Evolving methodology in seismic retrofit: stabilizing the Las Flores Adobe

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INTRODUCTION

The Las Flores Adobe, a National Historic Landmark, is located between two major fault lines aligned with the coast of Southern California, USA and is classified in seismic zone 4. It is in one of the most active tectonic fault zones in the world.

Figure 1
In this 1913 image, painted by E.S. Fenyes, the ranch house and outbuildings at Las Flores are depicted as they appeared before a 1916 flood and subsequent remodeling project. In this image, the Monterey block is the two-story section appearing on the right; the Hacienda block is the long, low section connecting the Monterey block on the right and the carriage house on the left. Of the many buildings in this image, only the ranch house and carriage house survive.

Built in 1868, the Las Flores complex includes a formal two-story Monterey block, a long, low Hacienda block with rooms opening onto a *portal*, and an attached carriage house. The Las Flores site is one of a few authentic nineteenth-century adobe ranch houses combining the Hacienda and the Monterey styles, which are unique to California. The United States Marine Corps, the National Park Service, the Graduate Program in Historic Preservation at the

University of Vermont and private sector architectural and engineering professionals have partnered in planning, design, and stabilization of the building complex.

Seismic stabilization has focused on implementing techniques advanced by the Getty Seismic Adobe Project (GSAP), which impart stability to adobe walls while preserving the historic fabric and structural system. The interventions also comply with performance standards for structural design as outlined in the Uniform Code for Building Conservation, particularly with respect to lateral design of unreinforced masonry buildings, and the California Historic Building Code.

Prior to GSAP research, retrofit technology routinely applied in similar cases involved installation of invasive concrete post-and-beam and bond beam assemblies, requiring major demolition of historic fabric. At Las Flores, the team has installed minimally invasive systems utilizing rods, steel strapping, grouted pins, and plywood sheer panels. The carriage house work required that a pre-existing concrete bond beam be incorporated into the retrofit design and presented the team with an opportunity to use earthen grouts as a more compatible material substitute for the epoxies used on the main house project. This case study represents one of several where this type of technology has recently been field-implemented.

HISTORICAL BACKGROUND

The Las Flores Adobe Ranch House is a 557 m2 two-story adobe building and once was part of an over 52,600-hectare ranch. It was taken over by the federal government in 1941 for use as a US Marine Military Training Base during World War II. It continues to be under the jurisdiction of the Marine Corps.

The site is representative of settlement patterns throughout most of California history, contained in one compact and largely undisturbed microenvironment. Archaeological and historical records at the Las Flores site indicate nearly 2000 years of occupation by Native Americans. In the eighteenth century, the first European colonization of California followed the spread of Franciscan missions throughout the region, and in 1798 Las Flores was established under nearby Mission San Luis Rey.

In 1834, the mission system was secularized after Mexico gained its independence from Spain and Las Flores was made a free pueblo. Borders with the United States were opened under Mexican control and trade practices liberalized, followed by the proliferation of *rancho* culture. Las Flores was purchased from the natives in 1844 and it became part of the larger Santa Margarita Ranch. California came under US sovereignty in 1848. In 1868 the property owner constructed the adobe house at the Las Flores site for his son as a wedding gift. Following the collapse of the *rancho* economy, the site was farmed by a single family for several decades before being acquired by the Marine Corps. The military presence has not negatively impacted the site, and in contrast to the surrounding communities where development has obliterated any historical context of the landscape, this property is unique.

The ranch house embodies the joining of Hacienda and Monterey architectural styles. The house is fronted by an elegant two-story Monterey block, with a full length two-story porch facing the Pacific Ocean. The ground level of the house is built of 61 cm thick adobe walls; wall thickness at the second level is reduced to 46 cm. Adjoining the Monterey block on the north side, the utilitarian Hacienda section is a long, one-story wing, one room deep in plan, with doors opening onto a covered *portal* (porch). At the south end, the *portal* connects to a large hallway running through the center of the Monterey block. The Hacienda block terminates at the carriage house which is oriented parallel to the Monterey block, so that the complex forms a large "U" around a central courtyard (which is a feature of the Hacienda style). Over the years many changes have been made to the buildings to accommodate new occupants and uses.

