tesorero Gueuara/ Martín Rivera / Franco Aluares tintorero Baltasar Gonzáles arriero" ("Bakery of treasurer Gueuara /Martín Rivera / Franco Aluares dyer Baltasar Gonzáles mule driver").

13 The research carried out by Juan Carlos Miranda Cárdenas and Gonzalo Paiva Villafuerte provides an excellent history of the chain of title for Casa Arones. A summary of their research is provided in the table below:

DATE		OCCUPANTS		REFERENCES
XVII	1651	Owner	Pedro Carrasco	ADC. en Salvador Meléndez, pag. 624
	1656	Owner	Bartolomé Palomares	ADC. en Meza Andueza, pag. 653
XVII	1682–1773	Owner	Cipriano Oblitas	Arq. Ramón Gutiérrez, pag. 195 AMSC. Libro de censos, vol. 01
	1773	Owner Owner Owner	Alberto Capetillo Fray Miguel de Sierro Esteban de Alzamora Antonio Alzamora y de la Fuente	Arq. Ramón Gutiérrez, page 195
	1794	Owner	Melchor Gómez Bustamante	ADC. En Rodríguez Ledesma 1744, fol 427
	1795	Owner	Antonia Alzamora	ADC. en Bernardo J. Gamarra, pag. 103
	1798	Owner	Mateo Aguinaga	Ramón Gutiérrez. *La casa Cusqueña*, pag. 195
XIX	1811	Tenant	Juan Clemente Jordán	Ramón Gutiérrez. *La casa Cusqueña*, pag. 195
	1820	Owner	Gaspar Castillo	
	1822-1823	Owner	Benigno Peralta	AMSC. Libro de censos 1833
	M. 1800	Owner	Casimiro del Castillo	ADC. Toribio Constantino Alosilla
	18xx-1897	Owner	Isabel Alcázar y Don Silvestre Cáceres	ADC. Toribio Constantino Alosilla

Source: Miranda Cárdenas and Paiva Villafuerte n.d., 44.

14 On the topic of settlement patterns and building typologies, Juan Carlos Miranda Cárdenas and Gonzalo Paiva Villafuerte write: "En el Cusco se distingue dos patrones de asentamiento; las viviendas asentadas sobre las kanchas Incas y las que se ubicaron en áreas de expansión (terrenos agrícolas), de estas últimas el Arquitecto Ramón Gutiérrez hace mención que el amanzamiento parece haber subdividido en cuatro solares a la manera española mientras que el Padre Antonio San Cristóbal menciona que para la arquitectura de las casas cuzqueñas, los primeros constructores españoles encontraron ya dispuesto en las kanchas incaicas el patio central, las crujías de base aprovechables al menos para la crujía frontera de la calle. y un vano de entrada en un costado de la fachada fácilmente transformable en el insustituible zaguán de las casas virreinales. El aprovechamiento de estas estructuras simples pre-hispánicas requirió ya desde el comienzo de la urbanización española en el Cusco el despliegue de una actividad creadora para adaptar las formas tradicionales hispánicas de vivienda a los condicionamientos concretos locales, que se pretendían aprovechar." Miranda Cárdenas and Paiva Villafuerte n.d., 20.

15 The drawing, from the Archivo Arzobispal del Cusco, is reproduced in Esquivel Coronado n.d., 24.

16 Cusco is inscribed on the World Heritage list with its alternate spelling of Cuzco.

17 The rear wing and garden are not further described in this section, nor are they included in building dimensions or area calculations.

18 The area calculation includes the open air central patio. The garden wing at the rear of the building is not included in the area calculation, as it is not part of this structural assessment.

19 During the period of the Spanish Viceroyalty in Peru, arched entrances were reserved for religious buildings; and, thus, only flat lintels could be used for secular building entries (Fraser 1990, 123).

20 Seismic zones are defined in Capítulo II, Parámetros de Sitio of the *Norma Técnica de Edificación E.030: Diseño Sismorresistente*, which is available online at http://www.igp.gob.pe/web_page/images/documents/ltorres/norma_tecnica_edificaciones.pdf.

