Stabilization of the landmark Las Flores adobe: a case study of restrained seismic retrofit

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**ABSTRACT:** The National Landmark Rancho Las Flores, built in 1868, was recently stabilized. Located in Southern California of the United States in an active seismic area, Las Flores is one of a few authentic nineteenth-century, two-story, adobe ranch houses combining the Hacienda and the Monterey style, which are unique to California. Lime plaster covers the exterior, and earthen plaster covers the interior of the adobe building. Both surfaces have traditional lime-wash finishes. The primary objective of this project is seismic stabilization using techniques recently advanced in the United States, which provide strengthening while preserving historic fabric. Many adobe buildings have been lost due to the impression that they are structurally unsuitable for contemporary use. Final restoration of the structure will be initiated when planning, research, and consultation concludes. The ultimate goal of this stabilization project is to ensure that architectural integrity is preserved while structural components are adequately strengthened.

**1 INTRODUCTION**

Situated several kilometers east of a major fault running along the coastline of Southern California, the Las Flores Adobe Ranch House underwent a stabilization effort to ensure its longevity in a rapidly developing environment. The 557 m², two-story adobe has not been actively used since the last resident departed in the 1960s. The property – once part of an over 52,600-hectare ranch – was taken over by the federal government in 1942 for use as a military base during World War II for the United States Marine Corps. By 1968, the building was threatened with demolition due to its poor condition. Local citizens launched a campaign to save the building. Deterioration continued unabated because minimal resources were available. Increasing recognition of the values and the deteriorating conditions precipitated the Marine Corps placing the property on the most endangered structures list. When funds finally became available, the Corps engaged the National Park Service (NPS) to assist with a stabilization and restoration effort. The NPS is the leading American agency in the field of historic preservation. The structural stabilization of the main house was concluded in 2004.

**2 HISTORY AND SIGNIFICANCE**

Archaeological and historical record at Las Flores indicates nearly 2000 years of occupation by Native American tribes in the vicinity of the ranch house. The first European colonization of California followed Franciscan missionaries in the eighteenth century, and in 1798, Las Flores was established under Mission San Luis Rey. The site, nearby ruins, ranch house, and the remaining open landscape surrounding the complex offer a microcosm of California history together in one compact and largely undisturbed microenvironment. The military presence has not negatively impacted the site; and in contrast to the surrounding communities where development obliterated any historical context of the landscape, this property is unique.

In 1834, the mission system was secularized after Mexico became independent of Spain and Las Flores was made a free pueblo. The Pico family, who owned the adjacent Santa Margarita ranch, bought Las Flores from the natives in 1844. Pio Pico went on to become the last Mexican Governor of California. The frontier, a closed border under Spanish dominion, was opened under Mexican control allowing trade, commerce, and travel to and from the United States. An influx of
American and British settlers began to influence the culture and the Mexican War of 1846–48 resulted in the transfer of sovereignty of California to the United States. During these tumultuous years, the ranch remained an intact land grant known as Rancho Santa Margarita Y Las Flores. The latter part of the nineteenth century saw the shift away from old-style ranching with large cattle herds and the Spanish padrone lifestyle to smaller farming operations and fenced properties. By 1868, Pico’s heir, John Forster constructed an adobe house at the Las Flores site for his son as a wedding gift.

The ranch house embodies the joining of Hacienda and Monterrey architectural styles. The Hacienda section is a one-story segment with rooms arranged in a row and doors opening to a covered portal (porch) and courtyard. This part, for mostly utilitarian uses, ends in the more elegant two-story, Monterrey section, with a second-level porch facing the Pacific Ocean. The ground level of the house is built of 61 cm thick adobe walls and the second level is of 46 cm. With the carriage house at the north end, the complex forms a large “U” around a courtyard. A large hallway runs through the center of the Monterrey opening onto the portal of the Hacienda wing. Over the years, changes have been made for occupant convenience.

