Seismic Retrofit Applications of Getty Seismic Adobe Project Technology to Historic Adobe Buildings

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Abstract: *This paper summarizes a range of seismic retrofit strategies that have been designed by the author for historic adobe buildings in California. The range of the fundamental retrofits includes the principal retrofit strategies covered in the Getty Seismic Adobe Project (GSAP) research program conducted in the 1990s by the Getty Conservation Institute (GCI). The range of buildings includes a single-story building with thick adobe walls, several two-story adobe buildings with thick adobe walls, a single-story adobe building with thin adobe walls built around 1920, and the ruins of an adobe house. The five buildings covered in this paper demonstrate a broad range of seismic retrofit applications.*

The only building with particularly thin walls was the small adobe at Rancho Camulos. The small adobe was built around 1920 and has an architectural style that is unlike the typical nineteenth-century adobe, which is represented by the other buildings covered in this paper. The remainder of the historic adobe buildings primarily had walls that are 1.6 ft. (0.5 m) to nearly 3.3 ft. (1 m) thick.

The range of retrofit measures included anchorage at the floor levels and at the roof. Vertical center core rods were used both in existing adobe walls and in adobe walls that were reconstructed. Vertical straps and horizontal cables and rods were used to stabilize more severely damaged adobe walls.

The final project is the stabilization of the single-story ruins of the Las Cruces Adobe. The stabilization measures are primarily composed of a lightweight steel frame used to prevent the overturning of the adobe walls, which are largely freestanding. Viscous dampers were used to reduce the size of the steel members in the exterior steel.

Introduction

The nature of a seismic retrofit system for a historic adobe building will depend on the goals of the project, financial flexibility, and the characteristics of the specific historic adobe building. The five projects presented in this paper provide a brief overview of the range of retrofit options that are available and that were tested during the research phase of GSAP. This multiyear project, conducted by the GCI, sought to develop structurally effective, minimally invasive seismic retrofitting strategies for historic adobe buildings. This project and its outcomes were described in three publications (Tolles et al. 1996 and 2000; Tolles, Kimbro, and Ginell 2002).

The first mode of failure common to adobe buildings is the overturning of the walls. Therefore, the first step in each of these retrofits was to attach the adobe walls at the roof and floor levels. The details of these connections are very important because the forces that may be imparted to these connections may be large. Therefore, the durability of these connections is critical.

The second step is the addition of vertical straps or center cores to individual walls, which can add significant stability to adobe walls. The walls may suffer significant cracking, but the restraint provided by the straps or center cores can prevent progressive types of failure. In addition, straps or center cores can prevent the out-of-plane failure of thinner walls between the support points at the floors and/or between the floor and the roof. Finally, center cores can increase the strength and ductility of a wall in both the out-of-plane and the in-plane directions.

Castro-Breen Adobe

The Castro Breen Adobe is currently owned and administered by the California Department of Parks and Recreation as part of the San Juan State Historic Monument. Mission San Juan Bautista is included in this complex. The adobe was commissioned by General Jose Maria Castro and was constructed between 1840 and 1841. The ownership of the house was passed to the Breen family in 1848: hence the name, the Castro-Breen Adobe.

The Castro-Breen Adobe is a two-story adobe building with multiple rooms and interior adobe walls on each floor. The exterior walls on the first floor are 33 in. (0.84 m) thick. The interior walls and the exterior walls on the second floor are 22 in. (0.56 m) thick, except for the gable-end walls, which are 33 in. (0.84 m) thick to the roofline. The walls are 10 ft. (3.05 m) high from the ground to the second-floor level and approximately 9 ft. (2.74 m) high from the second floor to the tops of the walls. Therefore, the slenderness (S_L = height-to-thickness ratio) of the first- and second-floor walls is only 3.6 and 4.9, respectively.

Retrofit of the Castro-Breen Adobe

The principal restraint for the retrofit system on the Castro-Breen Adobe was the tile roof, which is fragile and historically significant. Therefore, it was desirable to remove only portions of the roof as necessary for the installation of center core rods. Fortunately, the ceiling above the second-floor level is approximately 1.5 ft. (0.46 m) below the tops of the adobe walls. A partial plywood diaphragm was constructed to provide out-of-plane restraint at the tops of the adobe walls.

