

Dolphin Tower Condominiums Emergency Structural Repair

Sarasota, FL

Submitted by Concrete Protection & Restoration, Inc.

Constructed in 1974, the Dolphin Tower Condominiums in Sarasota, FL, is a 15-story, 117-unit building with the first three levels devoted to parking. To accommodate the parking spaces, the fourth floor was designed to be a 24 in. (610 mm) thick column transfer slab, distributing the 12-story column loads above to the non-aligning columns below. The building is conventionally reinforced concrete flat slabs supported by concrete columns and pile foundations.

On June 24, 2010, the resident manager who lived on the fourth floor observed the walls within her unit were buckling and the tile floors were cracking. She immediately contacted a structural engineer, who confirmed a major failure and incipient collapse and arranged for a contractor to immediately install emergency shoring. By the time shoring was installed, the crack spanned four column bays and in some areas the concrete floor had lifted as much as 4 in. (102 mm). The building was evacuated.

INSPECTION/EVALUATION AND TESTING

To identify the cause of the failure and determine feasibility and methods of repair, the building was intensely scrutinized. In addition to the Association's primary structural engineer, forensic engineers were employed by the insurance company and the association's coverage counsel. Following removal of interior walls and finishes, test methods included visual inspection, strength testing, petrographic analysis, surface-penetrating radar, and ultrasonic pulse velocity testing. Full building finite element analysis was performed to evaluate the stresses in the building and correlate the materials testing results with the observed failures.

Although no "trigger" was identified, the failure was determined to be punching shear caused by a combination of inadequate design for overlapping punching shear perimeters, low-strength concrete, poor-quality concrete, inadequate consolidation, and inadequate reinforcing steel detailing.

A side effect of the intense analysis of the building was the discovery of vulnerabilities, in addition to the failed transfer slab. These included inadequate lateral

design for hurricane wind resistance and inadequate punching shear capacity at the upper-level slabs.

REPAIRS/REPAIR PROCESS

Once the initial analysis and repair design was completed, a preferred contractor was selected. To help bring the cost of the project within budget, the contractor was afforded the opportunity to further refine the design, allowing the unit dimensions to be altered. The removal of this design constraint permitted a substantial cost savings. The design evolved from removal and replacement of the fourth-floor slab and installation of exterior shear walls to installation of post-tensioned drop panels combined with a structural overlay and interior shear walls. This ultimately resulted in a cost reduction of more than \$500,000 at the end of the project, and completion of the \$9 million structural repair on time.

REPAIR IMPLEMENTATION

SEQUENCING

When work began on site, there were already 1100 post shores in place, originally installed as an emergency measure and set up in clusters throughout the three levels of the garage. This shoring needed to be incorporated into the construction sequence and remained in place to support the tower columns above, and also relieved the damaged transfer slab while the repair work was being done. Due to the required shoring, access and storage space within the garage was limited; therefore, safety for the workers in these areas was paramount. Weekly safety meetings were held on site with all crews and subcontractors to make everyone aware of the specific safety concerns present in their work areas. Work proceeded concurrently on multiple levels of the garage and extra precautions were taken and monitored to ensure workers were safe from falling debris from the extensive coring operation above.

I—FOURTH-LEVEL CRACK REPAIR AND PHASE 1 FOUNDATIONS

The first phase of the repair was to fix the large shear failure crack within the fourth-level transfer slab, which spanned four column bays. The repair



Fourth-level transfer slab crack repair after demolition



Helical pile installation in the foundation area

comprised conventional selective demolition and replacement along with epoxy injection. This would further weaken the already damaged transfer slab, so additional shoring was installed. Additional steel was added to the repair areas where concrete was removed, and the floor was re-placed to its original level.

Simultaneously, work began on Phase 1 of the foundation strengthening, which consisted of areas that fell outside of the existing shoring and could easily be accessed. The foundation work consisted of demolishing and removing the slab-on-ground concrete, excavating down to the existing concrete pile caps, installing new steel helical piles, placing steel reinforcement, and placing of the new expanded pile caps.

