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By

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The Royal Club, a Condominium Community located in the heart of historical South Beach in Miami Beach, FL, was originally completed in 1983. The 18-story building was constructed using post-tensioning reinforcement and steel reinforcing bars. Located just 100 yd (90 m) off the Atlantic Ocean, the building was designed to fit into the "South Beach look" of modern high-rise construction which, since the early 1980s, has been transforming the architecture of South Beach from that of low-rise structures to the modern high-rise. To fully appreciate the mixture of architectural styles present in South Beach, we must first look back at the early history of the area and the different styles that were present.

PROJECT
The Royal Club Condominiums
2457 Collins Avenue, Miami Beach, FL

CONTRACTOR
National Concrete Preservation, Inc.
Miami, FL

ENGINEERING
Hillman Engineering, Inc.

SUPPLIERS
Adhesives Technology Corporation
Geophysical Survey Systems, Inc. (GSSI)

VERNACULAR STYLE—1900s THROUGH 1930s

From approximately 1900 through the early 1930s, the vernacular style was more a method of construction than a recognized style of its own and was common in South Florida at the time. The materials and forms encompassed wood frame and masonry construction. Many of the materials and methods used were brought over from abroad by the wave of immigrants coming to America. The new arrivals to the beach quickly defined what would become the "South Beach look." Most of these early wood structures were replaced over time, due principally from an inability to stand up to the harsh conditions found on the beach, often including hurricanes and other natural disasters. Wood frame construction was used often due to the availability of materials and ease in construction. The styles entertained a fun, carefree look that reflected characteristics of resorts found in other parts of the world.

BUNGALOW STYLE—1910s THROUGH 1930s

The bungalow is a popular structure typically of wood frame construction and built up to one and a half stories in height. The typical bungalow had gable roofs, overhanging eaves, and wood sash windows with awnings. Many had front porches that were a popular feature in the early beach neighborhoods. Local architects, including V. H. Nellenbogen, provided plans and helped to create the early look. Later structures included prefabricated and mail-order kits. The structures lent themselves well to the beach environment in that they were usually raised 3 ft (0.9 m) above grade and set on foundation walls. The raised foundations provided a means of protection from frequent flooding. Shade from landscaping and flow-through cross ventilation provided primary cooling for this style of structure.

TRANSITIONAL MEDITERRANEAN REVIVAL TO ART DECO STYLE—1920s THROUGH 1930s

In the 1920s, Mediterranean revival combined with the art deco look formed a unique mixture, or "hybrid," style of architecture. Several renowned local architects helped drive this new style, including V. H. Nellenbogen. Later on during this period, other architects, including Al Murray Dixon, began to influence the architectural look of the beach.

ART DECO STYLE—LATE 1920S THROUGH 1930S

The art deco style breaks away from the traditional revival forms during this period. The style was influenced by the 1925 Paris Exposition des Arts Décoratifs et Industriels Modernes. The exposition marked the union between the decorative arts and advancements in industry and technology, and was one of the first in the Americas to reflect this new look. South Beach was again ready to take on a new chapter in American architecture as many of the new projects adopted themes from ancient civilizations, some taking on Egyptian or other Mediterranean themes. The art deco style of South Beach also employed nautical themes as well as tropical flora and fauna motifs. The favored materials for executing this distinctive "art" decor included bas-relief stucco, keystone, and etched glass, combined with chrome, stainless steel leaded glass, cast concrete, patterned terrazzo, and other artistic materials. Today you can see the influence of this unique time in American architectural history through the design and application of modern materials, including glass block, synthetic stucco, painted wall murals, tile, and plastics. The evolution of the art deco style in the late 1930s began to take on a more modern feel, reflecting the growing interest in all things related to transportation and industrial design.

In the decades following World War II (WWII), the style began to change again. Post-war deco drew significantly from earlier styles including art deco, post-Roman, and Modern. Although single-block massing was predominant, the emphasis could be placed on either horizontal or vertical composition, dependent on the size of the structure, the character of the site, and the will of the architect. New decorative materials were introduced that reflected changing tastes nationally, including brick, synthetic stone, and cast architectural block in a variety of "open" patterns.

