3.4 Geological and Environmental Description

3.4.1 Geological description and seismic history

Hotel El Comercio (lat 12°02’41” S; long 71°01’42” W) is located in the center of Lima, where the rocky soil originates from the ejection cone of the Rimac River and extends to a depth of 50–100 m. In the vicinity of Hotel El Comercio, the rocks have a diameter between 0.20 and 0.30 m. The great depth is one of the main reasons why adobe structures in the historic center of Lima have performed well during past earthquakes.

The building is located in a level 3 seismic risk zone, as classified by the Peruvian Building Code, which is the highest level on a scale of 1 to 3.[3] As Hotel El Comercio was constructed in the middle of the nineteenth century, it has been subject to a number of seismic events throughout its history, including the 1974 earthquake near the coast of Peru, approximately 80 km to the southwest of Lima (M_W 8.1); the 1966 earthquake centered just off the coast of Callao, the port city to the west of Lima (M_W 8.1); and the 1940 Callao earthquake (M_W 8.2).[4]

3.4.2 Regional climate

The annual average temperature in Lima is 18°C, ranging from a minimum of 12°C to a maximum of 32°C. There is almost no rainfall in the area, and it is it prone to flooding when rain does occur. Termites are active in the area, which has an impact on wood elements within the structure.

3.5 Structural Description

The following sections describe the different structural materials, elements, and systems making up Hotel El Comercio (Fig. 3.18). Their current condition and any irregularities, alterations, damages, and decay observed during the construction assessment survey are described in greater detail in section 3.6 that follows the structural description.

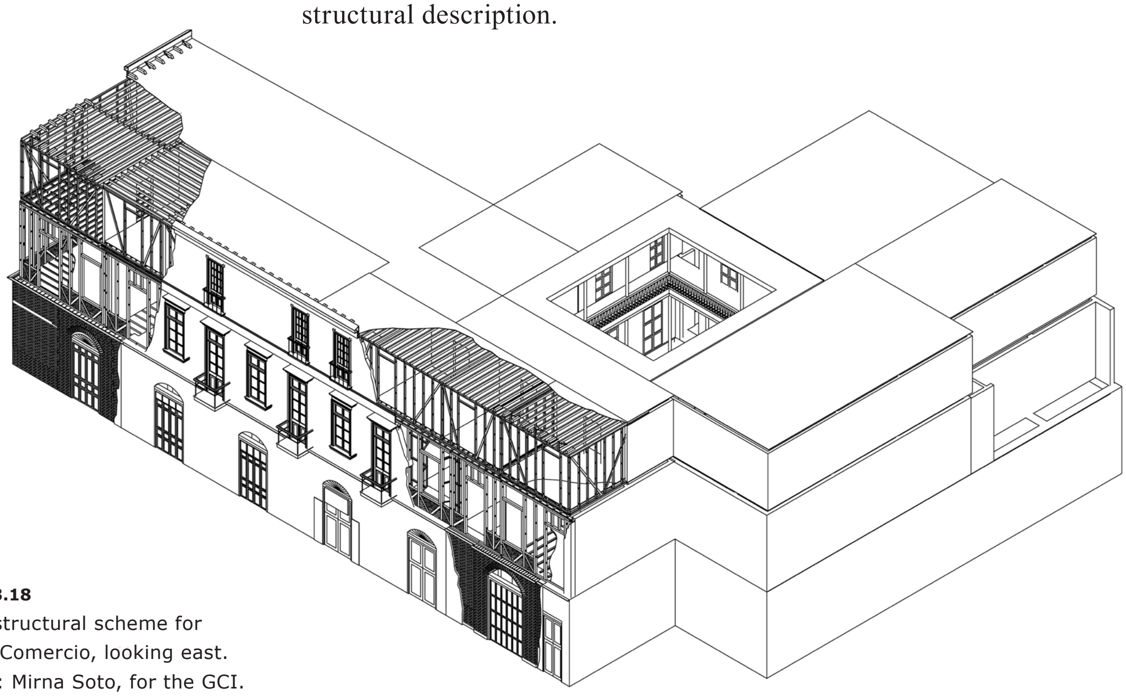


FIGURE 3.18
Overall structural scheme for Hotel El Comercio, looking east. Drawing: Mirna Soto, for the GCI.

3.5.1 Survey sectors

For the purposes of conducting the construction assessment survey, the first patio and northeast wing of Hotel El Comercio were divided into four sectors (Fig. 3.19). All four sectors appear to have been constructed at approximately the same time and exhibit similar construction materials and techniques. The sectors were selected based upon differences in their structural configuration, primarily related to the direction of the floor and roof joists. The sectors are as follows:

- **Sectors A-1, 2 and 3**: The building corner, including El Cordano bar, rooms 243 and 244 at the second floor; and rooms 344, 345 and 346 at the third floor.
- **Sectors B-1, 2 and 3**: From sector A-1, 2 and 3 to the far southwest end of the façade at Jirón Carabaya, including rooms 128 and 129 (El Cordano bar), room 130 (shoe store), stair hall 131, the entry hall 100, and room 101 at the first floor; rooms 242, 240, 238,236, 202 and 204 at the second floor; and, rooms 343, 342, 341, 340, 302, 304 and 306 at the third floor.
- **Sectors C-1, 2 and 3**: Also bordering sectors A-1, 2 and 3, including the bar bathrooms, kitchen preparation area, and the shoe store storage area at the first floor; rooms 241, 239, 237, corridor 246; rooms 307, 348, 349, 350, 338; and the stair from second to roof.
- **Sectors D-1, 2 and 3**: Bordering sectors B and C, sector D includes the kitchen pantry of El Cordano bar at the first floor; rooms 234 and 233 at the second floor; and, rooms 337 and 336 at the third floor.