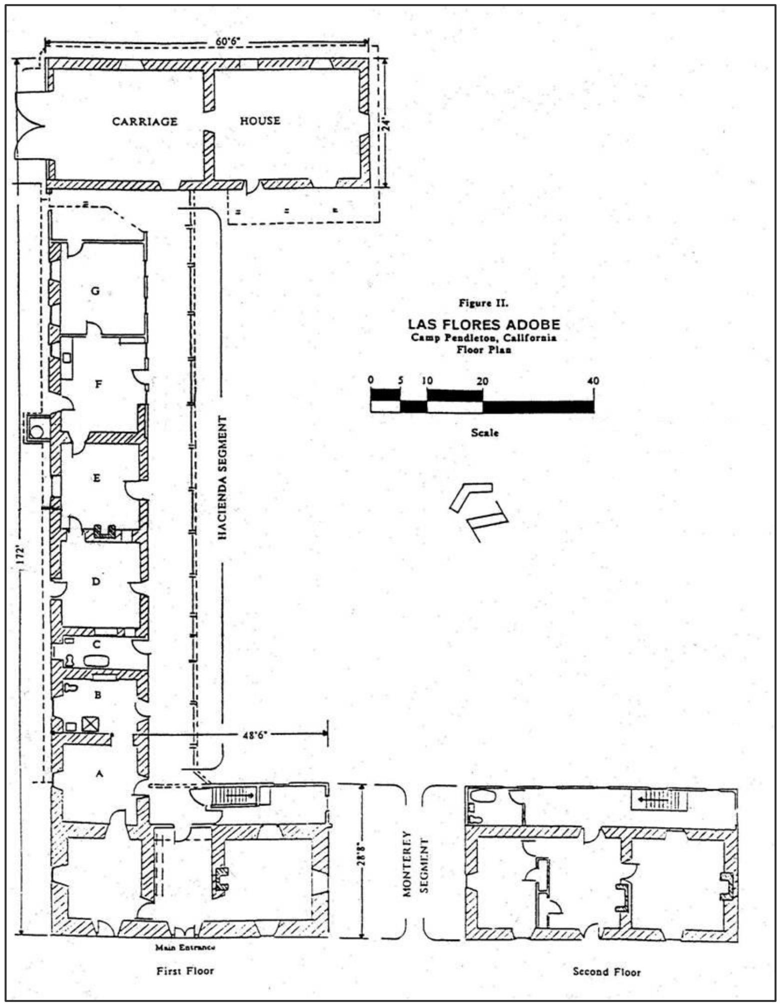

Figure 2
The buildings enclose three sides of a courtyard. Historically, fences and hedges on the east completed the enclosure.

By 1968, the ranch house and surrounding buildings were in an advanced state of disrepair. Public intervention saved the house and carriage house and had them placed on the National Register of Historic Places and proclaimed a National Landmark which is the highest designation for a historic property in the United States. In 1999, the military initiated a program to stabilize the house using a multi-disciplinary team involving themselves, the National Park Service, a consulting historical architect, and an engineer specialized in seismic and adobe preservation. At certain key points in planning, the California State Historic Preservation Officer was included in the review of program and design since ultimately the State has jurisdiction over the historic designation. In 2002 the NPS invited the Graduate Program in Historic Preservation at the University of Vermont to participate in the program.

PROJECT PLANNING, DESIGN, IMPLEMENTATION

Project goals were to reverse deterioration, ensure seismic and structural stabilization, accomplish limited restoration related to stabilization, and planning for future rehabilitation. Project work began with a condition survey focused on the main house in 2000-2001, which led directly to stabilization work in 2002 and 2003. During the 2003 season, a similar survey was conducted on the carriage house, which led to stabilization in 2004. The adobe walls of the ranch house were found to be generally sound with some localized cracking. The two-story porch on the Monterey block had been removed in the 1980s for safety reasons, leaving exterior adobe walls exposed to the weather and resulting in large sections of lime plaster losses. The second-story roof frame did not meet code and shingles throughout the entire complex were at the end of their useful life.