21 Information on earthquake dates, epicenter locations, and moment magnitudes (M_W) is summarized from United States Geological Survey (USGS) Historic World Earthquakes, Peru, http://earthquake.usgs.gov/earthquakes/world/historical_country.php#peru. Estimates of moment magnitudes for the 1943 Yanaoca, 1913 Abancay, 1746 Lima, and 1650 Cusco earthquakes are not available in the summary.

22 Construction date based upon the chronology provided on architectural drawing sheets EA-01 and EA-02, which are part of the Restauracion y Rehabilitacion de la Casa Arones, "La Casa de la Hispanidad Andina" project drawings prepared for C.E.G. Guaman Poma de Ayala by Architects Enrique Estrada and Yisela Ochoa Lind and dated January 2005.

23 Ibid.

24 Criteria for determining slenderness ratios are based upon those provided in Tolles, Kimbro, Webster, and Ginell 2000.

25 Wall height measurements are given from finish floor to finish floor. The height of the actual mud brick construction is somewhat less, as it sits on a 0.55–1.50 m high base course.

26 The term *English bond* is a common English-language term to describe a type of masonry bond pattern.

27 *Kur Kur* is a type of highland bamboo that is commonly used for roof coverings in the Cusco region. The canes are thin and without voids in the center.

28 The term *Spanish style* is used to describe roof tiles having a semi-cylindrical shape and are laid in alternating courses so that a tile with a convex side up is adjacent to and interlocking with a tile having its convex side down.

CHAPTER 7

Conclusions

7.1 Conclusions after the Assessment

The data collected for this assessment report is now being used for the development of the proposals for the numerical modeling and seismic analyses and the complementary experimental tests for the four historic earthen prototype buildings. Although this work is in progress, it is possible to make some general conclusions regarding the survey methodology and the collected structural data, as well as some preliminary conclusions regarding the observed structural behavior of the prototype buildings.

7.1.1 Conclusions regarding the survey methodology

- The survey forms developed for the project should be revised as necessary to include any missing data that is needed for the numerical modeling and seismic analyses and corresponding static and dynamic testing. The revised forms should be disseminated to Peruvian colleagues for use as a tool to structurally assess other earthen buildings. Eventually, these forms could be further modified to suggest and prioritize retrofitting interventions.
- Thorough building documentation is necessary to fully understand a building and its structural components. The architectural floor plans, elevations, sections, and particularly the annotated detail drawings illustrating the structural connections between roofs, walls, and foundations are providing critical structural data for the project. Conclusions related to the documentation methodology and resulting uses are as follows:
  - The prospection process, which methodologically opened up the buildings without causing damage to the sites, was necessary to create the annotated detail drawings. When determining which areas of a building to open up, it is important to strike a balance between what type of data is desirable to attain and what is feasible to obtain and will not jeopardize the integrity of the site. Engineers or other professionals who will use the data should be involved in the selection process, providing a detailed list of the critical areas to be explored; the type of data to be recorded, including any requirements for the amount and accuracy of recorded dimensions; and the requirements for the format of the resulting documentation—drawings, photographs, or video. Ideally, the data users should also be on site when the prospections are carried out (Figs. 7.1–7.4).
  - The architectural plans and prospection drawings are proving to be useful for the creation of the numerical model of each prototype building. However, as the prospection drawings only illustrate portions of the

FIGURE 7.1 (NEAR RIGHT)
Prospection process: workman opening up the second floor at Casa Arones.
Image: Sara Lardinois.

FIGURE 7.2 (FAR RIGHT)
Prospection process: project team engineers inspecting the opened floor area at Casa Arones.
Image: Sara Lardinois.

FIGURE 7.3
Prospection process: project team documenting the roof connections at the Cathedral of Ica, taking advantage of those areas made visible by the previous collapse of portions of the roof.
Image: Mirna Soto, for the GCI.

FIGURE 7.4
Prospection process: supervising architect narrating a video documenting what was discovered through a foundation prospection at the Church of Kuño Tambo.
Image: Claudia Cancino.

buildings and it is not feasible to open up an entire building, there have been some questions about what is appropriate to assume regarding the construction of the entire building. Similarly, even in those portions of the building that are opened up, it is not always possible to obtain dimensions for every connection, such as the size of dowels or tenons. This has also led to questions about what is appropriate to assume. Where possible, assumptions have been made based upon the project team's knowledge of historic construction techniques in Peru. The list of critical information mentioned above should also describe the permissible assumptions that can be made when additional information is desired, but not feasible to obtain, and the risk factors associated with making these assumptions.