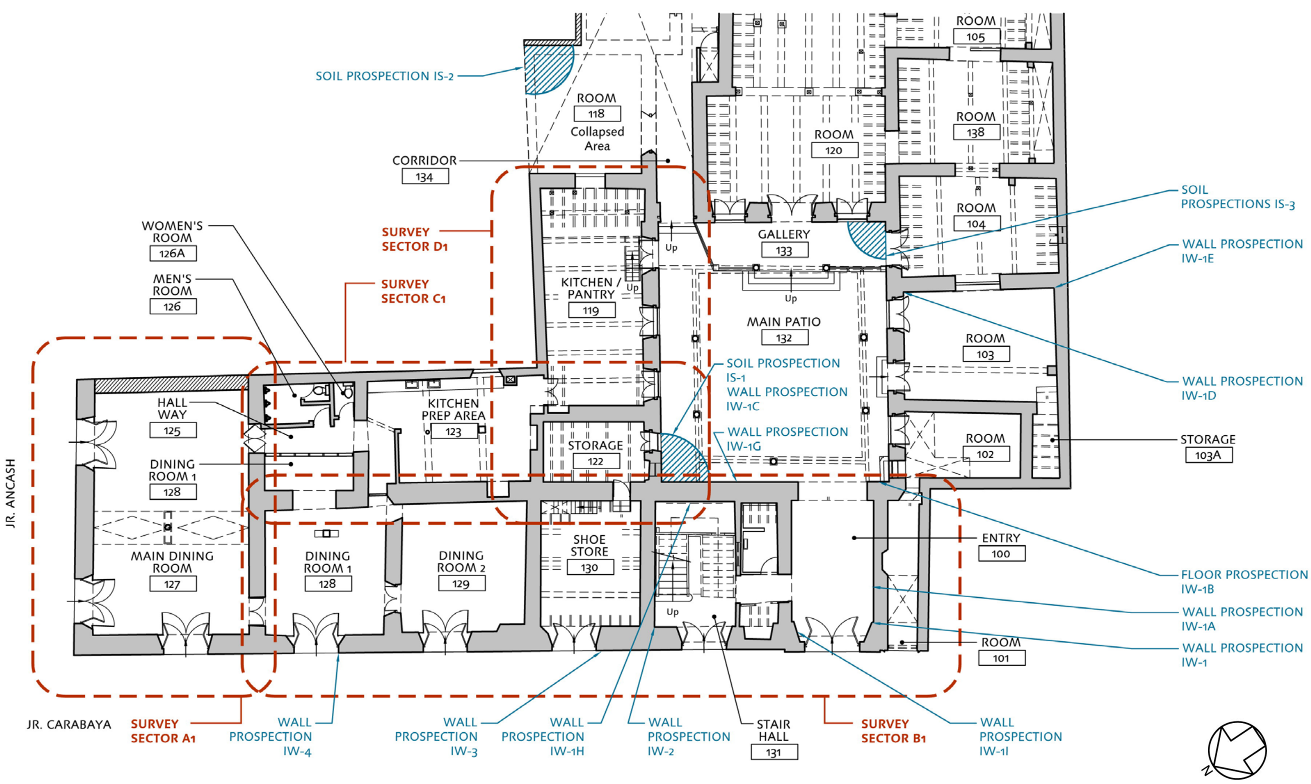
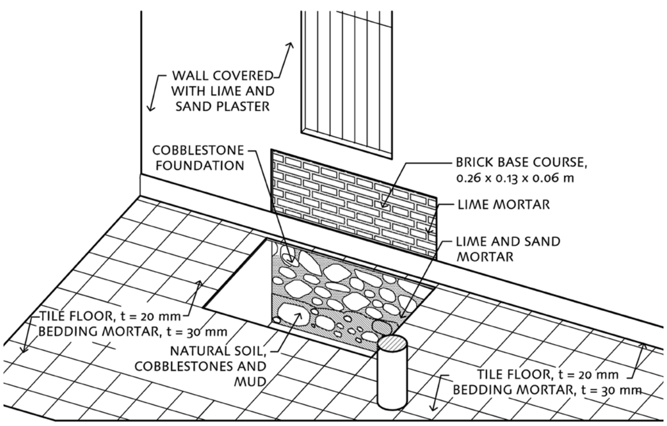


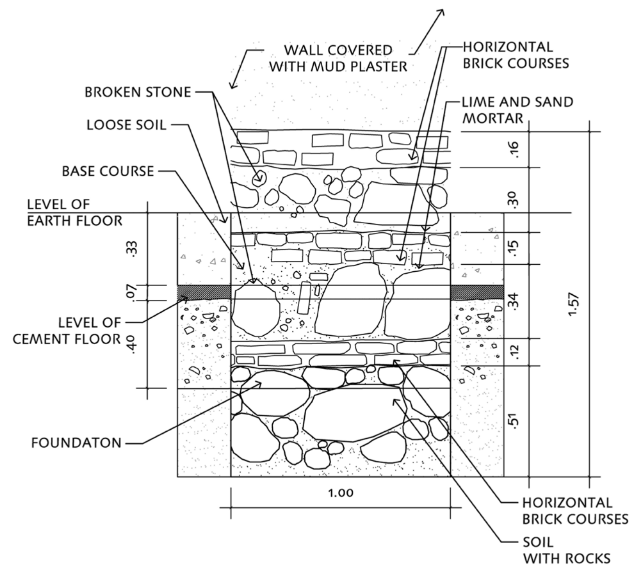
FIGURE 3.19
First floor plan, showing sector and prospection locations.
Drawing: Base drawing prepared by the Instituto Nacional de Cultura and edited by the GCI.

3.5.2 Foundations and base course

It is important to note that Hotel El Comercio has been constructed over the remains of earlier structures on the site, as it may have an impact on the way the structure performs during an earthquake. Below the tile floor of main patio 132, fired brick walls were found through prospection IS-1. These walls have a different layout than the current patio walls, indicating that they are the remains of a previous structure.

The current structure has a manmade foundation and base course. The foundation is typically constructed with rubble stone masonry set in a lime and sand mortar. The foundation hits rocky soil at an average depth of 0.50–0.80 m below the finish floor level. The base course is constructed with fired brick masonry set in a lime mortar, and it rises to an average height of 0.70–1.00 m above the finish floor level. The brick base course is incorporated into the fired brick surrounds at the door openings (see section 3.5.3.1 for further discussion). The horizontal and vertical mortar joints in the fired brick masonry have an average thickness of 25–30 mm (Figs. 3.20, 3.21). Prospection IS-2, carried out in collapsed room 118, showed a different configuration at the base course, with alternating courses of rubble stone and fired brick masonry (Figs. 3.22, 3.23).





FIGURES 3.20 (TOP) AND 3.21 (BOTTOM)
Prospection IS-1, at the northeast side of patio.
Drawing: Mirna Soto, for the GCI.

FIGURES 3.22 (TOP) AND 3.23 (BOTTOM)
Prospection IS-2, showing the foundation and base course at the northeast side of room 118 (the collapsed area).
Drawing: Mirna Soto, for the GCI.

3.5.3 Walls

3.5.3.1 Load-bearing mud brick masonry and quincha façade walls
Hotel El Comercio is constructed with mud and fired brick walls at the first story and quincha walls at the second and third stories.

Mud brick is typically used for the first floor walls. These walls have an overall height, including the base course, of 5.20 m from the finish floor level to the top of the mud brick wall. The exterior façades range in thickness from 0.85 m at the 12.80 m long northeast façade along Jirón Ancash to 0.82–1.25 m at the 39.65 m northwest façade along Jirón Carabaya. Thus, with a slenderness ratio between 4 and 6, they can be considered thick.[5] The patio façades have an average length of 10 m and a more consistent width, ranging from 0.80 to 0.90 m. Thus, they have a slenderness ratio of 6.5. At the door openings, there are fired brick surrounds that range in width from 0.42 m at prospection IW-2 to 0.98 m at prospection IW-3, extend the full depth of the wall, and interlock with the adjacent mud brick wall construction in nearly all of the surrounds (Fig. 3.24). The exterior and patio façades are covered with 30–40 mm of mud plaster and a 2 mm thick gypsum finish coat. A layer of cement plaster has been applied to the patio façades.

At the second floor, the typical quincha wall is 4.63 m high and is constructed with a wood frame made of 0.12 × 0.12 m posts (*pies derechos*); a 0.12 × 0.10 m top plate (*carrera*); and a 0.12 × 0.10 m sill plate (*viga solera*), which rests on the adobe wall below. The posts are connected to the top and sill plates by means of 0.06 m diameter by 0.10 m long dowels that go all the way through the plates. A 0.15 × 0.05 m wood cap plate (*viga de amarre*) spans across the top of the frame. The bottom 0.90 m of the frame is filled with mud bricks over two courses of fired bricks, as well as 0.11 × 0.11 m diagonal wood braces (*tornapuntas*). Over this filled base, four horizontal canes span across the posts, providing reinforcing, and vertical cane reeds are interwoven with the horizontal canes. In some panels *caña chancada*, or flattened cane reeds, are nailed over the wood posts. The panels are then covered with a 35 mm thick mud and straw layer, followed by a 25 mm thick mud layer, a 4 mm thick gypsum finish coat, and a final paint layer. The quincha posts do not align with the floor joists below (Figs. 3.25–3.29).

