Lessons Learned on a Runway Reconstruction Project

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Lessons learned are important elements of a successful project and should be passed on to PB staff. Several steps that were critical to the success of a runway reconstruction project at Pennsylvania's Allegheny County Airport, are described in this article, as is an effective method to repair short cracks that developed above the dowel bars in the transverse runway joints.

Allegheny County Airport (AGC), located in West Mifflin, Pennsylvania, 16 km (10 miles) south of downtown Pittsburgh, is the reliever airport to the Pittsburgh International Airport (PIT). In 1996, AGC was the third-busiest airport in Pennsylvania after PIT and Philadelphia International Airports based on the annual number of operations. AGC has an air traffic control tower that operates around the clock.

The management of AGC together with the Federal Aviation Administration (FAA) Airport District Office approved the full-depth replacement of the bituminous-concrete-surfaced Runway 13-31 with a new Portland cement concrete surface in 1997. PB was selected to provide construction management and inspection services.

Design of Runway

The design of the new, 30-m- (100-foot-) wide runway called for the majority of construction joints (transverse and longitudinal) to be saw cut. Dowels that permit horizontal movement of adjacent slabs were to be used at interior transverse joints to provide for transfers of loads across the joints and to prevent relative vertical displacement of adjacent slab ends. The diameter of the dowel bars was to be 2.5 cm (1 inch).

Dowels were to be placed across transverse contraction joints within 30 m (100 feet) of the free ends of the pavement and within 18 m (60 feet) of the expansion joints at intersections with existing pavement. Additional dowels were to be placed at expansion joints and at intersections of the runways, taxiways and aprons.

Some of the interior longitudinal joints were supposed to have smooth dowel bars to allow for minor horizontal movement between slabs, and tie bars were to be used across certain longitudinal contraction joints to hold the slab faces in close contact. Tie bars themselves do not act as load transfer devices, but by preventing the wide opening of the joint, they allow for load transfer to be provided by the aggregate interlock in the crack below the groove-type joint. The tie bars called for in the design were 1.3 cm (.5 inch) in diameter and deformed.

Phasing and Schedule Limitations

Runway 10-28, which intersected with Runway 13-31, was open to traffic at all times during the construction. Work within the Runway 10-28 safety area was:

- Not permitted from 6:00 a.m. to 9:30 a.m. and from 3:00 p.m. to 6:30 p.m.
- Not recommended during other daytime/daylight hours, but permitted if the contractor had all workers and equipment leave the safety area within 15 minutes of a request from the FAA control tower and permitted unrestricted aircraft movement on the runway.

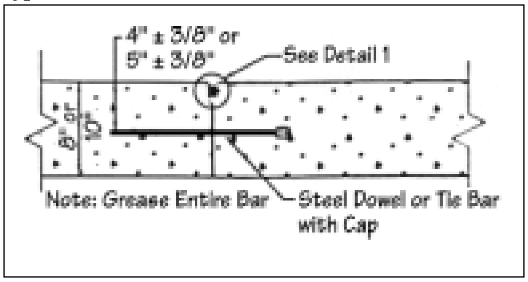
The contractor was provided a detailed work sequence and phasing of the project. All work was to be completed, tested and fully operational within 84 calendar days from the notice to proceed. The contractor would have been assessed liquidated damages of:

- $5,000 per day for each calendar day beyond the completion date that the project was not finished
- $100 for each 15-minute increment beyond 6:00 a.m. that the contractor failed to have Runway 10-28 re-opened. In addition, the contractor would have had to stop all operations an equal amount of time earlier on the next work shift.

Contractor Requests Change in Joint Types

The contractor used a Bid-Well paver that placed 15-m- (50-foot-) wide lanes. All longitudinal joints were to be saw-cut joints except for the centerline full depth construction joint. The design and construction considered the following types of slab joints:

Figure 1a: Doweled or Tied Construction Joint Type F, not to scale



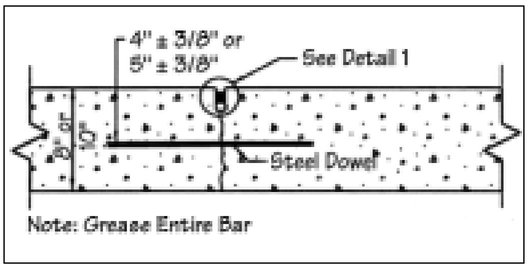


Figure 1b: Doweled Contraction Joint (Type D), not to scale

- **Type F, a full-depth, formed joint** (Figure 1A). FAA pavement design assumes that the smooth formed surface does not provide shear transfer, so the joint dowels are designed to provide the full shear transfer. The smooth dowels are also greased to permit temperature expansion/contraction and movement in the horizontal direction.
- **Type D, a partial-depth saw cut joint** (Figure 1B). The rest of the joint is formed by the cracked concrete below the saw-cut joint surface. The FAA pavement calls for shear transfer within this irregular cracked surface to be provided by the aggregate interlock and assures this transfer by placing "tie bars" to keep the cracked joint tight.