Anchorage was also supplied along the lengths of the long walls at the second-floor level. Anchors were placed below the floor level, and because the walls step nearly 1 ft. (0.30 m) at the second-floor level, it was possible to hide these anchors from view. The gable-end wall is the portion of the building most susceptible to significant earthquake damage (fig. 1). The original north gable-end wall is now enclosed by a wood-framed addition and does not pose the same problem as the south wall, because of the restraints provided by the floor, ceiling, and roof system.

The south gable-end wall was anchored to the roofline, and the tile roof was removed from the edge of the roof back 10 ft. (3.05 m) to provide room to reinforce the roof sheathing with plywood. Center core rods were placed in the wall from the tops of the walls to the ground level and anchored with a nonshrink, standard, commercially available nonmetallic cementitious grout. The average height of the wall was nearly 21 ft. (6.40 m), and the full height of the wall has a slenderness ratio of less than 7.6. A partial plywood diaphragm was installed and anchored to a horizontal steel rod. The locations of the elements of the retrofit system are shown in figure 2.

Casa de la Torre

Casa de la Torre was built in 1852 as a one-and-one-half-story building. Originally the adobe consisted of three rooms and an entrance hall. The building was modified in the early 1900s by removal of most of the second-floor framing and the addition of a large window in the north gable-end wall, as shown in figure 3. The adobe walls are 24 in. (0.61 m) thick and approximately 14 ft. (4.27 m) high to the plate line on the long east and west walls. The slenderness ratio is approximately 7 for the long walls and 8 for the gable-end walls. There are wood-framed rooms on both the south and west sides of the building. The kitchen at the northwest corner of the building was constructed with 12 in. (0.30 m) thick adobe walls, and the height of the walls ranged from 9 ft. (2.7 m) down to 7 ft. (2.13 m).

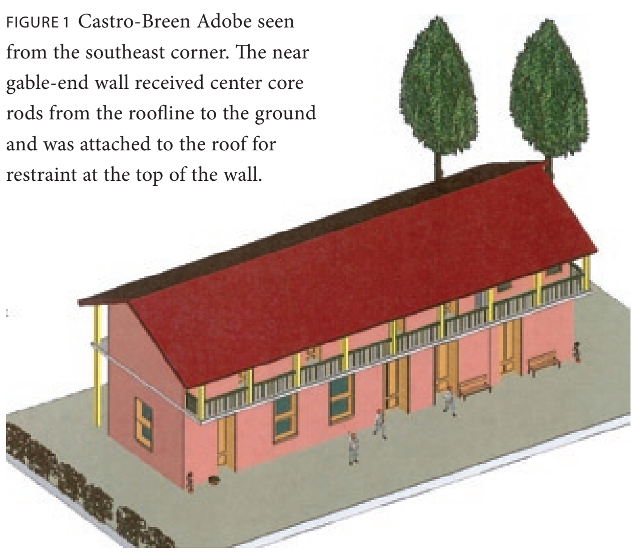

FIGURE 1 Castro-Breen Adobe seen from the southeast corner. The near gable-end wall received center core rods from the roofline to the ground and was attached to the roof for restraint at the top of the wall.

FIGURE 2 Selective use of full-height center core rods shown at the near gable-end wall, in the retrofit of the Castro-Breen Adobe. A partial plywood diaphragm with a horizontal exterior rod is used just below the roofline.

Retrofit of Casa de la Torre

All adobe walls were anchored to the roof system at the tops of the walls. No additional measures were used for the south and west walls of the large central room, since these walls are braced by a lower roof and by perpendicular walls.

Center core rods were installed into the north and east walls and anchored to the plywood roof diaphragm. The 0.75 in. (0.02 m) diameter center core rods were epoxy-coated steel reinforcing bars that were threaded on one end. The rods were placed in 2 in. (0.05 m) diameter holes that were then filled with a nonshrink cementitious grout. The north gable-end wall was already susceptible to collapse during strong ground motions, and the addition of the large window in this wall made it even more susceptible to severe damage or collapse. The long east wall is attached to the porch roof, but there are no transverse walls to provide additional lateral support. Therefore, full-height center core rods were also installed in the east wall.

Small Adobe at Rancho Camulos

The Small Adobe at Rancho Camulos was built in 1920, more recently than the other adobe buildings described in this paper. It is a one-story building with relatively thin adobe walls and many large openings throughout (fig. 4).