In 1888, 20 years after construction, the property passed out of the Pico/Forster family to new owners who in turn engaged the Magee family to live at and manage Las Flores. The Magees transitioned the cattle ranch operation into a large lima bean farm, which they maintained from the early 1900s until mid-century. In 1941, the Santa Margarita Ranch was absorbed into the new Camp Pendleton Marine Corps Base. The Magees were given lifetime occupancy and continued at the ranch until the last family member died in 1968, at which time the Marine Corps assumed management of the property (Wee, 1991).

By 1968, the ranch house and surrounding buildings were in an advanced state of disrepair. Demolition of many of the farm structures occurred when the viability of farming declined. Public intervention saved the house and had it placed on the National Register of Historic Places and proclaimed a National Landmark. The Marine Corps, seeking a tenant to help maintain the property, leased it to the Boy Scouts of America (BSA) in 1974. The BSA was unable to arrest the deterioration and by the 1990s, it was in unsafe condition. The house was boarded up and closed for safety reasons. The presence of a BSA camp manager living on site provided a level of surveillance.

In 1999, the Marine Corps contacted the NPS for the purpose of preserving the ranch house. A series of planning meetings were held from which emerged a multi-disciplinary team consisting of a Corps representative, a historic architect, an engineer with a specialty in seismic and adobe, and an architectural conservator. At certain key points in planning, the California State Historic Preservation Officer was included in the review of program and design.

3 PROJECT OBJECTIVES

The initial project goals were to reverse the deterioration, stabilize the structure, seismically retrofit, accomplish limited restoration related to stabilization, and continue planning future actions, including a Historic Structure Report (HSR), to guide the ultimate restoration of the ranch house. Once the structure could be stabilized and strengthened, limited public access, interpretation, and multipurpose use were envisioned. Work would occur in phases, with Phase 1 being the structural and architectural stabilization and Phase 2 being the selected restoration, adaptive restorations, and installation of building systems. Carriage House stabilization was postponed for future resource allocation.

4 PRESTABILIZATION CONDITIONS

Research, documentation, and surveying began in 2001, which led to an understanding and analysis of issues affecting the integrity and safety of the structure. The adobe walls were generally in good condition, but the loss of the two-story porch (removed in the 1980s for safety reasons) exposed the walls to the weather. Sections of lime plaster on the exterior were lost due to this exposure. Major and minor cracks in the walls were evident. The wood-framed, second-story roof did not meet code. Both the two-story and one-story roofs had no connections to the adobe walls. Nonhistoric, asphalt roof shingles were leaking at various locations. Second-floor joists were set into pockets.
in adobe walls without connection. The first-floor, wood-floor substrate, originally set on grade, was completely deteriorated. Evidence of termite and fungal deterioration of wood was seen throughout the structure. Windows and doors ranged in deterioration from totally missing to parts missing or local damage. Clear sheets of plexiglass were placed over openings to close up the structure. Burrowing animals created a habitat under flooring sections by entering through the porous, rubble-stone foundation. House fumigation treatments killed some of these animals resulting in extremely pungent odors trapped in the airless structure. Rodent feces in attic spaces created a hazardous environment. Live electrical wiring crossing through the house was a fire hazard (Mortier, 2001).

These and other less severe conditions quantified and qualified the problems and provided impetus for management to take remedial action.

5 DESIGN AND CONSERVATION APPROACH

The team established design criteria and performance expectations. Because a specific end use was not finally designated, a limited and restrained preservation agenda was adopted. The main objective of the stabilization was to preserve the building and all the values inherent in the structure that reflected the National Landmark nomination, including the significant subsequent history of the building. Restoration would be limited to elements essential to meet preservation and stabilization goals. No mechanical or electrical systems or interior finish restoration would be planned without the full evaluation of the HSR, which was designed to sort the entire architectural historical context and incorporate end-use requirements.