POST-WWII MODERN STYLE—1960 TO 1965

The post-war modern style that evolved in Miami Beach exhibited many elements of its companion style of the period, post-war deco, but clearly established its own unique status as a style of modern functional simplicity. The corridors began to be "open air" verandas on one side or more.

Large overhanging roof plates and projecting floor slabs became typical of the new style, along with dual-column symmetrical staircases and the use of parallel lines. Additional design elements added to the style with rounded eaves, stone and rock face features, cast concrete decorative panels, and applied masonry elements denoting marine and nautical themes such as shells, seahorses, marine animals, boats, and anchors.

THE POST-DECO STYLE—1980S THROUGH 2000

In the 1980s, land was at a premium and the trend to redevelop the South Beach district was catching on. Building up rather than out was a way to capitalize on premium locations—the post-deco boom was on. In the early 1980s, new modern building techniques were being used to create space without large columns and beams interfering with interior space. The use of post-tensioning in concrete structures lent itself well to this task.

CURRENT TRENDS AND STYLE—2001 TO THE PRESENT

Today, South Beach is recognized as a metropolitan area with the most noteworthy restoration projects to have taken place in American architecture, with literally hundreds of buildings restored to their original elegance, function, and design. Many post-deco structures were designed and built in the 1980s, 1990s, and even today to give the look and feel of a bygone era.

The blends of old and new have combined to present an eclectic mixture of structures in South Beach. The

Shoring in place.

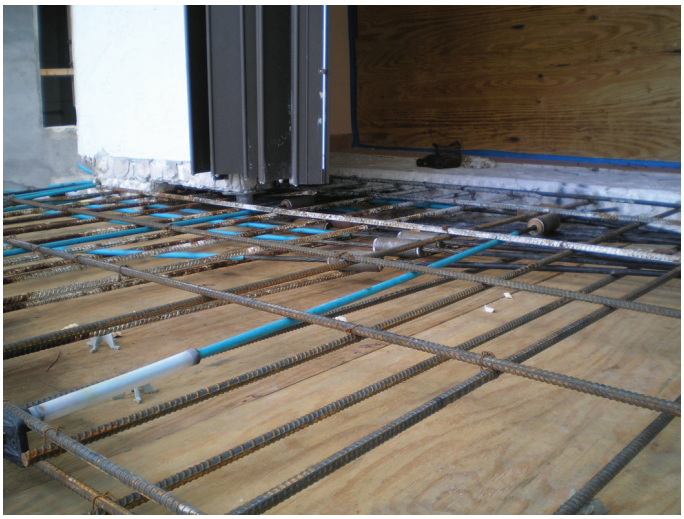
Removal of deteriorated concrete from balcony.

Royal Club is one of those unique buildings that has defined modern high-rise construction while reflecting its origins from the past. In the late 2000s, corrosion of steel reinforcement and post-tensioning tendons in the balcony sections, columns, and beams at the Royal Club became evident. The building was in need of immediate attention, first to stave off any catastrophic failure and second to ensure that the restoration would bring the building back to a safe and secure condition. Now, after more than 25 years of constant exposure to ocean salt spray, weather, and rain, the Royal Club is getting a new lease on life. The restoration process is nearly 50% complete with work progressing at a fast pace.

Hillman Engineering Inc., of Pompano Beach, FL, was chosen to provide site testing, surveys, and to design the project specifications for restoration. The degree of difficulty in performing the restoration while the residents continue to occupy the building was one of the many challenges of this project. Hillman is known for its work with post-tensioned structures and has worked on a number of restoration projects in the South Beach area.

National Concrete Preservation, Inc. (NCP) of Miami, FL, was chosen as the restoration contractor for the project due to its long-term involvement in the post-tensioning restoration industry and because of the unique conditions found on this site. More than 80% of the balconies would require full-depth removal, including complete replacement of steel reinforcement and post-tensioning.