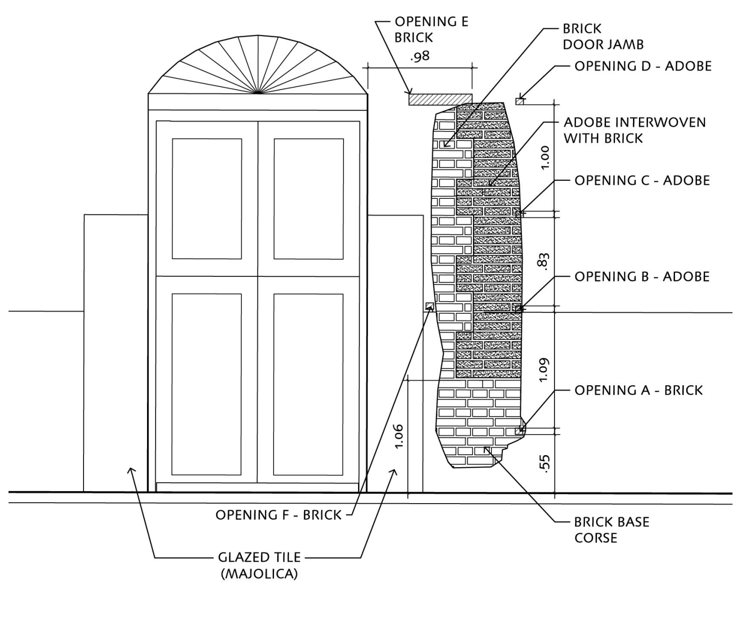


FIGURE 3.24
Prospection IW-E, showing fired brick masonry surrounds at openings in first floor mud brick walls at the northwest façade.
Drawing: Mirna Soto, for the GCI.

At the third floor, the quincha walls are of a similar construction to the second floor walls; however, they are somewhat shorter, the wood frame elements are smaller, there is not any mud brick infill at the base of the frames, and the diagonal bracing extends the full height of the frame. The third floor quincha wall frames are made of 0.08 × 0.05/0.06 m posts (*pies derechos*); a 0.08 × 0.06 m top plate (*carrera*); and a double 0.08 × 0.06 m sill plate *(viga solera*), which rests on the third floor joists below. The posts are joined to the top and sill plates with 0.04 m diameter by 0.06 m long pins or dowels. The 0.09 × 0.03 m diagonal wood bracing typically spans across two to three posts. The diagonals are connected to the top and sole plates by means of nails (Figs. 3.30, 3.31).

The wall construction is different at the main stair (stair hall 131 and hall 200) to accommodate the intermediate landing between the first and second floors. The exterior quincha walls at the second floor are constructed with two separate frames with a void in the middle. The external frame is vertically aligned with the external face of the mud brick façade below, while the interior frame is aligned with internal face of the mud brick façade. The mud brick infill in the lower portions of the frame is only used at the exterior frames and not the interior frames (Fig. 3.33).

The ratio of openings to the total vertical surface area of the façade walls is provided in Table 3.1.

Table 3.1: Ratio of openings to total vertical surface area of façades

Façade	Area of Openings/Total Vertical Surface Area of Façade
Northwest façade, along Jirón Carabaya	23.4%
Northeast façade, along Jirón Ancash	16.8%
Average of exterior façade ratios	**20.1%**
Northwest patio façade	31.06%
Northeast patio façade	16.90%
Southeast patio façade	23.10%
Southwest patio façade	28.70%
Average of all patio façade ratios	**25%**

3.5.3.2 Load-bearing mud brick masonry and quincha interior walls

Similar to the exterior walls, the interior walls are constructed with mud and fired brick at the first story and quincha at the second and third stories. The 0.60 –0.80 m thick interior mud brick walls at the first floor are somewhat thinner than the exterior walls. Thus, the slenderness ratio for these walls ranges from 6.5 to 8.6, which falls somewhere between the relatively thick and thin classifications. The only truly slender walls are at the El Cordano kitchen preparation area and pantry (rooms 123 and 119), which appear to be shared walls with the adjacent casona. These walls are 0.43–0.48 m thick. All of the interior mud brick walls appear to have interlocking corners.The interior quincha walls at the second and third floors are similar in design to the exterior walls; however, there is not a wood cap plate at the top of the second floor frames and there does not appear to be any diagonal bracing at the third floor frames. At the second floor, the sill plate at the base of the frame rests directly on the floor joists—not the adobe walls. Where the interior walls intersect with the exterior walls, the frames are connected with half-lap joints at the top and sole plates (Fig. 3.32). The longest quincha wall occurs at the second floor corridor 246—it is 27 m long and separates El Comercio from the adjacent casona.

FIGURE 3.25 (ABOVE)
Typical quincha wall at the second floor, showing the mud and fired brick infill at the bottom of the frame (prospection IIS-2). The horizontal canes at the right have been used to infill an earlier door opening.
Image: Mirna Soto, for the GCI.