Planning meetings that included the California State Historic Preservation Officer directed the interpretive period for the ranch house to reflect the broader context of history spanning all periods up to 1941, rather than to pick one specific period of time. The government’s 1941 takeover of Las Flores effectively changed the end use of the property, and removed maintenance incentives and proprietary interests from the occupants, resulting in very expedient and negative alterations. The building evolved over the 73 years and, within that evolution, all of the history was present and of high integrity.

Recognized impacting factors included: the location within seismic zone 4; the highly corrosive environment next to the coast; the dry climate; the inherent difficulty of the military to focus on historic preservation; and the relative remoteness of the site from water and utility infrastructure.

In addition to seismic agendas, fire danger was also addressed. Las Flores has only one stairway for second floor access and egress. By reducing the allowable number of people on the second floor to 10 and planning for the installation of a sprinkler system, life-safety considerations could be met without major alterations. The reduction in live loading on the second floor precluded the potential need to supplement these structural deficiencies.

Because the substructure of the first floor was hidden from view, it could be restructured to meet higher use needs. The criteria for the first floor would be to design for 292 kg/m² loading, consistent with light public use, such as a house museum. Plans to lower ground levels to prohibit wood contact with soil would necessitate archaeological monitoring during any excavation. These subfloor areas were tested and reported on before the current program due to the prehistoric Native American context.

The three chimneys on the building would be stabilized by inserting reinforcing inside the chimney section. The Marine Corps decided that, due to fire-safety issues, these chimneys would not be put into service.

During the course of the planning phase, two South African architectural interns from the United States National Committee of the International Council on Monuments and Sites’ summer training program field measured the building as part of a Historic American Buildings Survey. These drawings were used to develop project plans. Photographic and written documentation of before, during, and after work would be maintained.

The first phase of the project was divided into two parts with the first being all structural work, roofing, and reconstruction of the porch. The window and door restoration project would be accomplished as a training component and completed in the following year, 2003.

6 APPLICABLE CODES, STANDARDS, AND GUIDELINES

The building code applicable to this project was 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. The CHBC is a performance-based code whose intent is to achieve the life-safety objectives of regular code 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 structural issues of both vertical and horizontal loadings.

For seismic considerations, the structural objective was to ensure the life safety of the building occupants, while recognizing that damage to the building will
Figure 2. First floor walls and second floor framing with seismic retrofit details.

occur. The performance standards for the structural design included the Uniform Code for Building Conservation for lateral design of unreinforced-masonry buildings, and the research findings and guidelines of the Getty Seismic Adobe Project (GSAP). The Getty Conservation Institute is a program of J. Paul Getty Trust in Los Angeles that works internationally to advance the field of conservation through scientific research, field projects, education and dissemination of information.

GSAP (a 10-year study) began in 1990, and culminated with design guidelines released in 2003 (Tolles et al, 2003). The research included a survey of common techniques currently used by adobe design professionals, past practices, current codes, a survey of historic adobe buildings in the southwestern United States, and a summary of current design methodologies for the retrofit of adobe buildings. Most current retrofit practices were based upon a strength-based approach combined with static design forces. Instead, GSAP research focused on a stability-based approach coupled with dynamic force input. This allowed the possibility of understanding what may happen to a historic adobe building after cracks develop.

The subset of the GSAP research effort included dynamic shake-table testing on individual wall elements and small adobe buildings. Three walls and six 1:5 scale adobe buildings were tested. Coincidentally in January 1994, a large earthquake (Northridge) occurred affecting the Los Angeles area and a component of historic adobe buildings within the area. This event provided GSAP the opportunity to survey actual seismic effects on adobe structures in detail (Tolles et al, 1996). The damage to each building was fully detailed along with attempts to understand the dynamic performance of each structure. This survey was an invaluable part of the GSAP research effort; any effective research effort shows a strong correlation between results of laboratory tests and the damage commonly observed in the field.