– In addition to providing critical structural data for the project, the prospection methodology appears to have other valuable and further-reaching results. This method could be disseminated to other Peruvian colleagues working in the field of earthen site conservation as a means of investigating and studying a site.

- After initial on-site trials, thermal imaging was found to hold potential for nondestructive investigation of earthen sites. In particular, thermal imaging was able to reveal structural information that was not possible to obtain through visual observation only, thus supplementing the information obtained through the limited number of prospections. Many additional nondestructive investigation methods are available and may provide viable options for surveying earthen buildings. Ground penetrating radar, portable X-ray, and sonic pulse transmission are a few of the techniques that could be researched further for possible use in this project or others. The availability of instrumentation and expertise in Peru seems to be the limiting factor; but, if they can be found it would be interesting to see what types of information these investigation methods could produce when used on earthen buildings (Fig. 7.5).

7.1.2 Conclusions regarding the collected structural data

- The selected prototype buildings have proven to be more structurally complex than originally anticipated. As a result, uncertainties have been identified in the collected structural data which have required that assumptions be made about each of the buildings:
  - **Hotel El Comercio**: Through the prospections, the location, size, and spacing of wood quincha posts, diagonal bracing, and floor joists and beams were recorded; however, they were not found to be uniform. When constructing the numerical model of the entire building, the post dimensions, the distance between posts, and the presence of diagonal bracing has been generalized.
  - **Cathedral of Ica**: The spacing of the wood framing arches at the barrel vault and domes is irregular. As was done for Hotel El Comercio, the spacing will be standardized in order to develop the numerical model. Given the complexity and scale of the cathedral, the project will focus its study the central bay of the building, including its lateral walls, pillars,

FIGURE 7.5
The prospections were supplemented by thermal imaging, which revealed structural information that was not possible to obtain through visual observation alone.
Image: Mirna Soto, for the GCI.

barrel vaults, and central dome, and then extrapolate the results to the entire structure.

- **Church of Kuño Tambo**: Despite the fact that the walls do not have flat surfaces, the project assumed the contrary in order to build the numerical model. The wall thickness varies across the height of the wall; however, they were standardized for the purposes of the model. The model uses the thickness of the walls provided on the architectural floor plans—and taken at only one vertical elevation—for the entire height of the walls. Ideally, it would have been preferable to have different plans prepared to illustrate the wall thicknesses at different levels; but as this data was not collected, the assumptions noted above have been made. As with the walls, the floors are not level either. A standard floor height was used for each of the different sectors when building the model.
- **Casa Arones**: The construction sequence of Casa Arones is still unclear after a review of the extant historic research and numerous investigative prospections. For the purposes of the project, it has been assumed that the original construction included the stone masonry arcades at the north and south sides of the patio and the wood balconies at the east and west sides of the patio are later additions.

- The connections between the different elements, such as roof–wall, floor–wall, wall–wall (either L or T joints), and foundation–wall, are critical and must bell well-documented and understood. When possible, prospection openings should be used to investigate these connections. Nondestructive investigative methods, such as thermal imaging, have also proven to be effective when obtaining some of this information; however, they are not able to provide detailed information such as the size or number of nails or dowels.
- Special attention must also be given to material decay and deterioration. Criteria must be developed that allows material condition to be factored into the assessment of the strength capacity of the building. The condition of the termite-damaged wood elements at the coastal sites of Hotel El Comercio and the Cathedral of Ica must be considered, particularly when analyzing the structural connections between different wood elements.
- The mechanical and physical characteristics of the soil used in the construction of earthen buildings plays an important role when considering measures to control the decay of a building. The material properties, such as modulus of elasticity, shear modulus, and Poisson's ratio (including also compression and tensile strength), must be considered when building the model. This information can be obtained through both the collection of field data and experimental tests.