Roof frames on all of the buildings lacked substantial connections to the adobe walls. Floor frames on the ground level were set on grade and completely deteriorated. Second-floor joists were set into pockets in adobe walls without connection. Evidence of termite and fungal deterioration of wood was seen throughout the structure. Windows and doors were severely damaged or missing entirely as the result of vandalism, fungal decay, and termite infestation. Clear sheets of Plexiglas were placed over openings to secure the structure, resulting in reduced ventilation throughout the buildings. Infestations by burrowing animals and bees went unchecked, and bee hives entirely filled many of the stud bays of the north porch enclosure. The electrical service, un-improved after many decades of use, was a fire hazard.

The carriage house was extensively renovated in 1974. Installation of a concrete bond beam resulted in changes in elevation and roof construction, and consequent loss of the connection between the carriage house and the main house. A large section of the south wall of the carriage house, near the juncture of the two buildings, had collapsed from water damage and was repaired with a large concrete infill. The building was plastered inside and out with hard, cementitious stucco. At the same time, a concrete *contra pared* was poured around the base of the exterior walls.

The team established design criteria and performance expectations. The main objective of the stabilization was to preserve the National Landmark values inherent in the architecture. Restoration would be limited to elements essential to meet preservation and stabilization goals. Because many construction details were hidden from view, a flexible design process was adopted so that treatments might evolve in response to hidden conditions. The team elected to interpret a relatively long period of the buildings' history in order to preserve fabric from time periods associated with *rancho* culture and agricultural use of the property. The government's 1941 takeover of Las Flores changed the end use of the property, and removed maintenance incentives and proprietary interests from the occupants. This resulted in very expedient and negative alterations, and so marks the end of the period of significance.

The building code applicable to this project is the California Historical Building Code (CHBC). This code applies to all designated historic properties in California and serves as an amending document to the regular California Building Code (CBC). The CHBC is a performance-based code whose intent is to achieve the life-safety objectives of the CBC while allowing greater flexibility in the methods for achieving those objectives. In this way, it encourages the preservation of historic materials and features of the historic property. For the Las Flores project, the CHBC was applied to egress issues, as well as to vertical and horizontal loadings of structural elements.

With respect to the seismic retrofit, the team selected a minimal intervention among a range of options, balancing the life-safety requirement against the preservation objective to impact the integrity of the structural components in the smallest way possible. The seismic objective was to ensure the life safety of building occupants by preventing collapse, while recognizing that repairable damage to the building will occur. Since the adobe walls have slenderness ratios of ≤5, they would require minimal lateral restraint in order to prevent overturning.

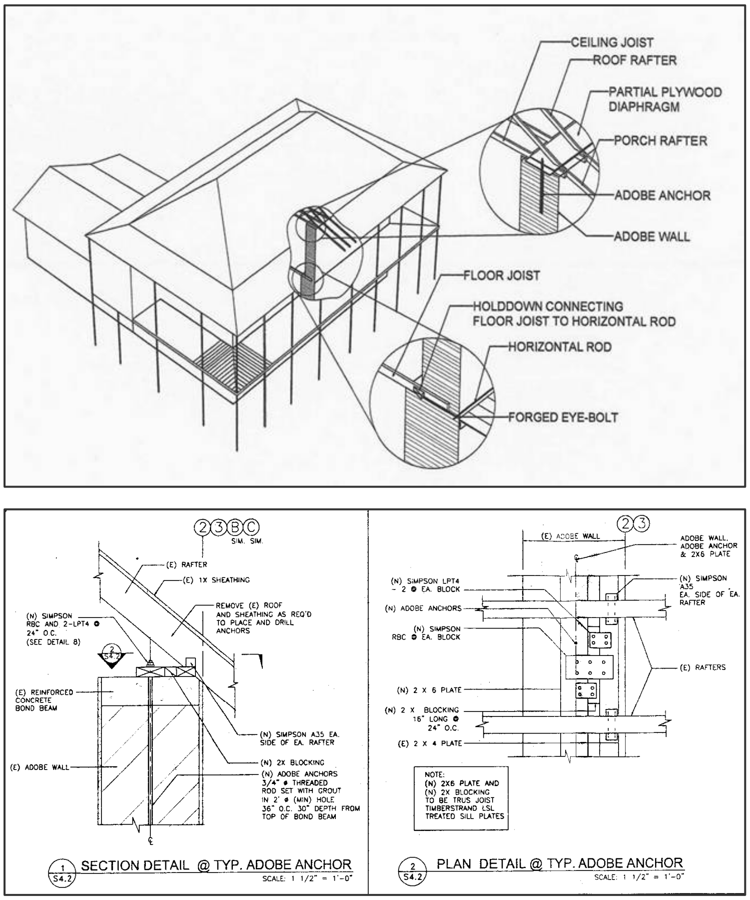

Figure 3
Retrofit design was focused on providing lateral restraint at the tops of walls and at the level of the second-floor frame in the Monterey block.