The final phases of the GSAP testing program included three small-scale models (1:5) of adobe buildings based upon a Taranto-style construction (partial second floor with approximately half-height bearing walls and gabled end walls) common to California, and concluded with tests on large-scale (1:2) models conducted at the Institute of Earthquake Engineering and Earthquake Seismology (IZIIS) facility in Skopje, Macedonia. Design of the small-scale models was effectively identical to the two large-scale models tested at IZIIS. The height of the walls from foundation to floor level was approximately eight times the thickness of the wall. The first model was of unreinforced adobe with minimal attachment of the adobe walls to the floor and roof framing typical of historic adobe buildings. The walls of the second model were fully anchored to the roof and floor framing. A perimeter cable encircled the building at the second floor. Both the roof and second floor had partial wood diaphragms attached to the floor framing. In addition, one out-of-plane wall and one in-plane wall had vertical straps on both sides of the
walls, and the other two walls had center core rods anchored with epoxy grout into small holes approximately 3 cm in diameter. The unretrofitted building collapsed during ground motions between 0.30 and 0.35 g. The retrofitted model survived a 50% increase in earthquake motion without collapse. The walls with straps suffered substantial crack damage while the walls with center core rods suffered very little crack damage. Substantive conclusions were drawn from the program. Shake-table testing demonstrated that retrofitting adobe buildings could ensure stability or reduce the amount of damage that may occur in larger seismic events. Vertical center core elements are an effective means of providing stability, and greatly change both the character and the extent of damage to adobe buildings during larger seismic events.

The collapse of thick-wall adobe buildings, those with slenderness ratios below 5 or 6, can generally be attained by anchoring the walls to the roof and/or floor framing. The out-of-plane collapse of adobe walls is typically the first and most dangerous form of failure. These failures may be a function of the condition and dryness of the adobe. Even a moderate amount of moisture (ranging from 5 to 10%) in adobe walls can reduce the strength of the adobe material by as much as 80%. In adobes with moderately thick walls (slenderness ratio of 8:1) or thin walls (10 or 11:1), a more aggressive retrofit system is required.

7 STRUCTURAL EVALUATION AND DESIGN – THE SEISMIC RETROFIT

Las Flores is situated along one of the most active tectonic fault zones in the world, in designated seismic zone 4. Fortunately, there has been minimal seismic activity affecting this structure. In recognized seismic zones, this is no justification for complacency. As such, the Marine Corps decided that the building needed stabilization.

The deficiencies identified in the survey led the team to consider three options, each with increasing
impact the structure. These options directly paralleled the GSAP research efforts. Option 1 was a basic minimum retrofit system that included anchorage at the roof and second floor levels, a partial plywood diaphragm at the roof level pinned to the adobe, and a perimeter steel rod around the first floor ceiling level for anchoring the second floor framing to the walls. Option 2 was the same as Option 1 with additional vertical straps on both faces of selected walls and higher slenderness ratios. Option 3 was again the same as Option 1 with the addition of center core rods extending the full height of the exterior adobe walls. After consideration, Option 1 was selected for Las Flores, balancing the life-safety requirement against the preservation objective to achieve the least amount of impact to the integrity of the structural components.

The primary elements of this seismic retrofit design are the bond beam (a layered plywood plating and partial diaphragm system in this case) at the roof level, the connections at the tops of the adobe walls, and the connection at the second floor level. The roof system had spaced sheathing, which has little strength and stiffness. The second floor was covered with solid 1x wood flooring boards that act as a minimally effective diaphragm. The potential for out-of-plane deflections of walls that are 3.04 m high and nearly 61 cm thick (a slenderness ratio of less than 5) is low. Bond beams are critical components of any adobe retrofit system. There are two important properties for a bond beam: (1) providing out-of-plane support for the top of an adobe wall to restrain overturning; and (2) providing tensile capacity along the length of an adobe wall to resist separation and offsets at cracked sections.