Given the 15-m- (50-foot-) wide slip-form concrete placement, the contractor requested and was given approval to replace the proposed Type F interior doweled construction joints (2nd and 3rd joints from the edge of the pavement) with Type D contraction joints and tie bars. The centerline joint would remain a full depth construction joint

The alignment and elevation of the steel dowels and tie bars across the joints is extremely important. Usually a wire cage or basket anchored firmly to the subbase of the pavement is used to hold the dowels or tie bars at correct horizontal and vertical locations.

Conflicting Requirements Yield Improper Joint Steel

The fabrication of the steel baskets was on the critical path of the job, and they required six to eight weeks for delivery after the order was placed. The contractor ordered the steel baskets for the project in accordance with Publication 407, Pennsylvania Department of Transportation (PENNDOT) specifications that referenced the PENNDOT Roadway Standard Drawings (RC Series) and used standard industry practices for PENNDOT and the Pennsylvania Turnpike (highway jobs).

Publication 407 was supposed to change only the formats of the FAA specifications, but it had unintentionally introduced changes to them because of discrepancies between FAA and PENNDOT specifications. Publication 407 had been generated for airports jobs and was used in hopes of encouraging bids from highway contractors, who were usually not familiar with FAA specifications.

All dowel bars were ordered as deformed bars even though some joints were designed to use smooth bars because PENNDOT specifications define steel dowels as deformed bars. FAA specifications, on the other hand, define them as smooth bars.

The contractor received all the steel baskets with greased deformed dowels or tie bars. Where the designer had specified a smooth dowel bar, the delivered material was a deformed bar; at locations where an ungreased deformed bar had been specified, a greased deformed bar was received.

Design firms in Pennsylvania have stopped using the PENNDOT Publication 407, consequently, as of the time of this writing. The field investigation concluded, however, that the grease coating of the deformed bars was the fabricator's error.

We asked the designer to analyze the effects of the coating on the steel and the effects of using the deformed dowel bars in lieu of smooth bars in order to avoid significant project delays and associated air traffic delay costs. After several discussions with experts in the field and given the nature of the runway's prime purpose (visual, cross-wing runway for light aircraft), the designer accepted the joints steel as received from the fabricator because there were no anticipated impacts to the life of the runway pavement.

Cracks Develop in the Concrete

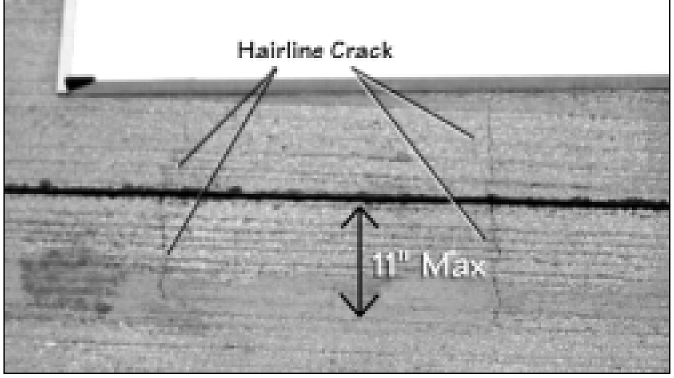
In placing the concrete pavement, ready-mixed-concrete trucks approached the fully automatic Bid-Well paver adjacent to the paved area of the runway and dumped the concrete onto a conveyor belt hopper. The concrete was conveyed laterally for up to 15 m (50 feet), and the operator controlled the point of discharge. The paver speared, vibrated and finished the concrete slab, then advanced forward. Concrete finishers performed minor manual touch-up work at the edge of the pavement and sprayed the curing compound on the fresh surface. Within the safety area of the intersecting Runway 10-28, however, concrete placement was done manually with hand-held vibrators and a 8-m- (25-foot-) wide finishing roller screed.