The initial design plan and second stage carriage house design were worked out on site by the team. These on-site design meetings focused primarily on seismic retrofit concepts coupled with architectural considerations and related stabilization issues. The GSAP guidelines were followed for development of the retrofit designs. The scope of work included replacement of the roof covering, allowing for access to the adobe walls from the top. To achieve lateral restraint of the walls, threaded rods (76 cm long x 1.90 cm diameter) would be grouted into the adobe walls at approximate 80 cm intervals on center. These interventions as planned could be installed without changing the visual aspects of existing walls and roof timber. Stainless steel containing molybdenum for increased corrosion resistance to chlorides and sulfides was prescribed for all rods, nuts, and straps. All nails and other fastenings would be stainless steel or galvanized.

During the 2002 and 2003 seasons, the work was focused on the house. The seismic retrofit consisted of the addition of a wooden bond beam to the tops of the adobe walls, installation of center core pins, attachment of the roof frames to the tops of walls, and installation of a steel band around the exterior of the Monterey block at the level of the second-floor frame.

Where the tops of the adobe walls were uneven and out-of-level, the walls were capped with soil cement applied in pise technique. The plywood bond beam functions as a partial diaphragm and consists of two overlapping layers of pressure treated material glued and nailed to provide longitudinal strength. Once the bond beam was placed, holes 2.5 cm in diameter were drilled down through the plywood and adobe wall center to a design depth of 80+ cm to receive the threaded rod. Center core pins were set into the adobe with an epoxy grout. The epoxy selected for the project was a proprietary high-viscosity epoxy which is designed for stabilizing anchors into unreinforced masonry. Stainless steel strapping was nailed at 10 cm intervals on center along the top of the plywood, and each rafter was fastened to the plywood with a nailed on Simpson “L” tie. Every other bolt was torque tested to at least 27 kg force to ensure good binding and grab in the section. This process proceeded linearly around the building until the interconnected strapping system was complete on both the one- and two-story sections.

Figure 4
The tops of the walls were leveled by adding a pise course. The wooden bond beam incorporated a stainless steel strap and was fastened to the walls using center core pins and to the roof frame using commercially-available metal clips (left). At the level of the second-floor frame of the Monterey block, a stainless steel belt was installed below exterior plaster and tied back to floor joists using eyebolts and Simpson anchor brackets (right).

The steel belt installed at the second floor level attaches the floor system to the perimeter walls. A 1.5 cm channel was cut though the existing lime plaster and adobe on the walls just above the level of the second floor porch deck. Simpson HD 5A brackets were fastened to every other interior joist behind the interior surface of the wall. A threaded eyebolt was fastened into the Simpson tie with the eye set in the channel on the exterior. A 1.27 cm threaded rod was inserted into the eye, which wrapped around the entire house and fastened at the four corners to an “L” flange. On the east and west end walls in line with parallel running joists, stabilization required longer rod connectors drilled through two perpendicular joists, bolted with nuts and washers, and extending through the adobe wall to tie to the belting rod. This type of belted anchorage will contribute ductility to the walls. The anchoring capacity no longer depends on the strength of the adobe; rather it serves to restrain the adobe wall. It is highly unlikely that the rod could be pulled through the wall, and only localized crushing of the adobe is anticipated in a seismic event.

The decision was made to reconstruct the lost two-story porch to better protect adobe walls, integrate seismic interventions, and recover the lost architecture. This porch, which completely surrounds the Monterey section, was well documented. The structural design of the porch incorporated through-wall fastening to interior floor joists, new upgraded footings, custom column stands, and wind uplift retention. By installing the connecting elements in the substrate, the installation was designed to be mostly hidden.

