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Time-Sensitive Runway Repair

The U.S. Army Engineer Research and Development Center conducted four years of testing to determine the best option for rapid-setting concrete for repairs to military airfields.

By Chris Davis

Time is of the essence when repairing spalls, cracks and craters caused by enemy fire on military airfields. For decades, engineers have been searching for the most efficient and effective means to perform these repairs. Solutions have ranged from landing mats developed during World War II to a host of materials and systems investigated during the Cold War, ranging from flexible and rigid caps over debris backfill to structural systems that bridge the craters. However, most of these solutions require materials to be readily available on site, which has often not been the case in the ongoing wars in Iraq and Afghanistan. Forced to make do with in-situ materials and resources, engineers have not been able to perform effective repairs, and airfields have required increased maintenance as a result.

However, new advances have pushed rapid-setting concrete to the forefront as a viable alternative for crater repair. Although the product has been used by the military for years to repair areas less than a cubic foot, technological advances—offering faster set times, higher early strengths and better durability under heavy loads—have made rapid-setting concrete a viable alternative for repairing larger craters. These advances have also made a variety of rapid-setting concrete products widely available off the shelf.

Rapid-setting concrete is not without its own host of issues, though. Mixing, placing and finishing the concrete before it sets up has often been a challenge for crews in the field. Proper placement of repair concrete is critical, as poorly executed repairs can pose significant damage to aircraft if debris is sucked up by moving tires, wind, or jet blast. To determine the best type of rapid-setting concrete in this highly-specialized environment, the U.S. Army Engineer Research and Development Center (ERDC) spent four years putting 10 products through a series of tests to determine the best option for crews on the ground.

Concrete Criteria

To pass the ERDC test, repair materials had to sustain heavy aircraft traffic within a span of just four hours from the initial assessment of the repair. The ideal repair material would minimize both repair time and logistical requirements, producing a quick-setting, long-lasting patch that can be placed with traditional portable concrete placing equipment.

Because of the time restrictions and temperature conditions in the field, the testers sought a product

In addition to strength, setting time also was measured in the lab, as this number is crucial for the timing of repairs—both too-long and too-short setting times can present problems in the field. Setting times were measured at both ambient and elevated temperatures, for both initial set times (at 500-psi, the strength at which the material can no longer be vibrated) and final set times (at 4,000-psi, the strength at which the material is ready to carry loads). Due to their varying compositions, the materials exhibited a wide variety of set times—from a six-minute initial set for a magnesium phosphate-based cement to a nearly five-hour final set for the alumina phosphate product—but all reached final strength within the desired timeframe of three hours.

Field Testing

Nine of the rapid-setting concrete options were next tested in the field on a 60-ft-wide, 140-ft-long simulated airfield at the ERDC testing facility in Vicksburg, Miss. After the test section of concrete was placed, various Series 1 (5-ft by 5-ft), Series 2 (8-ft by 8-ft) and Series 3 (10-ft by 10-ft) craters were cut into the pavement and excavated to depths of 2-ft to 3.5-ft.

The craters were backfilled and capped with rapid-setting concrete according to each manufacturer's instructions. The concrete caps were given three hours to reach the desired final strength, then were trafficked with a load cart designed to replicate the weight of an F-15E fighter jet. Each repair was subjected to up to 5,000 passes, with data on surface roughness and deterioration collected at various points during the passes. The Series 1 craters were tested first, and the three products that held up during the initial 112 passes and showed only minor deterioration under subsequent passes were approved for similar tests on the Series 2 and 3 craters. All four products also met the criteria for durability during subsequent tests, although the ease of use varied widely. Pavement SLQ, for example, is contained in buckets, which crews found added 30 percent to 50 percent to the placement time. Rapid Set earned it ERDC's top recommendation going into the next round of testing because of its capability to be placed easily with traditional mixing equipment.

The next step in field testing was to fully simulate real-time field conditions. Crews, without assistance from the manufacturer, were timed to see how quickly they could perform a repair with each product, from initial assessment to a simulated plane landing. ERDC's repair procedure, which includes methods, equipment and materials, was tested at a that could gain 3,000-psi unconfined compressive strength within three hours. In addition, because the repair material will be placed adjacent to ordinary Portland cement concrete, it needed to achieve a 500-psi bond strength to Portland cement within one day of curing. It also needed to attain a 1,000-psi bond strength to other rapid-setting materials, as sometimes repairs are performed in a series of small lifts.

The types of materials tested represented the variety of available rapid-setting concrete compounds, including polymeric patching material, magnesium phosphate-based and high alumina cements, and specialized proprietary blends.

Laboratory Testing

The initial series of tests involved casting each of the products in 6-in and 12-in cylinders at both an ambient 73° F and at 90° F to mimic likely conditions in the field. After curing for two hours, then again at six and 24 hours, the products were tested for unconfined compressive strength. The research team also cast additional cylinders to compare early strengths to 28-day strengths. The majority of the materials reached the desired 3,000-psi early strength in just two hours in ambient temperatures, but under elevated temperatures, most of the products experienced a slight to severe deterioration in strength. Only three products, CTS Cement's proprietary Rapid Set Cement, and BASF Building Solutions' high-alumina Tho-Roc 10-61 and magnesium phosphate-based Set 45 HW (both of which are formulated specifically for extremely high temperatures) were able to attain the 3,000-psi threshold at the 90° F mark.

Similar cylinders were cast to test early and 28-day bond strength to Portland cement and other rapid-setting materials. All eight of the products subjected to this test attained the requisite 500-psi strength after one day when bonded to Portland cement, but the polymeric patching compound and one magnesium phosphate-based cement exhibited a decline after 28 days. The polymeric compound, along with the Portland cement blend, failed to reach the 1,000-psi threshold when bonded to other rapid-setting materials, but the six other products passed easily.

U.S. Air Force base and enabled the airmen to assess damage, repair and open to air traffic within six hours from initial damage. This final testing occurred at the end of August 2009 and is pending the final report.

Through this series of complex testing procedures that measured a variety of factors, including strength, bond to substrate, durability, modulus of elasticity and workability, Rapid Set proved to be the top contender for repairing spalls, cracks and craters. Because of the success of these tests, Rapid Set is being evaluated for other types of concrete repair in military applications.

Alternative Applications

With rapid-setting concrete now a proven method for performing time-sensitive repairs on military airfields, its potential in other fast-track combat repair situations is waiting to be tapped. For example, similar repairs could be conducted on roadways in combat zones, where slow-curing concrete poses the risk of improvised explosive device implantation. While tests have not yet been conducted for other types of repairs, the product's performance in the challenging arena of airfield repair indicates that rapid-setting concrete is a viable solution for a wide variety of military-specific repair jobs.

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