During excavation of the first pile cap location, it was discovered that the existing cap was only 16 in. (406 mm) deep. However, the original construction as-built drawings showed a pile cap depth of 29 in. (737 mm). The same was true for 10 out of 12 of the Phase 1 pile caps. Based on these existing conditions, the structural engineers had to revise their original designs.



Post-tensioned drop panels with formwork

II—LEVEL 3 DROP PANELS AND UPPER-LEVEL EXTERIOR SHEAR WALLS

The second phase of the project was to install the post-tensioned drop panels on the underside of the fourth-floor slab. The ceiling was prepped using hydrodemolition, and then column enlargements were installed on Level 3. Six-hundred 8 in. (203 mm) holes were cored through the fourth-level slab to install “shear lug keys.” These would tie the new drop panel to the fourth-level overlay, creating a new composite slab.

The area of the drop panel construction was over 7700 ft² (715 m²) and was split up into four subphases. The process took over 2 months, 400 yd³ (305 m³) of concrete, 22,000 ft (6705 m) of post-tensioning cable, and over 42 tons (38,000 kg) of reinforcing steel to complete. Because access within the formwork was limited, self-consolidating concrete was used. The steel cages for the new drop



Steel lug keys and reinforcing bars in the drop panels

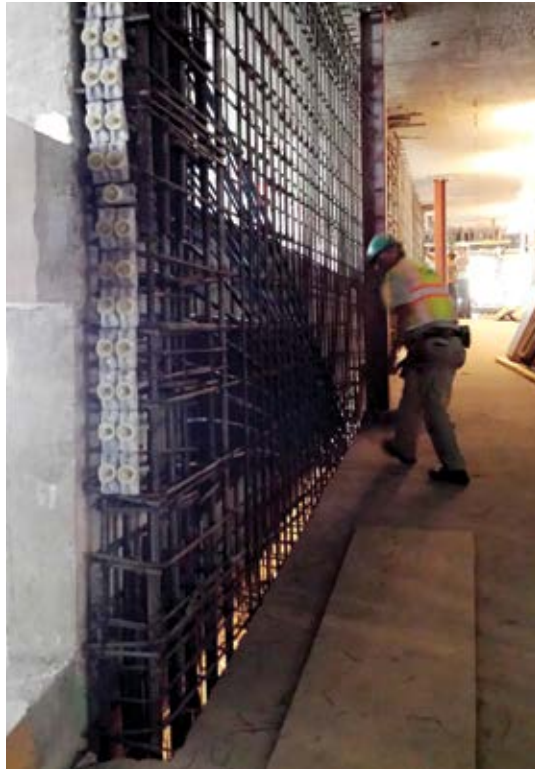
panels were hung from the lug keys, and the post-tensioning cables were installed within the cage. Post shores were installed underneath the drop panel formwork and across 100% of the tower area on all three levels of the garage. This shoring would support the new construction of the drop panels and overlay. In total, 2800 post shores and 200 shoring towers were used for the drop panel and overlay construction.

Also during the second phase, exterior wall segments at the four corners of the building were

converted to concrete shear walls. The existing windows and concrete masonry unit (CMU) walls were removed, reinforcing steel was installed, and concrete was placed.

III—LEVEL 4 OVERLAY SLAB, INTERIOR SHEAR WALLS, UPPER-LEVEL SHEAR REPAIRS

The third phase commenced with construction of the fourth-level overlay slab. The overlay was roughly 13,500 ft² (1250 m²) split into two subphases. Over