During the 2004 construction season at Las Flores, the team implemented the seismic and structural stabilization of the carriage house; the work represented a departure from several aspects of the main house intervention. Work accomplished during the 2002 campaign was evaluated and changes in tool use, method, and materials were adopted. The scope of work included installation of a seismic retrofit system, replacement of concrete wall infill with adobe materials, reinstatement of the connection between the ranch house and carriage house, conservation of earthen and lime plasters and finishes, and replacement of the roof covering.

Figure 5
The crew used a resin-based grout for installing center core pins in the ranch house retrofit (left). For the carriage house retrofit, techniques were developed for installing an earthen grout (right). The earthen grout is more compatible with the historic wall materials and provides greater possibilities for reversibility of the treatment.

Since a concrete bond beam without documentation had been added to the carriage house in a 1970s repair project, the retrofit needed to guarantee attachment of the bond beam to the walls and of the roof frame to the bond beam. Removal of this bond beam was determined to be potentially damaging to historic fabric and unnecessary. The large section of concrete infill was determined to be detrimental to the structure since material and structural continuity was broken and traditional lime plasters would not adhere well to the surface. Adobe repairs were installed to replace the concrete infill; new work was integrated into the wall by stepping and lacing new adobe into the old.

Following the main house intervention essentially, the seismic retrofit system consisted of a series of center core anchors that pass vertically through a continuous wooden plate, through the bond beam, and into the adobe wall below. A series of holes were bored using light coring bits; holes were bored through the concrete bond beam and into the adobe using non-vibratory drilling equipment.

Rods were fixed in place using a soil-cement grout. This marked a major change in design, and represents a desire for greater compatibility and reversibility of treatments. The main house retrofit system relied on a resin-based grout with strength characteristics in excess of design criteria. Earthen grouts are compatible with historic adobe materials and offer greater potential for reversibility and thus were chosen for the carriage house. The grout mix selected was similar to one developed and tested for use in the repair of the historic Pio Pico Adobe in Whittier, California, and consisted of adobe soil, sand, a small amount of Portland cement, and a grout additive (SikaFlex II) to minimize shrinking during curing.

Low-tech methods were developed for placing the grout. An adobe test wall was constructed and placement methods were developed and practiced until placement could be effected smoothly, yielding a consistent result. A placement device was made by attaching a grout bag to a length of plastic pipe. The pipe allowed placement to begin at the bottom of the holes, preventing voids due to trapped air bubbles. The method for placement involved filling the device with grout and twisting off the bag to prevent loss of material when transferring the grout to the hole to be filled.

Figure 6
By the close of the 2004 construction season, structural and seismic stabilization of the buildings was complete, porches on the Monterey block were reinstated, building envelopes were secured against weather, and interior rehabilitation was started.

Holes were minimally pre-wetted with a 1:1 mix of denatured alcohol and water to retard absorption of the mix water by the wall materials. Grout was placed in a pre-wetted hole by squeezing the grout bag and simultaneously withdrawing the pipe from the hole. Once the hole was filled to within two inches of the top, the threaded anchor was inserted.

A new wooden plate was installed around the building perimeter on top of the concrete bond beam, fastened to the threaded anchors with stainless steel nuts and washers. Using commercially available "L" clips, the existing roof structure was fastened to the new wooden plate, effectively tying the roof structure to the walls. Because the west wall of the carriage house is of wood-frame construction, a bond beam had never been installed along this wall. To tie the north and south bond beams together, the crew installed a steel tie rod in the wall cavity; the rod is fastened to commercially available clips anchored to the ends of the bond beam at the northwest and southwest corners of the building. Interior plaster was removed and this wall was re-sheathed in plywood.

CONCLUSIONS

Key to the success of the Las Flores project, measured by limited alteration to the historic character-defining features of the house, was the multidisciplinary planning/design process and the flexibility built into the construction phase by retaining architectural and engineering services throughout. This prevented a break in linkage between disciplines that often occurs in large construction campaigns. Management participation ensured that project goals and resource allocation stayed viable throughout. Bringing the University of Vermont into the process offered capacity building, training, and research opportunities. The design solutions represent a minimal and efficient treatment approach achieving the basic goals while accomplishing resource preservation agendas simultaneously.

Documentation and maintenance by site stewards will ensure that a post-seismic event review occurs that will fully evaluate the levels of efficacy achieved. The true test is during and after the event, which cannot be presupposed or fully anticipated until it happens.

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