Casa Bonita II: New Approaches to the Age-Old Problem of Corrosion

By Stephen M. Bauer and William "Bud" Earley

The Casa Bonita II condominium complex is located in the town of Bonita Springs, FL. Known as "The Gateway to the Gulf," Bonita Springs lies just north of Marco Island, between Naples and Fort Myers. Casa Bonita II, which overlooks the Estero Bay and the sparkling Gulf of Mexico, represents the typical cast-in-place (CIP) concrete masonry unit (CMU) construction commonly specified for multi-residential structures in Florida. Casa Bonita II has withstood many years of exposure to the surrounding elements including harsh weather conditions ranging from intensive heat to damaging hurricane-force winds and punishing rainstorms. Over the years, however, time and weather have taken their toll on this once beautiful structure.

Casa Bonita was originally constructed with reinforced concrete because of its optimal wear performance. Due to environmental conditions, however, significant concrete spalling began appearing in various locations throughout the building.

Because earlier repair attempts failed dismally, it was decided early on to determine and remedy the root cause of the problem rather than simply address the obvious symptoms. All available information about the project was gathered for an in-depth review. This included previous repair work and maintenance records, as well as all on-site visual inspections and mapping achieved by mechanical sounding.

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Inspection Results

The preliminary condition survey was conducted during the summer of 2004. Because Casa Bonita is located directly on the Gulf, air-borne chlorides easily enter into the concrete slabs through the cracks in both the parent concrete as well as the repair work completed just a few years earlier.

These previous repairs were made approximately 3 to 5 years before the condition survey taken in 2004. During this time, salt spray from the Gulf provided a continuous source of water and chloride ingress into these problematic areas, mostly on the west side of the structure (directly facing the Gulf of Mexico). Severe section loss of up to 50% of the existing reinforcing steel was prevalent in the slabs, requiring supplemental retrofit.

Repair was achieved by chipping further down to expose sufficient lap length of the clean unaffected bar. This allowed for the installation of a mechanical coupler. The diminished bars that continued into the concrete walls and columns were replaced with epoxy-set dowels that were fit into pre-drilled holes.

Of the total balcony repair job, approximately six of the decks displayed a massive extent of hidden decay and required complete replacement. The condition survey results showed a majority of the balcony slab surfaces were covered with ceramic tile and that the perimeter edges were obstructed at the floor and ceiling by various owner-installed appurtenances such as glass enclosure frames and shutter boxes. Exposed preexisting reinforcement created macrocells within the slabs that resulted in secondary corrosion that spread and literally consumed much of the steel.

Corrosion of reinforcement along the internal edge of the balcony created great concern for future damage to the interior of the condo unit

Typical spall on underside of balcony edge

Causes of Deterioration

The primary causes of the concrete reinforcing steel deterioration were due to constant exposure to sea spray from the Gulf, insufficient protective cover of the reinforcing steel and adjacent slab edges, and localized failures of previous repairs.

Obstacles Abound from the Beginning

The renovation project, which immediately followed the condition survey, took place while the building was fully occupied and furnished. From the beginning of the repair job, there were numerous restrictions. The crew was allowed on site for only a limited number of hours per day. Of these hours, there was an additional restriction on when any type of noise was permitted. Like many condominiums along the coast, many residents stay at the Casa Bonita year round. Therefore, the crew would have to abide by the noise guidelines established by the owners' association—the result was all major renovation had to be scheduled between 8 a.m. and 5 p.m., Monday through Saturday.

Repair System Selection

The customer's main objective was to restore the structural integrity of the balconies without a decrease in the load-bearing capacity from the original design. They requested repairs that did not extend inward under the walls of the condominium units, as this would have affected the overall cost of the repairs dramatically.

Once demolition of deteriorated concrete was underway, however, the full extent of the damage was discovered, and this changed the scope of repair that was required. What started as a conventional balcony repair evolved into a much more extensive and complicated project. This included a combination of complete balcony replacement, full-depth edge repairs and partial depth center slab repairs, and a comprehensive sliding glass door removal and reinstallation.

Corrosion Damage

Initially, the reinforcing steel corrosion process occurs when water and chloride intrusion at the surface of the concrete wicks its way through the pores and capillaries of the slab, finally reaching the reinforcing steel. When contamination from carbonation, chlorides, or other aggressive ions in the surrounding concrete reaches the level of the steel reinforcement, the passive oxide layer dissipates. Corrosion begins and is followed by the formation of rust.