Steel and cables in the post-tensioned beam

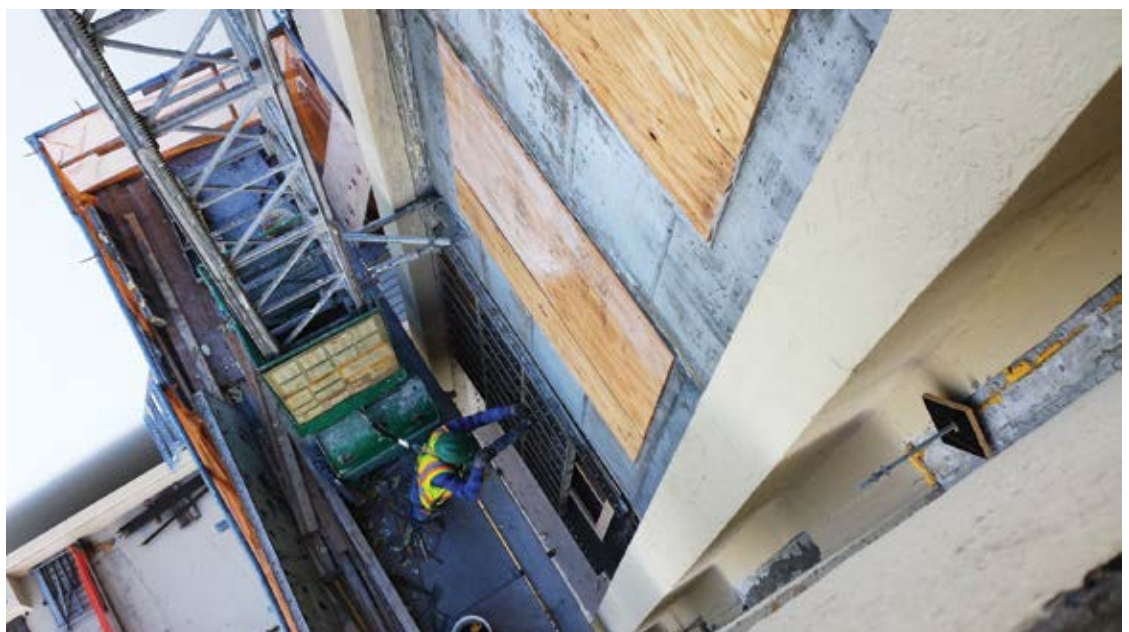
68 tons (61,700 kg) of reinforcing steel and 300 yd³ (230 m³) of concrete was used. Additionally, because the floor height was being increased by 6 in. (152 mm), the two elevator doors required relocating.

After the overlay slab was completed, interior shear wall construction began starting on the fourth level and continuing up to the penthouse. In conjunction with the installation of new interior shear walls, upper-level slab overstress was relieved through jacking. Once the concrete cured, the shoring would be released, redirecting stresses in the floor to the new shear wall.

To supplement lateral wind load capacity and address upper-floor punching, existing CMU walls were filled with grout and 108 steel “T-columns” were installed at various locations. Originally, these columns were to be placed-in-place concrete, much like those done on the garage levels.

IV—PHASE 2 FOUNDATIONS

The final stage of work was to finish the second phase of the new foundation pile caps—those areas which were previously inaccessible due to the substantial amount of shoring required for the fourth-level repairs. For these foundations, the existing pile caps were 4 ft (1.2 m) or more below the upper slab-on-ground, resulting in excavations extending 2 ft (0.6 m) or more below the water table. Consequently, undermining of the slab surrounding the excavation areas was a major concern. Temporary sump-pump pits were created to lower the water table level and reduce soil erosion. Several large concrete piers buried within the existing foundations were discovered, making it very difficult to install helical piles, so these had to be removed. The final foundation area to be completed was within a



Exterior shear walls

subgrade mechanical pump room. Due to limited headroom, holes were punched in the ramp slab above to install the helical piles. Because of the depth of this excavation, the water was again an issue and undermining of the surrounding slab needed to be controlled. Therefore, soil grouting was used to maintain support of the existing mechanical units and prevent further erosion.

PROJECT COMPLETED

The Dolphin Tower project was very challenging and used many interesting and groundbreaking

design concepts. Constant communication between the contractor, design engineer, and owner was a necessity to adapt to continuously changing conditions, which required quick solutions to maintain the aggressive schedule. Despite many challenges, the repairs were completed on schedule and under budget.



Steel overlay

Dolphin Tower Condominiums

OWNER

Dolphin Tower Condominium Association
Sarasota, FL

PROJECT ENGINEERS/DESIGNERS

Karins Engineering
Sarasota, FL

Morabito Consultants
Sparks, MD

REPAIR CONTRACTOR

Concrete Protection & Restoration, Inc.
Baltimore, MD

MATERIAL SUPPLIERS/MANUFACTURERS

CEMEX
Sarasota, FL

Aluma Systems
Tampa, FL



The Dolphin Tower building