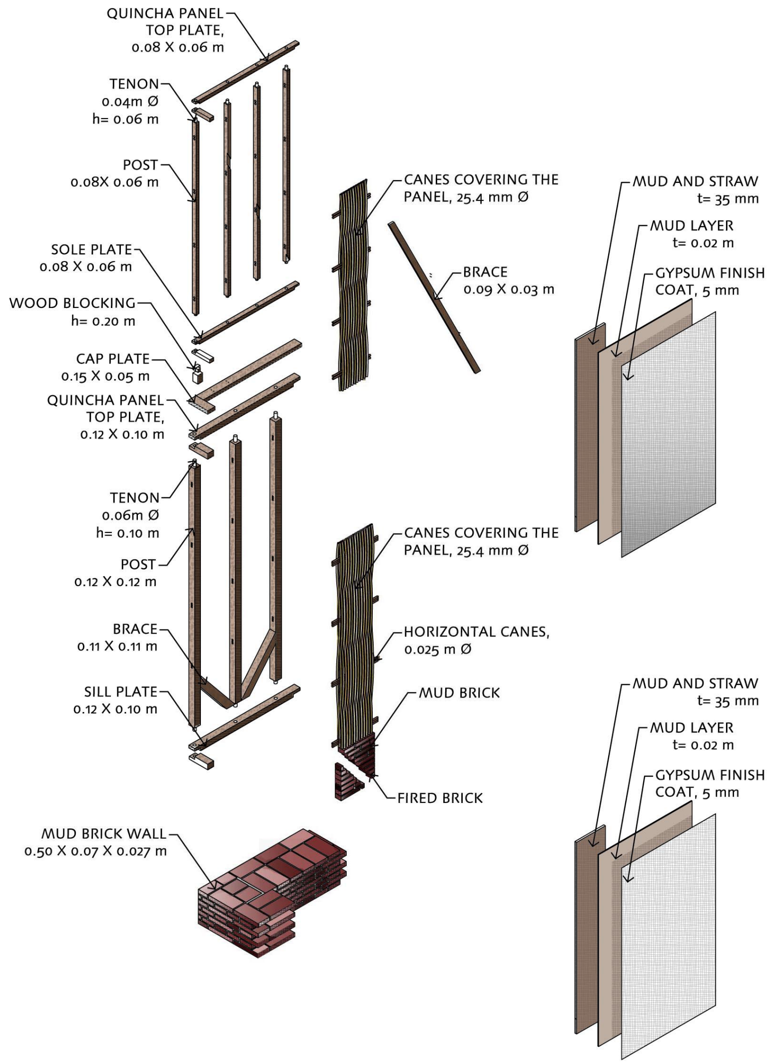
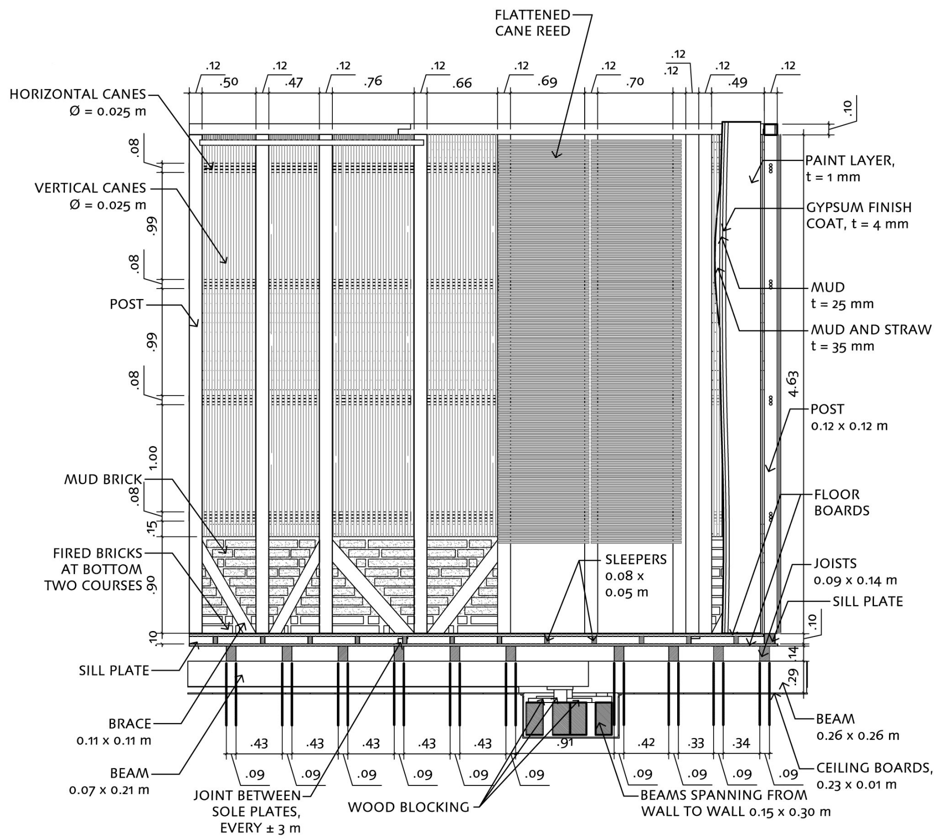


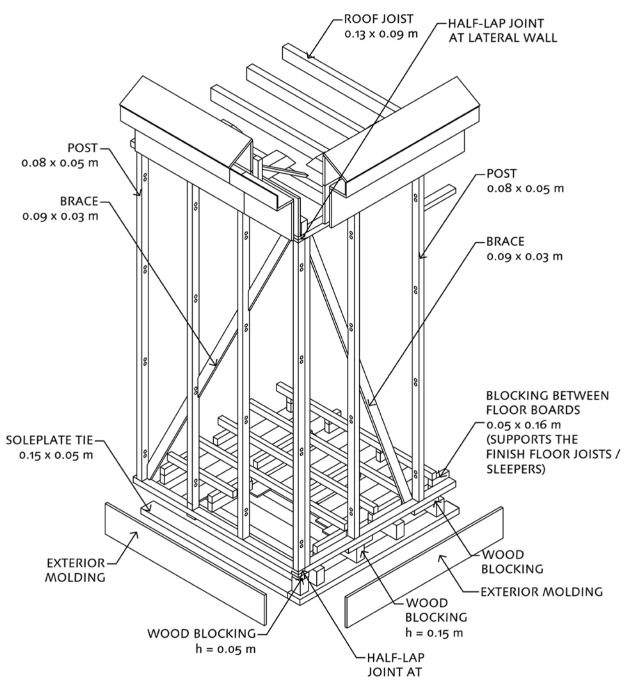
FIGURE 3.26 (RIGHT)
Exploded isometric view, showing the quincha wall construction at the second and third floors of the northeast façade.
Rendering: Jabdiel Zapata, for the GCI.

FIGURE 3.27 (NEAR RIGHT)
Detail view showing the connection of vertical quincha post and horizontal canes.
Image: Claudia Cancino

FIGURE 3.28 (FAR RIGHT)
Prospection IIIS-1, showing the quincha posts and floor joists do not align.
Drawing: Mirna Soto for the GCI.

FIGURE 3.29
Prospection IIS-2, elevation of typical second floor quincha wall. Drawing: Mirna Soto for the GCI.





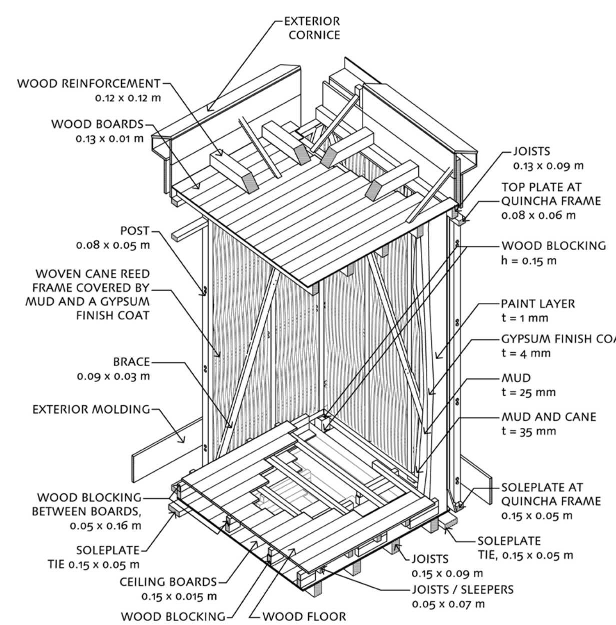


FIGURE 3.30
Prospection IIIS-1, third floor quincha wall frame. Drawing: Mirna Soto for the GCI.

FIGURE 3.31
Prospection IIIS-1, third floor quincha wall frame and cover. Drawing: Mirna Soto for the GCI.

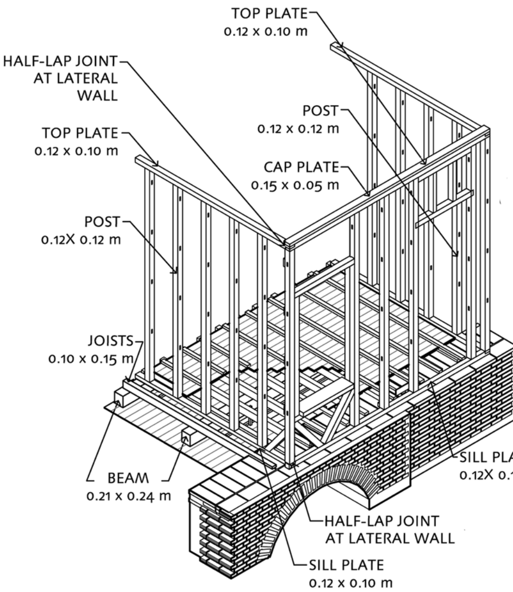


FIGURE 3.32 (ABOVE)
Prospection IIW-2, showing the framing connection between the front façade and lateral walls.
Drawing: Mirna Soto for the GCI.