Post-tensioning construction involves a grid pattern of steel tendons across the spans of concrete slabs to transfer loads to the outer walls or column supports. The tendons typically consist of 1/2 in. (12.7 mm) diameter seven-wire strands coated with corrosion-preventative PT coating and encased in extruded plastic sheathing. These tendons are draped to provide the necessary uplift and encased in concrete. After the proper concrete strength has been achieved, the post-tensioning tendons are stressed to the proper tension. Using thinner slabs and reducing the number of columns ultimately reduces the time to complete a construction project and lowers both labor and material costs. Many high-rise condominium buildings could have in excess of 3000 tendons. Early designs did not take into consideration long-term effects of chloride ion penetration from exposure to salt spray, found in coastal areas, and from deicing salts used in areas exposed to ice and snow. Lack of inspections and proper maintenance during the operation of the structure can also lead to a shortened lifespan of the post-tensioning system. Buildings constructed with post-tensioning before 1985 should be on annual inspection programs and need to be closely monitored for signs of corrosion or tendon breaks. Advancements in corrosion-inhibiting PT coating and fully encapsulated tendons have contributed greatly to the success of the post-tensioning industry. When combined with other advancements in concrete technology in recent years and the need for sustainability, the growth potential for post-tensioning construction looks to be very good for the foreseeable future. Early post-tensioning systems focused on obtaining the desired initial tension force, which provided the load capacity of the slabs and less on long-term durability. By improving the components used to protect the prestressing steel from corrosion and through technological improvements in installation



PTC splices in place.

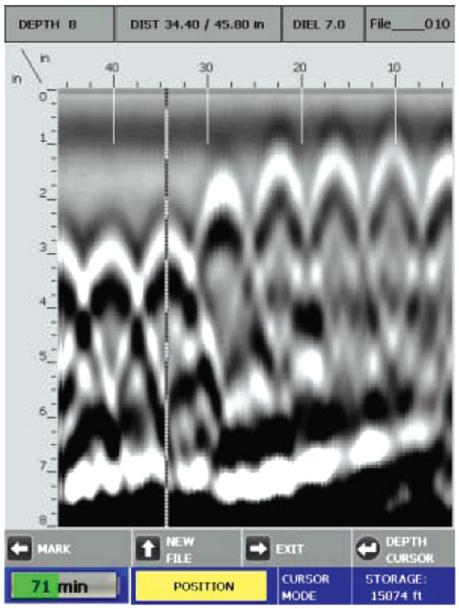


Fig. 1—Steel Survey Report indicating location of steel reinforcement.

procedures, the industry can now offer post-tensioning systems that deliver both exceptional strengths and load capacities with long-term durability. The advancements in corrosion protection for PTC systems is especially important in areas that experience significant exposure and damage from freezing-and-thawing cycles, deicing salts, seawater, salt spray, and other corrosion mechanisms.

In slabs that employ post-tensioning, corrosion occurs when moisture penetrates the tendon sleeve through abrasion nicks or damage to the protective outer sleeve and/or moisture migration through protective expansion grout at sleeve ends or splices. Corrosion of post-tensioning will ultimately result in tendon breaks or sudden snaps, causing a loss of structural integrity. If left unattended, corrosion can spread, creating additional stresses on neighboring tendons and the potential for catastrophic failure.

The Royal Club was not a typical post-tensioned structure. When first surveyed, the corrosion team uncovered many inherent defects that contributed to the level of damage found. The inherent defects included improper tendon anchoring and lack of reinforcement bars in key areas, and a lack of adherence to architectural details in the original construction, which resulted in leaks through pipe chases, flashing, and windows and door openings. The original slab placement also had warping and poor drainage properties, which led to water ponding and penetration into the building. The combined damage, along with original construction flaws, ultimately led to premature failure of many tendons in exposed balcony slabs. As a result of the poor drainage, some areas around flashing or pipe chases had been leaking for years. Moisture that was able to pond on the surface would facilitate the migration of salt-laden water into the slabs. In many of the balconies, tendon loss was significant, reducing the load capacity to less than acceptable limits. Emergency shoring was put in place prior to starting the restoration process to ensure the safety of residents as well as the work force.