The roof is flat, and there is an interior open courtyard in the center of the building. The courtyard is formed by a wood-framed addition in the south-central area of the building which was added at some uncertain date prior to 1950.

FIGURE 3 Casa de la Torre seen from the northeast corner. The retrofit included anchoring the adobe walls into the upper roof on all sides of the building; center core rods were also placed in the two walls that are visible.

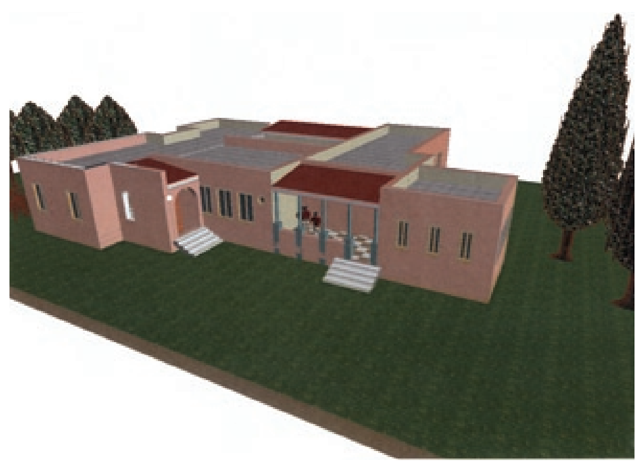

FIGURE 4 Small Adobe at Rancho Camulos seen from the northwest corner. The walls were retrofitted with center core rods throughout, because of the thinness of the walls and the large number of openings.

FIGURES 5A AND 5B Small Adobe at Rancho Camulos, which suffered severe damage during the 1994 Northridge earthquake. Shown here are the collapsed walls at the southwest corner (a) and the southeast corner (b) of the building.

(a)

(b)

Retrofit of the Small Adobe at Rancho Camulos

The Small Adobe suffered severe damage from the 1994 Northridge earthquake. The south walls of two of the rooms along the south side of the building collapsed (figs. 5a and 5b). Other walls were damaged so severely that they needed reconstruction.

The principal stability issues for this building are relatively thin walls (S_L = 8) and numerous doors and windows. To compensate for these features, which are not typical of historic adobe construction, center core rods were placed in all the walls. The rods are 0.75 in. (0.02 m) in diameter and were placed in 2 in. (0.05 m) diameter holes that were then filled with a nonshrink cementitious grout. The center core rods are placed at a maximum of 6 ft. (1.8 m) on center. In addition to the center core rods, there are anchors that connect the center core to the roof at 2 ft. (0.61 m) intervals.

Main Residence at Rancho Camulos

The Main Residence at Rancho Camulos was constructed starting in the 1840s and was completed in the 1860s. The original house has two stories. Its exterior walls are 24 in. (0.6 m) thick, and interior walls are 12 in. (0.3 m) thick. The first-floor story height is 11 ft. (3.35 m). The additions to the main residence are all one story and extend to the west and north of the main residence. As in the original construction, the exterior walls of the additions are 24 in. (0.6 m) in thickness, and the interior walls are 12 in. (0.3 m) thick. The walls in the additions are 9.5 ft. (2.9 m) in height. The building is shown in figure 6.

The Main Residence at Rancho Camulos also suffered serious damage during the 1994 Northridge earthquake, as shown in figures 7a and 7b. There was crack damage to many of the walls throughout the building. The walls of the bedrooms in the southeast and southwest corners of the building collapsed and required reconstruction.

FIGURE 6 The Main Residence at Rancho Camulos seen from the southeast corner.

(a)

(b)

FIGURES 7A AND 7B Severe earthquake damage to the Main Residence at Rancho Camulos. Collapse of the walls occurred in the southwest corner (a) and the southeast corner (b) of the building.

Retrofit of the Main Residence at Rancho Camulos

The retrofit of the Main Residence used a variety of retrofit techniques. The roof system was tied into the roof diaphragm with top-of-wall anchors attached with epoxy grout. The more severely damaged walls were reinforced with vertical straps on both sides of the walls. A perimeter cabling system was used throughout the building to provide longitudinal continuity to the walls. The second-floor framing was attached to the cabling system through the adobe walls. Finally, the walls that had collapsed were reconstructed with new adobe bricks and were reinforced with horizontal ladder ties in the mortar joint of every fourth course, and with vertical center core rods in 2 in. (0.05 m) diameter holes spaced at approximately 26 in. (0.66 m) on center; they were anchored in epoxy grout.