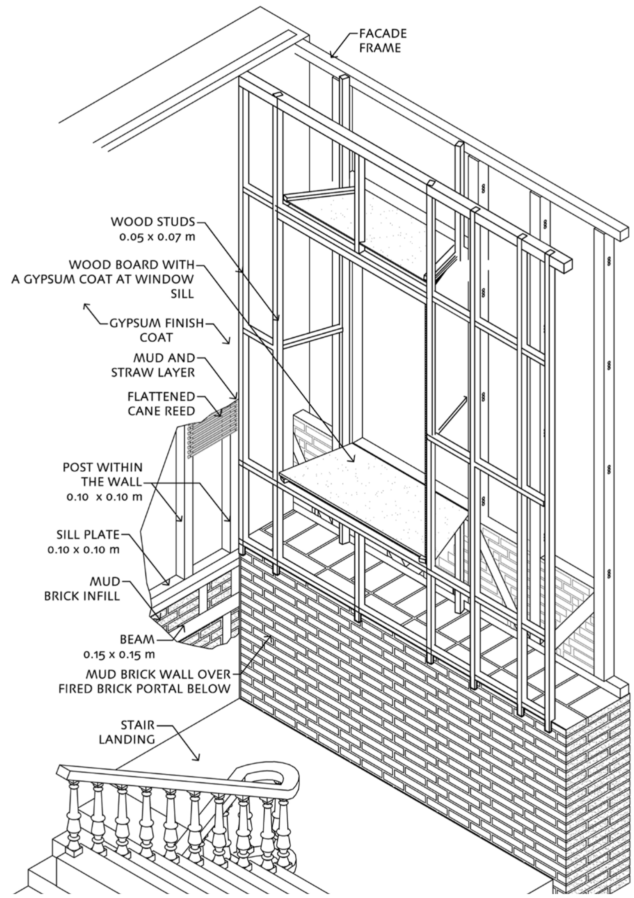


FIGURE 3.33 (RIGHT)
Prospection IW-1F, illustrating the double quincha frame construction at stair hall 131.
Drawing: Mirna Soto for the GCI.

3.5.4 Floors

The floors at Hotel El Comercio are constructed with tongue-and-groove wood floor boards over wood sleepers over wood floor boards over wood joists. Wood boards are typically attached to the underside of the floor structure to provide a finish ceiling for the room below (Figs. 3.34–3.36). The second and third floors are of a similar construction; however, at the second floor the sole plate at the bottom of the quincha frame and the floor joists are embedded in the top of the first floor mud bricks walls.

During the survey and investigations, particular attention was given to the floor configurations at the corner of the building above El Cordano bar, including second floor rooms 243 and 244 and third floor room 344, through prospections IIW-1, IIW-2, IIS-1, and IIIS-1. This area appears to have undergone a number of alterations, including the removal of a first floor wall and replacement with a column and four closely-spaced beams or girders (see section 3.6.4 for further description). The second floor construction (as described from bottom to top) consists of a false wood ceiling nailed to wood beams running parallel to the northeast façade along Jirón Ancash. These beams do not span the full length of the bar below, rather shorter lengths overlap one another by a significant amount above the column and girders. This beam configuration may be an alteration related to the removal of the adobe wall below. Over the beams, joists run in the opposite direction. The joist ends are pocketed into the mud brick walls along Jirón Ancash (Figs. 3.37–3.40). Over the floor joists are wood boards, followed by wood sleepers running in the same direction as the joists and nailed to the joists, and finally tongue-and-groove wood boards which serve as the finish floor. The space between the sleepers is filled with a mud and lime-based mixture. The third story floor construction is similar, but without overlapping beam ends. It is important to mention that the quincha partition wall between rooms 243 and 244 does not align with the floor beams which would have originally been embedded at the top of the now removed mud brick wall below. This suggests inadequate construction or later alteration of the second floor walls.

A slightly different configuration was observed at the floor structure in rooms 204 and 306 through prospections IIW-3 and IIIS-2 (Figs. 3.41, 3.43). In this area, the wood beams run parallel to the long façade at Jirón Carabaya with perpendicular joists above. The second floor joist ends are pocketed into the mud brick walls, and the third floor joist ends rest on a sole plate tie over the second floor quincha frames. Over the joists there is another layer of wood framing, wood boards, and sleepers with a mud and lime-based soil infill between them. As with the earlier prospection, the sleepers run in the same direction as the joists. Finally, there is a tongue-and-groove wood plank finish floor.

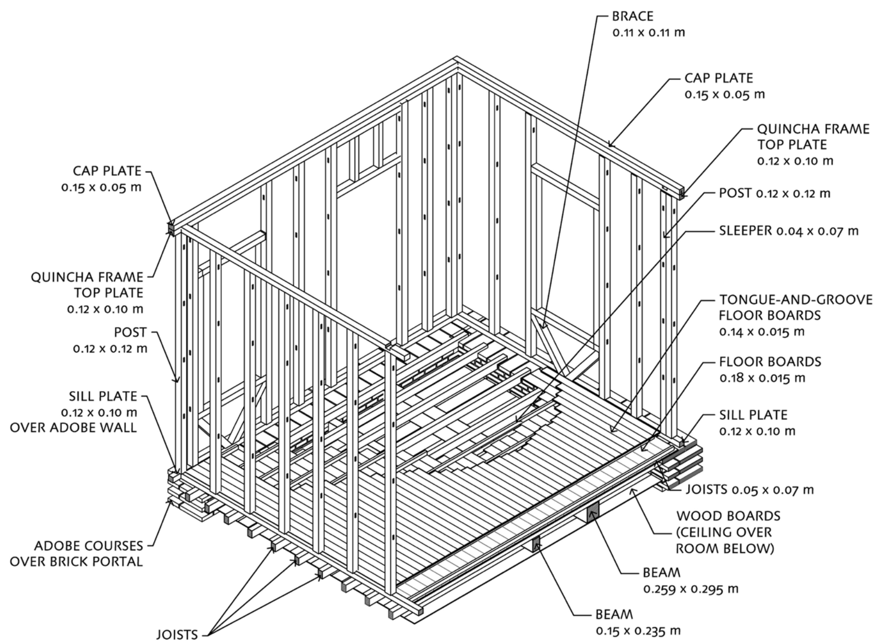


FIGURE 3.34
Prospection IIW-1, showing the second floor construction in the north corner of the building.
Drawing: Mirna Soto, for the GCI.

FIGURE 3.35 (NEAR RIGHT)
Prospection IIS-3, showing the third floor construction at the patio galleries.
Image: Sara Lardinois.

FIGURE 3.36 (FAR RIGHT)
Typical finish ceiling at the underside of the floor construction.
Image: Amila Ferron.