One of the more obvious problems occurring at the Royal Club was broken post-tensioning tendons identified as popouts. Popouts are the result of strand breaks within the slab where, as a result of the released tension, the steel strand breaks through the concrete slab. A popout can occur after corrosion has eaten away steel wires within the strand until the strand breaks. The load or stress is carried by decreasing steel cross-sectional area until the stress becomes too great for the remaining steel area to carry the load, resulting in a release or "pop" of the strand. After the strand breaks, its pieces retract within the sheathing and the force of the action causes the concrete to "pop," often breaking through the slab surface. The Royal Club had many such breaks visible on the slab.

The restoration project at the Royal Club would require a number of specialized restoration processes to not only restore building integrity but also to ensure long-term protection for the structure going forward. The primary scope of the job includes the following procedures:

- Structural concrete restoration;
- Post-tensioning tendon replacement;
- Steel reinforcing bar replacement;
- Column and beam restoration in the parking garage;
- Pool deck restoration and pool shell water-proofing;

Formwork in place.

- Waterproofing membrane system application to the parking garage;
- Installation of new doors and windows;
- Installation of new aluminum and glass balcony railings; and
- Pool deck waterproofing and pool restoration.

The first step in the project was to locate the steel reinforcement and post-tensioning tendons throughout the slabs. This was accomplished using a combination of methods including ground-penetrating radar—a "nondestructive" test method used to locate reinforcing bar, conduits, and post-tensioning tendons.

The method can be used to determine concrete slab thickness in real-time (Fig. 1). The radar unit used on this project was the StructureScan Mini, which safely locates metallic and nonmetallic targets within concrete structures up to a depth of 16 in. (400 mm). The system incorporates an auto-target feature that marks the detection of features of interest. This function also estimates the depth of targets and automatically adjusts the depth scale. Once the targets were located, the concrete surface was marked for demolition. In other areas, chipping out sections of the slab to reveal post-tensioning tendons and reinforcement bars was done. Chipping out the concrete to expose the post-tensioning tendons and reinforcement bars falls under the "destructive method" category of testing.

As the project progresses, each area is staged and addressed according to schedule. Today, work is progressing at a fast pace, putting most tasks ahead of schedule. Replacement or augmentation of steel reinforcement is being done by doweling in new steel to areas where the

North face of building: ready for restoration.

East face (note spalls evident on balcony edge).

East face formwork removed, concrete placed.

surrounding concrete is structurally sound. The use of fast-setting high-strength epoxy anchoring material is facilitating a fast turnaround time for steel replacement. Using Ultrabond 1™, a product by Adhesives Technology, the set time was kept to a minimum to facilitate maximum production rates. The typical set time between 35 and 115°F (2 and 46°C) was 4 hours with a 20-minute working time. Typical tension load strengths at 1/2 in. (12.7 mm) diameter strand were averaging 22,500 lb (100 kN). Independent ASTM C881-99 technical data are provided in the chart (refer to Table 1).

Jairo Flores, Project Supervisor with NCP stated, "The biggest surprise I have experienced on this project was to find that many balcony slabs had almost no steel left in the concrete... Many of the balconies were just barely hanging on." Warped slabs and sections that did not have proper post-tensioning terminations were also a factor. When a post-tensioning slab begins to have tendon breaks, the remaining tendons work harder to support the load.

NCP's 15-man crew works approximately 5 days per week on the project and is expected to complete the work by fall 2010. Once completed, this architecturally significant structure will once again stand the test of time and take its rightful place among the unique structures of South Beach.

Scott O'Connor *is president of Phoenix Engineering Services Inc., Ponte Vedra Beach, Fla. He has more than 20 years experience in specialty coatings, industrial flooring, and commercial building restorations.*

Table 1—Independent ASTM C881-99 technical data

Properties	ASTM	Results
Compressive yield strength, psi	D695	9880 (7 days)
Compressive modulus, psi	D695	191,280 (7 days)
Tensile strength, psi	D638	6790 (7 days)
Elongation, %	D638	1.9 (7 days)
Bond strength, psi	C882	1100 (2 days)
Bond strength, psi	C882	1640 (14 days)
Consistency	C881	Nonslag gel
Heat deflection temperature, °F	D648	134 (7 days)
Water absorption, %	D570	0.40 (24 hours)
Linear coefficient of shrinkage	D2566	0.003