Reinforcing steel corrosion eventually leads to cracking of the concrete cover. Delamination develops; and as the concrete cover breaks up, a spall is formed. The result is a major degradation of the surrounding concrete by chipping, cracking, or delamination. These extremely damaging effects develop because rust, the product of corrosion, occupies several times the volume of the parent steel. This volume expansion ultimately imparts tremendous tensile stress on the concrete that eventually results in the cracking of the concrete slab from within. If left alone too long, this degradation will compromise the integrity of the structure resulting in a potentially hazardous situation.

In concrete repair projects, the removal and replacement of damaged concrete, if completed in accordance with industry guidelines (ICRI Technical Guideline No. 03730), will address the areas with the highest levels of corrosion. New corrosion sites, however, are likely to form in the surrounding contaminated concrete that was passive before the repairs.

When spalled concrete is repaired on corrosion-damaged structures, abrupt chemical changes in the concrete surrounding the reinforcing steel are created. Typical concrete repair procedures call for completely removing the concrete around the circumference of the reinforcing steel; cleaning of steel; and refilling the patch area with new, chloride-free, high pH concrete or cementitious repair

An embedded galvanic anode, with"V" notch easily attached to reinforcement before installation of repair mortar

mortar. This procedure leaves the reinforcing steel embedded in adjacent environments with abruptly different corrosion potentials. This difference in corrosion potential (voltage) is the driving force for new corrosion sites to form in the surrounding contaminated concrete.

Because of the chloride-induced corrosion, this adjacent corrosion activity is commonly referred to as "anodic ring effect." Patch-accelerated corrosion is a phenomenon specific to concrete restoration projects. The evidence of this activity is the presence of new concrete spalling adjacent to previously completed patch repairs. It is not uncommon to need additional repairs in as early as 2 to 5 years. This was the procedure used just a few years earlier to patch the noticeable concrete delaminations.

Because the previous patches failed, the owners desired a system that could provide long-term durability. To achieve this, low-permeability repair mortars were specified along with a self-generating cathodic protection system of embedded galvanic anodes. This advanced corrosion mitigation system was chosen because of some of its unique design features. The exclusive insulating barrier will not dump current into the attachment bar, extending the life of the cathodic protection device. The intent here was to nullify the potential electrochemical activity between the various zones of differential alkalinity.

As the Casa Bonita II project highlights, a highly effective solution to this problem is to incorporate an advanced cathodic protection device that eliminates the anode ring effect and delivers long-lasting corrosion protection.

Repair Project

The removal of spalled concrete was conducted in accordance with ICRI Technical Guideline No. 03730, which recommends removing concrete until clean steel is exposed. Following demolition, the substrate and reinforcement are cleaned by sandblasting to provide a clean, structurally sound substrate along with a white metal profile on the steel.

For additional protection, the project specifications called for a reinforcing steel coating at noncontact areas with the anodes. After the installation of the anodes along interfaces with existing sound concrete, replacement of excavated concrete was completed with a high-slump material with factory blended coarse aggregate in the form-and-pour areas. A fast-setting mortar was used at slab surfaces along interior-exterior transitions to enable timely reinstallation of sliding glass doors. Finally, a nonsag mortar was used to pack notched areas above formed columns and wall bases.

A major challenge was to avoid congestion in the excavated slabs due to reinforcing steel splices, couplers, and anodes. This required precise preplacement layout in the field and direct coordination with the contractor.

Installation was accomplished by extensive shoring to temporarily support interrupted slab spans as well as to relieve service loads from columns that required significant chipping of the gross concrete section. Full deck replacements with ready mixed concrete were required to have a maximum water-cement ratio of 0.40 for exterior coastal exposure, which was achieved with water-reducing and air-entraining admixtures at the batch plant.

Customer satisfaction was guaranteed with consistency of quality maintained through the use of a single source supply. Every attempt was made to acquire all materials necessary for the project from a single manufacturer. No material shrinkage was noted at any of the completed repairs, and the interfaces along the existing concrete exhibited a stable bond line.

The duration of the project was substantially greater than expected due to increased repair quantities, full deck replacement cure times, shoring complexity, and delays relative to reinstallation of railings. Despite the lengthy repair time that was required, the primary objectives were achieved. The owners were completely satisfied knowing the root

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Specifier/Engineer
Jenkins & Charland/
TRC Worldwide Engineering, Inc.

Contractor
Spectrum Contracting, Inc.

Project Partner
The Euclid Chemical Company

Completed balconies at rear elevation facing the Gulf of Mexico

problem was properly identified and corrected using a strategy that would provide the longest-lasting repair possible given the aggressive environmental conditions. Today, Casa Bonita II is once again structurally and aesthetically what her namesake describes—a "beautiful house."

Balconies on Gulf side of building

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