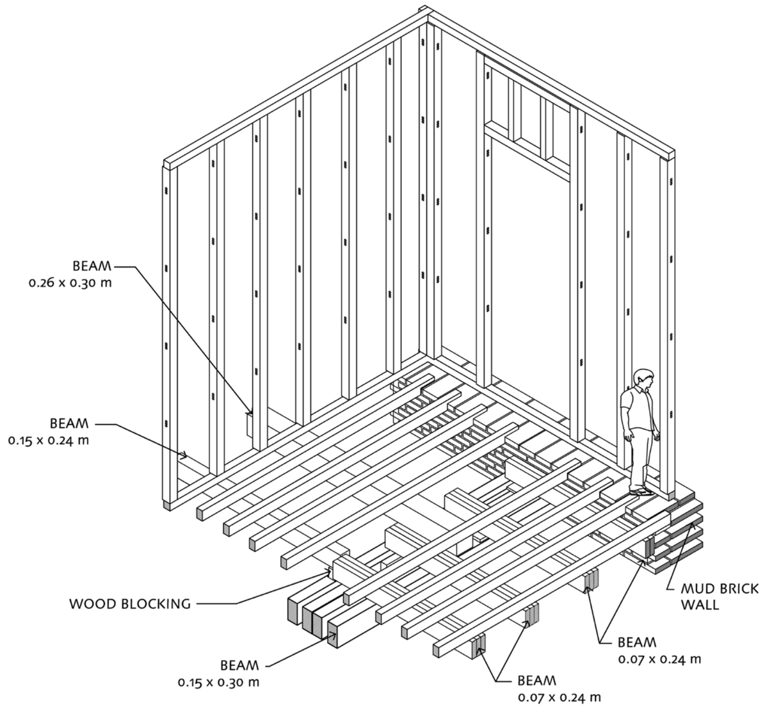


FIGURE 3.37 (TOP)
Prospections IIS-1 (room 243), showing the second floor construction above El Cordano bar with overlapping beams.
Drawing: Mirna Soto, for the GCI.

FIGURE 3.38 (BOTTOM)
Prospection IIS-1, showing the joist ends pocketed into the top of the first floor mud brick wall at the northeast façade.
Image: Sara Lardinois.

FIGURES 3.39 AND 3.40 (TOP AND BOTTOM)
Prospection IIS-1, showing the overlapping beam ends, which presumably relate to the removal of a wall in the bar below.
Image: Mirna Soto, for the GCI.

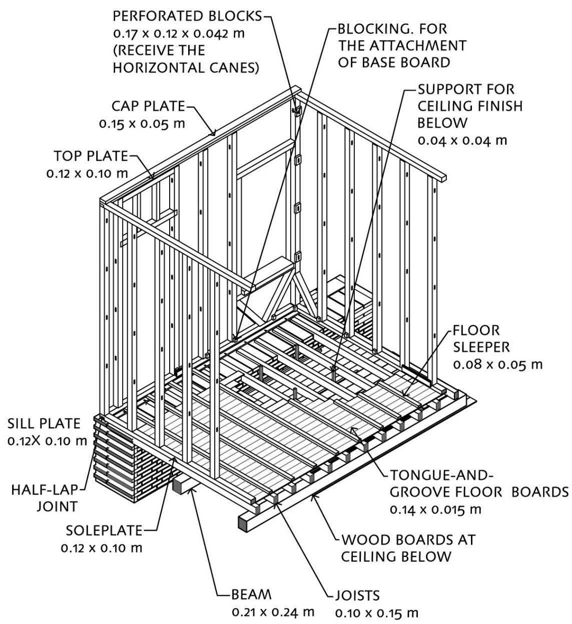


FIGURE 3.41

Prospection IIW-3, showing the second floor construction at the northwest façade (room 204).
Drawing: Mirna Soto, for the GCI.

FIGURE 3.42

Prospection IVR-1, showing the roof construction at the northwest façade.
Image: Mirna Soto, for the GCI.

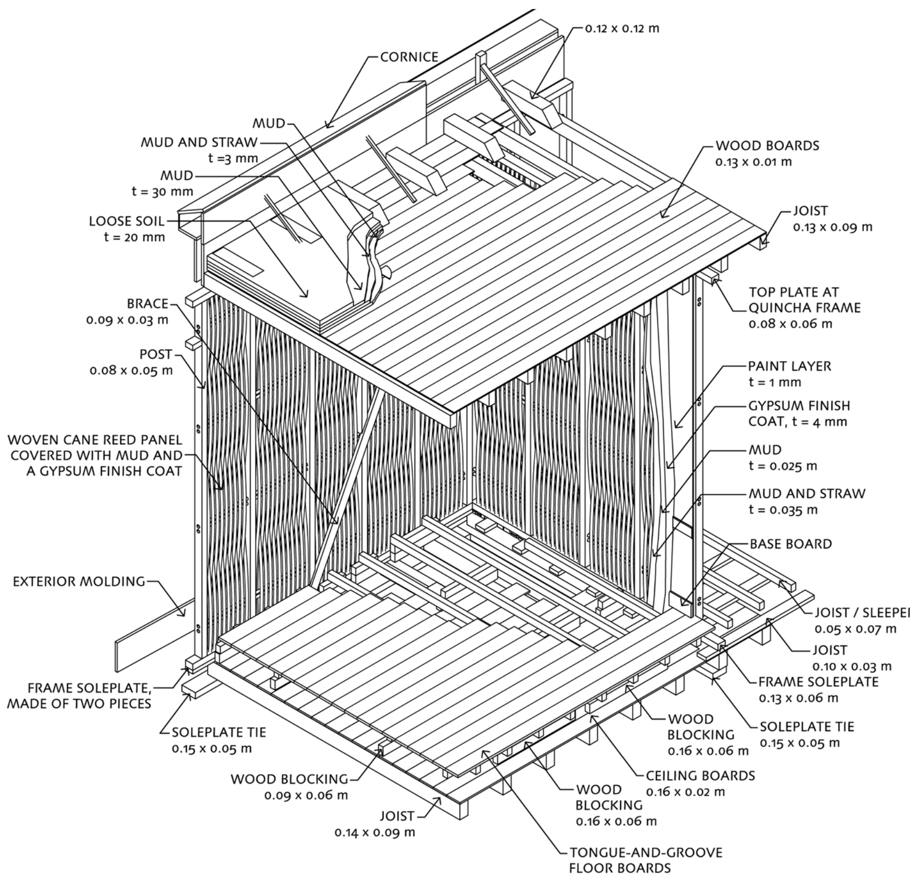


FIGURE 3.43

Prospections IIIS-2 and IVR-1, showing the third floor and roof construction at the northwest façade (room 306).
Drawing: Mirna Soto, for the GCI.

3.5.5 Roof

The roof framing system is similar to the floor framing. One notable difference is the lack of a finished ceiling at the third floor which leaves the roof joists exposed. The top of the joists are covered with a layer of wood boards, followed by a 30 mm layer of mud, a 30 mm layer of mud with straw, a second 30 mm layer of mud, and a 20 mm layer of loose soil (Fig. 3.42).

3.6 Irregularities, Alterations, Damages, and Decay

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

3.6.1 Foundations and base course

The foundation and base course appear to be in fair condition overall, and the masonry is generally cohesive. In those areas that were opened up for the structural prospections, humidity was observed in the soil. This humidity is likely the result of improper site drainage in the patios of Hotel El Comercio and the adjacent casona. As a result of this humidity, disaggregation was noticeable at the soil layer above the rocky soil, particularly in the collapsed area of room 118.

