FAST-SETTING SUCCESS FOR TROPICAL CLIMATES

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When it comes to concrete construction and repair, use of fast-setting cementitious materials is often the best way to ensure crews can work around the weather and more conventional challenges like traffic. The key to success often lies in specifying rapid-hardening, durable cement products that are easy to mix and place. These should be formulated to set fast, minimize shrinkage, maintain strength—even when submerged in water—and resist chemical attack.

Whether Hawaii, Southern Florida, or Puerto Rico, a tropical climate brings a host of unique construction challenges. In Puerto Rico, the focus of this article, the average temperature hovers near 27 C (80 F), with humidity varying by region, and strong easterly trade winds pass across the island year-round. A rainy season also stretches from late April through November, not to mention hurricane season from June through November. Even after construction is completed, the built environment is susceptible to corrosion brought on by salt-infused sea breezes from the surrounding ocean.

The following case studies show how rapid-hardening cement-based products have been used to speed construction and fortify structures and infrastructure against corrosion in the harsh climate of the island. The projects address corrosive environments, windy and wet conditions, and hot-weather concreting methods.

WORKING AROUND THE WIND

National University College has five campuses located throughout Puerto Rico. The Arecibo campus sits just 15 m (50 ft) from the Atlantic Ocean, which means the facility is subjected to strong winds and corrosion. As a result of these factors, the campus parking structure was in dire need of structural repairs.

In April 2016, the university contracted a San Juan company to repair the 8-m2 (86-sf) covered parking lot. The owner wanted a durable solution able to withstand the corrosive seaside environment and be installed within five months.

The contractor used high-performance, rapid-hardening cement products to provide full- and partial-depth repairs with rebar replacement for the structure's beams and columns. All materials were one-component mixes, which were combined with water onsite via barrel mixer. The fast-setting materials enabled the contractor to perform the bulk of repairs before daily high-wind conditions set in. Further, because the repair materials can be applied at thicknesses up to 152 mm (6 in.), the crew was able to achieve full depth in a single coat, completing repairs more quickly.

For partial-depth repairs, the crew removed the top third of damaged slabs and replaced it with a corrosion-resistant material. The polymer-modified blend of rapid-hardening cement, additives, and specially graded fine aggregates is fortified with a corrosion-inhibitor and fibers. Designed for vertical/overhead (V/O) repair and resurfacing applications, it bonds well with existing concrete and achieves rapid strength gain, high durability, and low shrinkage.

The contractor also employed a multipurpose mortar for all full-depth repairs. Like the cement product mentioned previously, this mortar mix is designed for V/O applications. This combination of rapid-hardening cement and quality sand is durable in wet environments, sets in 15 minutes, and is ready for traffic in one hour. As work took place during temperatures that ranged in the high-20s C (mid-80s F), the crew added one packet of a powder-based, set-retarding additive and three packets of a powder-based flow-enhancing additive to every 25 kg (55 lb) of the mortar mix to keep the material from setting too fast. The set-control additive effectively slowed setting times, while the flow-control additive increased the fluidity of the mixture. Additionally, by replacing water in the mix with the flow enhancer, the contractor was able to increase concrete strength and further reduce shrinkage.

The crew's biggest challenge was the need to work around sea breezes and strong ocean winds threatening to blow around the material. For example, while performing partial-depth repairs, the crew mixed and placed the V/O repair material during the early morning hours, when wind conditions were most favorable. It was placed by 9 a.m. each morning, when the wind typically changed directions and grew stronger.

The V/O repair mix contains self-curing technology, which means it does not need to be wet-cured in most applications. This enabled the material to set in 45 minutes and achieve structural strength in two hours, well before the intense mid-morning sea breeze. Repairs were completed months ahead of schedule, which resulted in profits for the contractor as well as cost savings for the owner. As an example, early completion allowed the university to save two months of payments on a rented parking lot for students and staff during construction.

For Puerto Rico's Teodoro Moscoso Bridge, a corrosion-resistant vertical/overhead (V/O) repair material was used for vertical partial-depth repairs. The gray material bonds well with existing concrete, and is resistant to both freeze/thaw and corrosion.

MINIMIZING TRAFFIC DISRUPTION

The Teodoro Moscoso Bridge is the longest bridge spanning a body of water in Puerto Rico. The four-lane, 2-km (1 ½-mi) long toll bridge spans the San José Lagoon, connecting the cities of San Juan and Carolina while also serving as the main entrance to the Luis Munoz Marin International Airport. With the airport on one end and a premier shopping destination (the Mall of San Juan) on the other, the 23-year-old bridge is subjected to a high level of vehicular traffic. Its total length, including access roadways, is 3 km (2 mi).