GSAP demonstrated that the structural connection at the roof level is the most critical connection for an adobe building. In many cases, the roof system provides the lateral support directly. However, in this case, the bond beam is a separate element attached to the ceiling framing, which is in turn attached to the roof framing with steel clips.

The spacing of the top of the wall anchorage is another critical element of a retrofit system. Adobe materials are relatively weak in tension so the tendency is to place anchors very close together in an attempt to increase strength. However, close anchorage spacing will actually decrease the anchorage capacity of this connection. Anchors should be placed no closer than one and one half to two times the thickness of the walls.

The connection at the second floor level attaches the floor system to the perimeter walls. This area of anchorage can be difficult because the forces can be large if fully activated since the adobe masonry is so weak in tension. Following the GSAP guidelines, the floor framing is attached to a horizontal rod wrapping around the perimeter of the building. This type of anchorage will behave in a ductile manner. 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.

Additional seismic design for the chimneys and porch structures followed standard practice.

8 ARCHITECTURAL EVALUATION AND DESIGN

The initial design schematic was worked out on site by the team. This on-site design meeting focused primarily on seismic retrofit concepts coupled with architectural considerations. The GSAP guidelines were prescribed. Recognition that the roof would be replaced would allow for access from the top down to address adobe walls. To achieve the lateral restraint, 76 cm long, 2 cm diameter threaded rods would be grouted into the adobe walls at 76 to 81 cm intervals on center. These interventions as planned could be installed without changing the visual aspects of existing walls and roof timber.

Discussions led to a decision 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 two-story section, was well documented. The porch would be connected with through-wall fastening to interior floor joists. By installing the connecting elements in the substrate, the installation was designed to be mostly hidden.

Front rooms at the ground floor level of the ranch house had deteriorated floors that needed to be repaired. Most of the floorboards were salvageable, but all the substrate was completely deteriorated by fungal rot and termites. The design scheme involved the excavation of subgrade soils to allow for air circulation under framing and keeping new wood out of contact with soils. New concrete grade beams would be established inside the foundation walls, and the replaced floors would be relaid on new pressure-treated framing and pressure-treated plywood constructed according to code.

Throughout the building, timber parts from ground level to the rafters indicated localized termite damage. Each piece of wood would be examined and repaired/replaced if termite/fungal damaged. All wood, both new and old, would be treated with Boracare™ (Boron salt-based product in ethylene glycol vehicle), a nontoxic fungicide, and termicide. Any wood touching the earth or near ground level would be copper chromate arsenate (CCA) pressure treated.

Ground-burrowing rodents entering through the rubble-stone foundation had to be controlled. The solution was to excavate a 46 cm deep trench on
An NPS construction team, including a project manager/architectural conservator, a field project work leader, carpenters, masons, and helpers mobilized and commenced work in the beginning of May 2002. The size and complexity of the project allowed for several teams to work simultaneously accomplishing tasks sequentially organized to maximize efficiency and productivity. The progression of work evolved around the seismic retrofit and structural stabilization. Project work ensued as planned and concluded at the end of September 2002. A scheduling matrix allowed for the rear porch work, interior floors, and seismic retrofit of adobe walls to occur simultaneously. Once the wall tops were stabilized, the roofing structure and decking were replaced, preparing for the restoration of wood shingle roofing. Once the two-story section details were internally accomplished, the porch construction could follow. The porch necessarily had to be completed before wood shingling the second story, and in conjunction with the belting and pinning operations.