3.6.2 Walls

The following irregularities in the wall construction were observed during the construction assessment survey:

- The mud brick and quincha walls do no align vertically between the floors, thus creating some stress and deformation at the floor and ceiling structure, particularly between the first and second floors of sector A and the second and third floors of sectors B and C.
- The quincha frames are only connected to the floor and roof joists by a cap or top plate and sill plates and, thus, are not properly interlocked.

The structural configuration of the walls been modified through recent alterations, including:

- **Sector A**: The southeast wall of the main dining room at El Cordano bar (rooms 127 and 128) has been reconstructed. The bar owners indicated that it was rebuilt with mud bricks; however, this was not verified through any investigative work by the project team.
- **Sectors A and B**: New openings have been cut in the adobe walls to connect the main dining area with auxiliary dining rooms 128 and 129, in order to improve the functionality of El Cordano bar.
- **Sector C**: New partitions have been added to create bathrooms adjacent to the El Cordano dining rooms.

Both of the street façades show some signs of cracking, particularly at the second floor spandrels. There is diagonal and vertical structural cracking at the corner of the first floor at the northeast end of the long northwest façade (Jirón Carabaya). The northeast façade along Jirón Ancash also shows significant cracking in the second floor at the southeast end near the adjacent casona and at the third floor spandrels (Figs. 3.44, 3.45). The patio façades are in fair condition but also show signs of cracking at the third level spandrels and also at the corners of the openings (Figs. 3.46, 3.47).

Humidity was observed in the base of the mud brick walls, which could jeopardize their structural performance, particularly during a seismic event. The cement plaster finish at the patio façades prevents any dampness from migrating out of the wall, which has likely led to the interior deterioration of the mud bricks. This humidity may in part be related to changes in use and the insertion of plumbing lines in the kitchen and bathrooms. If not properly installed, plumbing may introduce water in the base of the walls. For example, humidity was observed in the base of the walls in sector D, where the bar kitchen pantry is located.

The second floor quincha walls are in poor condition, particularly in sector A and at the long wall in sector B that borders the adjacent casona. Cracks and plaster detachment were observed in many walls, typically in areas corresponding to posts within the walls and at openings. The detachment of the painted mud plaster at the quincha frame bases and posts is exposing the internal wood structure to deterioration (Figs. 3.48–3.51). The presence of termites in nearly all wood elements suggests that the panel structure connections may not perform well during future seismic events. The deterioration and previously-mentioned lack of proper connections / interlocking makes it difficult for the quincha frames to restrain lateral or vertical movements.

The second floor walls in sector B and D are in better condition, but still exhibit cracking and plaster detachment at their bases and around openings.

The quincha walls at the third floor are also in better condition with the exception of sector A, where the walls are structurally exposed to detrimental environmental conditions such as pigeon and buzzard nests and excrement. The damage to the quincha walls seems to be superficial, although it is difficult to determine the level of deterioration at the quincha structural elements and connections.

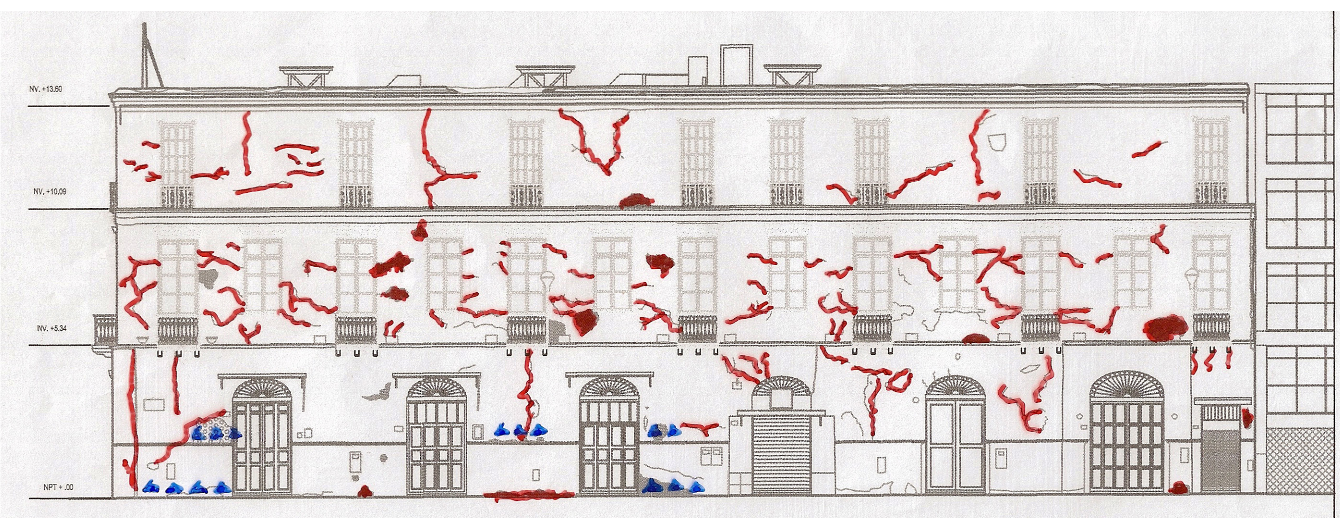


FIGURE 3.44
Northwest façade, graphic condition survey indicating observed cracks and areas of plaster loss in red and humidity in blue. Drawing: Claudia Cancino.

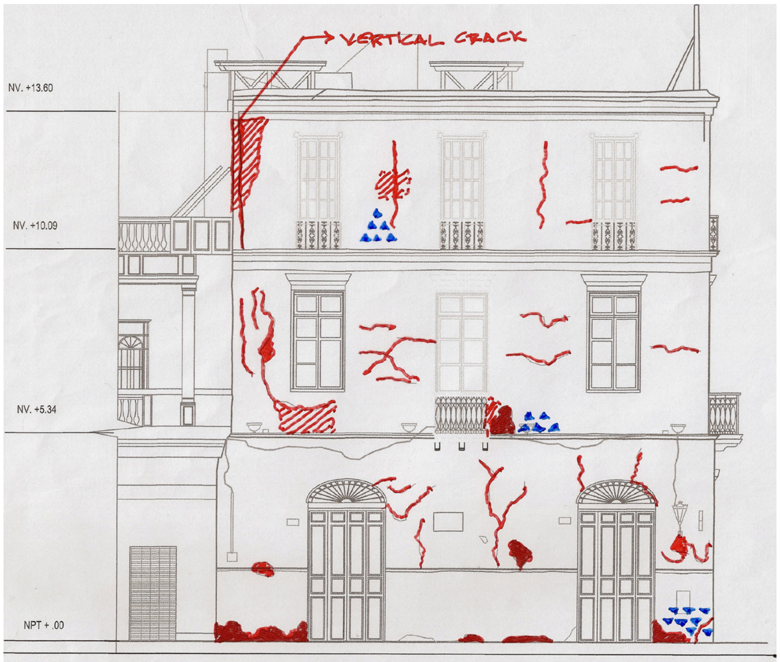


FIGURE 3.45
Northeast façade, graphic condition survey indicating observed-cracks and areas of plaster loss in red and humidity in blue.
Drawing: Claudia Cancino.