In summer 2015, Albertis—the private company that manages and maintains the bridge—began a comprehensive rehabilitation program involving various levels of repair. The goal was to perform repairs with minimal road closures for drivers.

The National University College Arecibo campus sits just 15 m (50 ft) from the Atlantic Ocean, and the winds caused heavy corrosion to the campus parking structure. As a result, the structure was in dire need of structural repairs.

The contractor recommended several single-component, fast-setting hydraulic cement products that would allow Albertis' maintenance crew to restore the bridge faster and reduce downtime. These products' ability to harden quickly and achieve high early strength, even while underwater, also allowed the crew to work through flash rains—which are common in the summer rainy season—without compromising strength and durability. Repairs were accomplished in three separate phases.

PHASE 1–PARTIAL-DEPTH REPAIRS

Since the top rebar in areas of the pavement near the toll plaza did not have enough concrete cover, it was attacked by the high concentration of chlorides in the environment. In turn, this caused deep cracks and fragmentation in the concrete. To minimize road closure time, the crew needed a very fast-setting structural mortar with early high strength to perform the partial-depth repairs.

A mix especially made for harsh environments was chosen, consisting of rapid-hardening cement, specialty sand, and high-performance additives. An integral, powder-based corrosion-inhibiting additive was introduced to create a protective barrier on the embedded steel that both repels water and reduces chloride migration to the rebar. The crew was able to open all lanes to traffic three hours after repairs were made, which

Parts of the pavement required partial-depth repair due to corrosion deterioration and concrete delamination. A rapid-setting cement was selected, as it is a durable solution for time-critical jobs in harsh environments.

meant minimal interruption to the operation of the toll plaza.

"Using the rapid-setting product really made the difference," says Juan Matos Ostolaza, the bridge's operation manager.

PHASE 2–LATERAL-BARRIER REPAIR

The bridge's lateral barriers were at least 23 years old, with concrete delamination spalling (also due to corrosion from chlorides) quite evident in numerous areas. All damaged areas were scattered spots—isolated zones approximately 1×1 m and 2×2 m (5×5 ft and 8×8 ft) in size—so the bridge needed a durable, yet aesthetically pleasing solution that would blend well with the existing concrete.

For these vertical partial-depth repairs, the contractor recommended the same corrosion-resistant V/O repair material used in the National College University project. Tinted gray to match most Portland concrete surfaces, the material bonds well with existing concrete and is resistant to both freeze/thaw and corrosion. The integrally added corrosion-inhibitor contributes additional embedded-metal protection.

The crew finished the barrier surfaces with a thin layer of concrete-patching compound to provide a smooth surface ready to receive the anticarbonation protection coat. The concrete-patching material is formulated with a premium-grade fast-setting cement, high-performance polymers, and a finely ground aggregate. It is suitable for moist environments.

The original plan was to repair 91 m (300 ft) of barrier, but once the bridge's management team discovered how quickly and easily the crew could perform repairs, it extended the work to 2414 m (7920 ft) of barrier. Soon after, the decision was made to repair the other side of the bridge (another 2414 m) and the toll plaza structure. In the end, the crew repaired more than 7620 m (25,000 ft) of concrete barriers.

"It was great to see the crew working with materials that allowed them to complete repairs in a highly efficient manner," says Matos Ostolaza.

A multipurpose repair mortar known for its rapid structural strength and long-lasting durability in corrosive environments was used for the airport repairs. The surfaces were ready for traffic and most loads within two hours.
Photo © Guillermo E. Alvarez Cartañá

PHASE 3–NEW FLOOR DRAINS

During the final phase of the project, a new system of floor drains was needed on the east side of the bridge to allow all surface water to discharge. For the drain pipe installation, the crew core-drilled the new drains and saw-cut and chipped out the drain ditch with a jackhammer. The new pipes were anchored and fixed with a fast-setting, high-strength, nonshrink grout. The multipurpose product is durable in wet environments, typically sets in 15 minutes, and is ready for traffic in one hour. The crew also added a corrosion-inhibiting additive to the grout mix.

The drain ditch was finished with a concrete resurfacer typically employed for damaged or discolored concrete. Like the V/O mix used for National University College, this product contains self-curing technology and generally sets fast without needing to be wet-cured.

The products were easy to mix, apply, and clean, and produced minimal waste—even with a constant breeze and temperatures soaring above 32 C (90 F). To keep materials from setting too quickly in the high heat, the crew used iced water and added two packets of set-retarding additive for every bag of product during the mixing process. Each product cured in two hours, allowing the crew to move to the next phase quickly.