Seismic retrofit work teams were divided into two-man units to accomplish simultaneous independent tasks. While one team worked to remove roofing and deck boards, and to provide temporary shelter coverings for the work areas, another group followed installing the rods into adobe wall tops with epoxy, plates, straps, and rafter ties. Simultaneously with that activity, another team began dismantling the rear wood porch, piece by piece, to accomplish structural wood repairs. This carpentry team also constructed the supplemental framing system in the second floor roof. A fourth team began work on the floors with the excavation of soils, installing new reinforced-concrete grade beams and joists. The existing floorboards were treated with BoraCare removed to storage for reinstallation. Hand digging the infill and substrate was required to create a depth of approximately 35 cm beneath the existing floor level to allow air to circulate and prevent any wood from soil contact. All excavation work was monitored by an archaeologist. Once excavated, the grade beam sections were prepared and framing installed. A 2.85 cm thick, CCA pressure-treated, plywood subfloor was installed, and the original flooring was nailed down in its original configuration and placement. The subfloor was held in slight relief from the adobe wall to allow air to circulate.

As shingles were taken off the Hacienda roof and sheathing boards were carefully removed for reuse over the wall tops, the seismic retrofit proceeded. The double course of interlacing plywood-laminate board was laid in overlapping sections nailed to the bottom chord and ceiling joist of the rafter system. Generally, the adobe wall top required augmentation due to eroded and out-of-level condition. The soil cement mix was used to build up the section in a “cast-in-place” pise technique. The plywood diaphragm was placed and 2.53 cm diameter holes were drilled down through the plywood and adobe wall center to a design depth of 81.2 cm to receive the 1.90 cm threaded rod. Holes
were drilled into the adobe with augers and extensions as necessary to achieve required depth. Augers work well in adobe because they allow earthen material to evacuate out of the hole along the shank of the bit as drilling proceeds. Drilling into adobe with a standard masonry bit is ineffective due to the nature of the material that quickly binds and builds density at the tip, effectively blocking the drilling operation. Once drilled, the holes were cleaned with approximately 25 kg of air pressure blowing out the hole. The epoxy was hydraulically injected into the holes. The bolts were inserted down into the epoxy and fixed to the plywood with a washer and nut. 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, one to the other, until the interconnected strapping system was complete on both the one- and two-story sections.

Once all the horizontal wall tops were completed, the seismic team proceeded to accomplish the belting and connections around the framing of the second story.

A 1.5 cm channel was cut though the existing lime plaster and adobe on the walls just above the level of the missing second floor porch deck and the existing rear floor deck. Simpson HD 5A brackets were fastened to every other interior joist below the surface of the wall. It was necessary to excavate a pocket around the joist end to fasten this bracket. A threaded eyebolt was fastened into the Simpson tie with the eye set in the channel on the exterior. 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 out through the adobe wall to tie to the belting rod.

In a similar but reversed fashion, the new porch joists were installed into the existing adobe pockets and tied to interior floor framing. Pressure-treated plates were added to the underside of these joists to provide uniform bearing. All new wood for the porch and other exposed wood repairs was accomplished using clear and select, old growth Douglas fir to match the original. The porch structural design incorporated new upgraded footings, custom column stands, and wind uplift retention. While this construction was underway, shingling the Hacienda wing began. In this manner, the porch framing, second floor joists, and the adobe walls section were all tied together with a system of steel fastenings allowing for a restrained but somewhat flexible structural system.

Just before shingling, the chimneys were stabilized and provided with new flashing sections in preparation for the roofing.

Remains of windows and doors were removed from the building, catalogued, documented, and transported to the wood shop. The building openings were fitted with temporary ventilating enclosures to ensure airflow throughout the year. Over the course of the following 2003 summer months, two restoration-training programs both repaired and restored deteriorated window and door units and reassembled units into repaired jambs on the building. A chromo chronology analysis provided new flashing sections in preparation for the roofing.
dictated the finishes and color scheme for the work. This work, and cosmetic repairs to adobe, lime plaster, and the whitewash finish, effectively achieved a stabilized building envelope – restored in part, and protected from environment impacts.

10 CONCLUSIONS

In the course of accomplishing the building stabilization, new knowledge of the building history came to light and will be incorporated into future planning. Key to the success of the Las Flores project, measured by limited alteration to the historic character-defining features of the house, was the multi-disciplinary 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.

The design solutions represent a minimalist approach. 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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