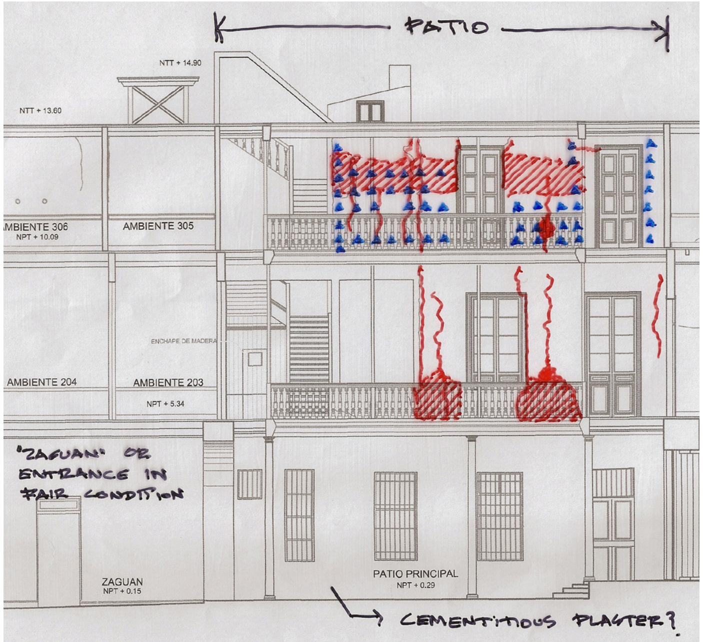


FIGURE 3.46
Northeast patio façade, graphic condition survey indicating observed cracks and areas of plaster loss in red and humidity in blue.
Drawing: Claudia Cancino.

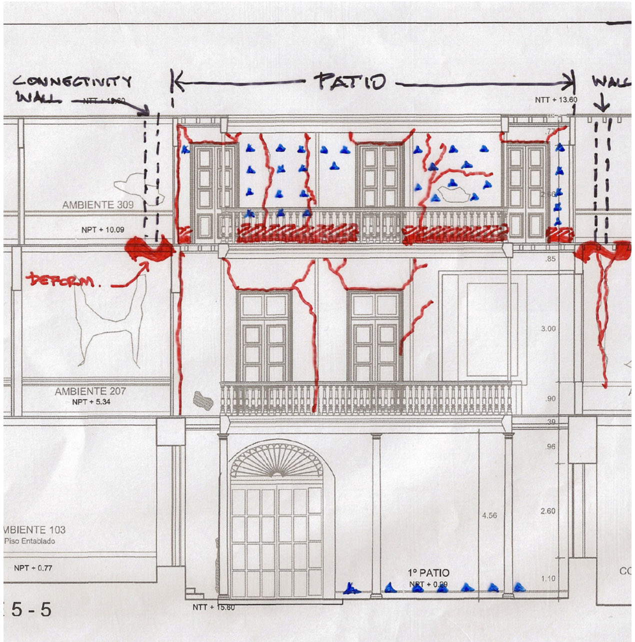


FIGURE 3.47
Northwest patio façade, graphic condition survey indicating observed cracks and areas of plaster loss in red and humidity in blue.
Drawing: Claudia Cancino.

FIGURE 3.48
Typical plaster detachment at quincha wall bases and posts.
Image: Claudia Cancino.

FIGURE 3.49
Typical crack pattern at openings in quincha walls.
Image: Claudia Cancino.

FIGURE 3.50
Typical crack pattern, corresponding to the quincha post locations.
Image: Claudia Cancino.

FIGURE 3.51
Vertical cracks corresponding to quincha post locations, southeast wall of corridor 246, sector C.
Image: Amila Ferron.

3.6.3 Floors

The floor structures are in fair condition in most sectors; however, the area above rooms 125 and 127 in sector A (El Cordano bar) has suffered significant damages. The floor beam ends are weakly embedded in the tops of the mud brick load-bearing walls and do not properly distribute the vertical forces. The presence of soil between sleepers in some areas adds load to the floor structure and makes the diaphragm stiffer.

The installation of heavy machinery in the building in the 1980s damaged the floor structure. The damage is most severe at the southwest area of second and third floors, adjacent to the neighboring concrete building, and includes severe deformation of the floors. Shoring has been installed to avoid collapse of this area, however, it remains in a precarious state.

FIGURE 3.52
Northwest wall of room 243.
Image: Claudia Cancino.

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

The structural configuration of the building has been modified through recent alterations, including:

- **Sector A**: It is likely that the wall separating sectors B and C at the first floor probably originally to the northeast façade. It has since been removed to create a larger dining room for El Cordano bar and a metal column has been installed to support the floor structure above. The overlapping wood beams at the second floor, above the El Cordano main dining room, appear to be alterations made to accommodate this transformation. Of particular concern is the northwest wall of room 243 over the bar dining room. With the removal of the mud brick wall, the second floor quincha wall frame was left hanging from the third floor quincha frame and is not bearing on the floor, thus creating a total disconnection between two floors (Fig. 3.52).
- **Sector B**: The original configuration of the entry hall and staircase is unclear.
- **Sector B**: At the first floor shoe store (room 130), a storage mezzanine was constructed with metal beams running parallel to the northwest façade.
- **Sector B**: The kitchen preparation area contains two wooden columns supporting two wood beams. It is unclear if this is part of the original design or a later alteration.
- **Sector D**: The mezzanine in the kitchen pantry area was likely added by the bar owners.
- **Sector D**: The area adjacent at the far southeast end of the sectors D-1, 2 and 3 has collapsed.

3.7 Preliminary Findings

The following preliminary findings on the structural behavior of Hotel El Comercio 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 the 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:

- Hotel El Comercio is a highly complex structure due to the multiple modifications of its floor structures and other modifications related to changes in use. However, this situation is typical for many historic buildings in Lima and other Spanish colonial cities in South America. Despite the modifications, the site is in fair condition overall but with areas in serious danger of collapse.
- The structure of sector A is in most danger, as it appears that an original internal mud brick wall that originally supported the quincha walls above has been replaced with a column. Furthermore, the placement and overlapping of the wood floor beams above does not work and only adds load to the structure above. At that same sector, the conditions of the quincha partition walls at the second floor are poor and may lead to the collapse of the third floor area above the bar. Finally, the fact that this sector is located at the corner makes the building even more vulnerable to collapse during an earthquake.
- The presence of humidity at the base of the mud brick walls is a condition that jeopardizes the stability of the walls and may also have a negative effect in the event of an earthquake.
- The ongoing exposure of the quincha structural elements to the environment and termite damage creates a severe threat to the frames.
- The insufficient interlocking between quincha wall frames may reduce the structural performance of the building in future earthquakes. Without proper connections, the wall frames are unable to restrain lateral or vertical movements without collapsing. The collapse of the quincha walls may lead to collapse of the floor and roof structure above.
- The embedment of the wood sole plates at the bottom of the second floor quincha wall frames into the top of the mud brick walls below does not appear to be sufficient enough to allow the floor structure to work as a proper diaphragm.

Notes

1 The information in the following section is summarized from a 2010 report, "Hotel Comercio," on the history and significance of Hotel El Comercio prepared by María del Carmen Corrales Pérez of the former Instituto Nacional de Cultura in Peru.

2 As quoted in Corrales Pérez 2010, 9.

3 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.

4 Information on earthquake dates, epicenter locations, and moment magnitudes (Mw) is summarized from United States Geological Survey (USGS), Historic World Earthquakes, Peru, http://earthquake.usgs.gov/earthquakes/world/historical_country.php#peru.

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