"As a civil engineer working in roads and bridges, I have been using concrete repair products all my professional career," says Matos Ostolaza. "This is the first time I had the chance to work with a single-component product. The most significant advantage was the yield of the products; it really saved a lot of time and money. Multiple-component products cost you more and take more time to mix—and you always end up wasting perhaps 20 percent of the products."

QUICK AIRPORT RUNWAY REPAIRS BETWEEN FLIGHTS

Tourism typically plays an important economic role in regions with tropical climates, with infrastructure that must remain accessible during repairs and maintenance. San Juan Airport, known officially as San Juan Luis Muñoz Marín International Airport, is located 5 km (3 mi) southeast of San Juan. With four terminals and two runways, it is the busiest airport in the Caribbean, serving as a gateway both to the Caribbean Islands and the United States.

The airport's two runways had taken a fairly understandable beating over the years and eventually began to show signs of wear and tear, including slab fragmentation at curled joints. At least 4.5 m2 (50 sf) of deteriorated concrete surface was identified, with most of the damage located in the apron areas where planes stop to unload and load passengers.

In May 2016, Aerostar Airport Holdings, which manages the airport via a public-private partnership (P3), embarked on a year-long maintenance program to repair the runways without having to shut them down. The program's success relied on the maintenance crew's ability to quickly perform partial-depth concrete slab and joint repairs and return those repaired portions of runway to service within a two-hour window, so as not to disrupt scheduled flights. Only a fast-setting repair material could make this extremely tight turnaround possible.

Aerostar worked with the contractor to select a repair material capable of meeting the maintenance program's objectives. They chose a multipurpose repair mortar known for its rapid structural strength and long-lasting durability in harsh environments. The mix of rapid-hardening cement, specialty sand, and additives can also be extended with coarse aggregate, up to 100 percent by weight. Most importantly, surfaces repaired with the material require only one hour of wet-curing, and are ready for traffic and most loads within two hours.

The weather also played a part in the material selection process. Average highs stay within the high-20s to low-30s C (mid- to high-80s F) range most of the year, with average lows in the 20s C (70s F). Aerostar anticipated maintenance crews would often be working in temperatures from 29 to 33 C (85 to 92 F). The hot weather could cause the repair material to harden too quickly. In order to offset the high temperatures, the contractor included a set-retarding additive in the mix, giving crews more time to place and finish the material.

San Juan Luis Muñoz Marín International Airport's two runways had taken an understandable beating over the years, and eventually began to show signs of wear and tear, including slab fragmentation at curled joints.
Photo © Santiago Alvarez

A flow-enhancing additive was also used to increase the fluidity of the mix while reducing the amount of water needed for increased strength and reduced shrinkage. When the additive is employed as a replacement for water, the same slump can be achieved with approximately 20 to 40 percent less mixing water.

Finally, training was critical to ensure all work and materials complied with Federal Aviation Administration (FAA) specifications for concrete repair. The contractor educated the airport's entire civil works maintenance crew on concrete slab-on-grade repair, and specifically on using fast-setting materials. Much of the training took place during a three-hour seminar.

Once all personnel were trained, Aerostar launched the runway maintenance program with great success. As was hoped, crews were able to return repaired areas to service in less than two hours.

CONCLUSION

Combating corrosion and working in wet conditions are constant struggles for concrete construction professionals in tropical regions, but these challenges can be easily overcome with the right concrete repair materials. Whether working around the wind, rain, cars, or planes, these project teams found using one-component, fast-setting hydraulic concrete products was an instrumental component of project success.

By Guillermo E. Alvarez Cartañá

Guillermo E. Alvarez Cartañá, PE, is a new technologies construction consultant with AT Specialty Cements & Polymer Technologies in San Juan, Puerto Rico, a distributor for CTS Cement Rapid Set Products. He has provided consulting services with AT Specialty Cements for 15 years and has worked in the concrete construction and repair industry for nearly 30 years. Alvarez Cartañá works closely with industry leaders and project owners to provide support and solutions for projects such as high-rises, bridges, airports, wastewater treatment plants, and government buildings. He also has extensive experience with concrete flooring systems. Alvarez Cartañá can be reached via e-mail at atscements@gmail.com.

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POSTSCRIPT

This article was written before Hurricane Maria hit Puerto Rico in September 2017. The author has since been able to verify all the repairs mentioned withstood the ferocity of Hurricane Maria without any deterioration.