Las Cruces Adobe

The Las Cruces Adobe was constructed in the 1840s and has been unoccupied since the early 1900s. A shelter was built over the site in the 1970s to protect the fragile ruins (fig. 8). The walls (fig. 9) and roof framing are both in poor condition. What remains of the building is original and indicative of the type of construction characteristic of that period.

Stabilization of the Las Cruces Adobe

The goal of the retrofit was to have as minimal an impact as possible on the original building but to stabilize the ruins so that the public could access the building safely. To achieve these goals, a lightweight steel frame was designed to provide overturning stability to the walls. To increase the effectiveness of the steel frame, viscous dampers were added which allowed the steel frame to be even lighter than the original design. By increasing the damping of

FIGURE 8 Las Cruces Adobe covered by a wood shelter that protects the ruins. Photo: Gail Ostergren.

FIGURE 9 An interior wall of Las Cruces Adobe, representative of the general condition of the building. Photo: Gail Ostergren.

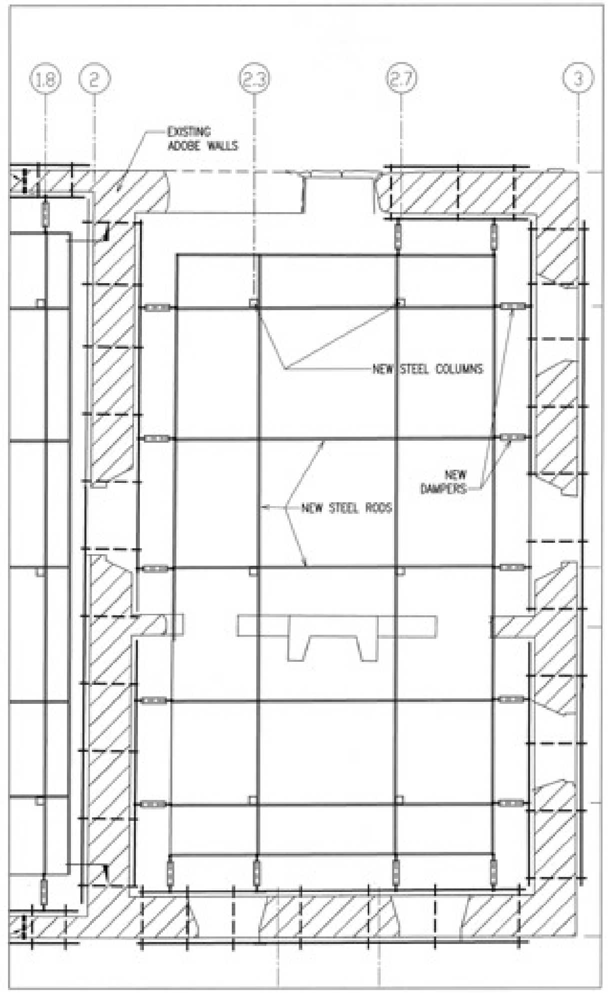

FIGURE 10 Lightweight steel frame designed for Las Cruces Adobe.

the support frame, the viscous dampers would also significantly decrease the displacements that might occur in larger seismic events. The framing system is shown in figure 10. The steel columns were 3.5 in. (0.089 m) square tubes, and the horizontal steel rods were 1 × 2 in. (0.025 × 0.05 m).

The GSAP began with a vision to develop innovative methods for retrofitting historic adobe buildings. The vision was based upon the author's doctoral research work at Stanford University (Tolles 1989). This early research demonstrated that minor interventions could have a major impact on the seismic stability of thick-walled adobe buildings.

The examples of the successful design and implementation of the methods developed during the multiyear GSAP research effort presented in this paper demonstrate that these methodologies can be effectively implemented in the field. Building officials throughout California have approved these techniques. The governing building code for historic adobe buildings in the state of California is the California Historical Building Code, which has reduced seismic force levels and recognizes the use of identified "archaic" materials such as adobe.

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