Figure 2: Paving Train

The productivity rate of this paving train (Figure 2) was high, with up to 610 m (2,000 feet) of pavement being placed per night, when most of the paving was done to allow the 8-km (5-mile) haul from the concrete plant to the site to take place with no delays. The majority of the paving activities were completed within two weeks.

Each night's paving activities were followed within 12 hours by the "green" cut of the concrete surface. Widening of the original joint cut followed. The saw cutting generated concrete slurry that covered the concrete surface, so cleanup of the surface was required before the joint material was placed.

Figure 3: Hairline Cracks Appeared Adjacent to Transverse Joints



We noted several hairline cracks adjacent to transverse joints during these cleanup operations (Figure 3). The cracks appeared to be surface cracks ranging from 100 mm (4 inches) to 300 mm (12 inches) in length. They were located directly above the dowel bars. Core samples taken immediately indicated that the cracks were 25 mm (1 inch) to 38 mm (1.5 inches) deep. In some places the cracks went down to the top of the dowels. They occurred only in places where the Bid-Well paver had been used for concrete placement.

Our Investigation Turns Up Several Possible Causes

Some theories we considered as explanations for the formation of the cracks include the following:

- The pavement over the steel might have cured faster that the rest of the pavement, with the steel dowels acting as moisture barriers.
- The vibration rate on the Bid-Well paver might have been set too high, causing uneven vibrations over the steel dowels. This could have caused segregation of the aggregates, resulting in additional shrinkage.

- Vibrators touching the dowel baskets might have caused a localized mix segregation that could have promoted excessive shrinkage.
- The dowel baskets might have rebounded as the paving head moved above them.
- The dowel baskets might have tipped, leaving the dowels grossly out of alignment and possibly shifted close to the concrete surface.
- The surface might have torn as the paving head moved above the baskets.
- Settlement cracks, as described in the ACI 224R-38, "… are the natural result of heavy solids settling in a liquid medium."

Rebar locators used to confirm the locations of the dowel bars indicated that they were perpendicular to the joints and in a horizontal position, as designed. The concrete cover was within the design tolerance of 16 mm (5/8 inches).

Related Web Site:
http:// www.concrete mender.com

Microscopic-level petrographic examination of the hardened concrete was performed to determine the probable cause of the crack formations and to predict future performance. Concrete cores were taken from a cracked section of the runway and tests were performed in accordance with the American Standard Test Method C856. The results showed that the cracks were formed very early during the concrete curing process—the top surface had hardened prematurely because it lost moisture to evaporation faster than the moisture could be replenished by bleed water.

The concrete mix had a relatively low water content. The paving was performed at night, which reduces the chance of dry shrinkage, but the airport is situated in an area subject to constant wind conditions. These conditions may have contributed to the quick evaporation of water from the concrete.

The rate of application of the curing compound met the specifications requirements, but the time gap between the placement of the concrete and the placement of the curing compound may have been the cause of the cracks.

We concluded that most probable cause of the cracks was that the concrete surface shrank more quickly than it was supposed to. Windy conditions caused the surface to dry out too quickly, which caused shrinking and cracking. We also concluded that this was a highly localized condition, and the majority of the runway surface was acceptable.

Lessons Learned

1. Do not use FAA specifications that are modified to another industry's specifications, such as PENNDOT Publication 407—or use them only with extreme caution.
2. Identify long-lead items in the project early on and communicate the design intent with the contractor.
3. Apply curing compound as early as possible to fresh concrete surface to minimize premature water evaporation.
4. Consider using Roadware 10-Minute Concrete Mender™ for hairline crack repairs.

A Search for the Best Repair Method

It was determined that a crack repair method should be identified and analyzed as a potentially acceptable solution instead of removing and replacing the cracked slabs. We led the search and performed analysis and testing.

The American Concrete Paving Association suggested an epoxy injection repair that had been used successfully in Denver to repair shrinkage cracks in a new airport runway surface. With the contractor's help, we identified and tested two possible epoxies. Both manufacturers' representatives demonstrated their products by repairing a dozen cracks each. Post-injection testing was performed by analyzing cores from the test sites.

Based on visual examination of the penetration depth of the material, the polymer product, Roadware 10-Minute Concrete Mender™ from Elas-Tech was selected for further testing. It had penetrated to the bottom of the crack easily with its low coefficient of viscosity. It was also applied easily with an application gun and did not require preparatory steps for the crack. The polymer stained the concrete surface amber, however, so we used cement powder to absorb excess material and minimize staining.

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