1.7.3 Conclusions regarding the observed structural design and behavior

Although the four buildings studied for this construction assessment represent very different structural typologies, some general observations regarding their structural design and behavior can be derived from this assessment. These observations are subject to revision following the completion of the experimental testing and numerical modeling and seismic analyses. The general observations are as follows:

- When assessing a building it is necessary to accurately define and understand the structural system as it was originally designed to resist the vertical loads resulting from its own weight and the inclined forces resulting from vaults and sloped roof loads.
- In both the coastal and Andean regions, the residential structures have typically been subject to more elective alterations than the religious structures. Alterations to the religious structures have generally been related to the repair or rebuilding of earthquake-damaged or deteriorated portions of the structure. While earth is the predominant wall material in all four buildings, other materials have been introduced through alterations:
  - In the case of Hotel El Comercio and Casa Arones, which have both been subject to multiple alterations related to changes in use, there are a number of different wall materials, including mud brick, fired brick, and stone masonry. In some cases—typically in altered areas— all three materials are used in one wall. Due to their potential effect on a building's structural performance, all of these materials must be identified, tested, and modeled.
  - In the case of the Cathedral of Ica and the Church of Kuño Tambo, the original earthen construction remains as the predominate material for the walls (and roof in the case of the Cathedral of Ica). If alterations or additions were made, in-kind or other compatible materials were used.
- With the exception of the Church of Kuño Tambo, which has a base course bearing mostly on hard rock, the prototype buildings all have shallow to moderately-deep foundations. Despite this, none of the buildings exhibited anomalies or distress that could be attributed to foundation settlement problems. It should be noted that the prototypes are essentially low-rise structures, mainly one or two stories in height, and the dead load, or self-weight of the structures, that is transferred through the foundations to the soil is very low as compared to the design loads for new buildings.
- When assessing a building, it is important to identify structural elements—whether original to the design or later additions—which improve the earthquake resistance of the structural system. The following types of earthquake-resistant elements and systems were identified during the construction assessment:
  - **Hotel El Comercio**: Use of light-weight quincha construction for the walls at the second and third stories, which likely acts as a flexible diaphragm.
  - **Cathedral of Ica**: Thick mud brick walls, with a slenderness ratio of 3, which are considered stable during earthquakes and have a low probability of lateral overturning. Original barrel vault and umbrella domes made of wood arches and plastered cane reed mesh that act as a lightweight roofing system.
  - **Church of Kuño Tambo**: Wood tie beams connecting long thick mud brick lateral walls and exterior buttresses, which potentially reduce lateral overturning.
  - **Casa Arones**: Mud brick walls with interwoven corners and wood tie beams which improve the lateral stability of façade walls.

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Glossary of Architectural Terms

English - Spanish

aisle	nave lateral
altarpiece	retablo
arch	arco, cercha (when referring to structural framing)
ashlar masonry	aparejo isodomo, mampostería escuadrada
barrel vault	bóveda de cañón
base	zócalo
base course	sobrecimiento
batten	listón
bay	crujía
beam	viga
bearing wall	muro de carga
blocking	taco
bond	aparejo
bonder	perpiaño
bondstone	aparejo de tisón
brace	tornapunta
brick paver	ladrillo pastelero
buttress	contrafuerte
choir	coro
cleat	listón
cloister	claustro
cochlea	escalera de caracol
collar tie	nudillo
colonnade	columnata
column	columna
common rafter	viga de tejado común
corbel	ménsula
cornice	cornisa

course	hilada
coursed masonry	mampostería hilada
cross section	sección transversal
cross wall	muro divisorio
crown post	pendolón
dome	cúpula
elevation	elevación
entranceway	vestíbulo
entry hall	zaguán
facade	fachada
false ceiling	cielo raso
finish	acabado
finish ceiling	falso cielo
finish coat (plaster)	enlucido
flattened cane reed	caña chacada
flooring	pavimento
frieze	friso
girder	viga peraltada
groin valut	bóveda de crucería
gutter	canalón
gypsum	yeso
half lap (joint)	a media madera
hand hewn	azuelada
herringbone pattern	aparejo esquina de pez
hip	lima tesa
jamb	derrame
joint	costura, junta, llaga, nudo
joist	vigueta
lath	tequillo
lathing	enlistonado
leather strap	huasca
lime	cal
lookout	can
lunette	luneta
masonry	mampostería
mortar	mortero

mortice and tenon	caja y espiga, mortaja y espiga
mud	barro
nave	nave central
niche	hornacina
pediment	frontis
peg	clavija
pendentive	pechina
pier	mocheta
pillar	pilar
plan	plano
plaster	tarrageo
post	pies derecho
principal arch	arco fajón
principal rafter	viga de tejado principal
purlin	correa
rafter	cabrio, pare, viga
reinforcement	armadura
ribbed vault	bóveda de crucería
ridge beam, ridge purlin	cumbrera, viga cumbrera
ridgepiece	parhilera
ring	anillo
roofing	tejado
rubble	escombro, ripio
rubble masonry	mampostería ordinaria
section	sección transversal
shoring	puntales
sill plate	solera, viga collar
site plan	ubicación
sleepers	durmientes
spandrel	enjuta, albánega
Spanish tile	teja árabe o curva
spiral stair	escalera de caracol
splay	derrame
stringer	puente

subfloor	falso piso, falso suelo
terrace	terraza
tie beam	tirante
tongue and groove	machihembrado
transept	transepto
truss	armadura de cubierta
typmanum	tímpano
underpitch vault	bóveda de lunetos
valley rafter	cabrio de la lima hoya
vault	bóveda
wall plate	solera, viga collar

Español - Inglés

acabado	finish
albánega	spandrel
anillo	ring
aparejo	bond
aparejo de tisón	bondstone
aparejo esquina de pez	herringbone pattern
aparejo isodomo	ashlar masonry
arcada	arcade
arco	arch
arco fajón	principal arch
armadura	reinforcement
armadura de cubierta	truss
azuelada	hand hewn
barro	mud
bóveda	vault
bóveda de cañón	barrel vault
bóveda de crucería	ribbed vault
bóveda de crucería	groin valut
bóveda de lunetos	underpitch vault
cabrio	rafter
cabrio de la lima hoya	valley rafter
caja y espiga	mortice and tenon
cal	lime
can	lookout
caña chacada	flattened cane reed
canalón	gutter
cercha	(structural) arch
cielo raso	false ceiling
claustro	cloister
clavija	peg
codal	collar beam
columna	column

columnata	colonnade
contrafuerte	buttress
cornisa	cornice
coro	choir
correa	purlin
costura	joint
crujía	bay
cumbrera	ridge beam, ridge purlin
cúpula	dome
derrame	splay, jamb
durmientes	sleepers
elevación	elevation
enjuta	spandrel
enlistonado	lathing
enlucido	finish coat (plaster)
escalera de caracol	cochlea, spiral stair
escombro	rubble
fachada	facade
falso cielo	finish ceiling
falso piso	subfloor
falso suelo	subfloor
friso	frieze
frontis	pediment
hilada	course
hornacina	niche
huasca	leather strap
junta	joint
llaga	joint
ladrillo pastelero	brick paver
lima tesa	hip
listón	batten, cleat
luneta	lunette

machihembrado	tongue and groove
mampostería	masonry
mampostería escuadrada	ashlar masonry
mampostería hilada	coursed masonry
mampostería ordinaria	rubble masonry
a media madera	half lap (joint)
ménsula	corbel
mocheta	pier
mortero	mortar
mortaja y espiga	mortice and tenon
muro de carga	bearing wall
muro divisorio	cross wall
nave central	nave
nave lateral	aisle
nudillo	collar tie
nudo	joint
pare	rafter
parhilera	ridgepiece
pavimento	flooring
pechina	pendentive
pendolón	crown post
perpiaño	bonder
pies derecho	post
pilar	pillar
plano	plan
puente	stringer
puntales	shoring
retablo	altarpiece
riñón	spandrel
ripio	rubble

sección transversal	cross section, section
sobrecimiento	base course
solera	wall plate, sill
sotocoro	space or area below the choir loft, in a church
tabique	partition
taco	blocking
tarrageo	plaster
teja árabe o curva	Spanish tile (also called Mission tile in the US)
tejado	roofing
tequillo	lath
terraza	terrace
tímpano	tympanum
tirante	tie beam
transepto	transept
tornapunta	brace
ubicación	site plan
vestíbulo	entranceway
viga	beam, rafter
viga collar	wall plate, sill
viga cumbrera	ridge beam, ridge purlin
viga de tejado común	common rafter
viga de tejado principal	principal rafter
viga peraltada	girder
vigueta	joist
yeso	gypsum
zaguán	entry hall
zócalo	base, plinth

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