

Case Studies in Accelerated Practices for Airfield Concrete Pavement Construction

David Peshkin¹, Monty Wade¹, James Bruinsma¹ and Norbert Delatte², Member ISCP

Abstract

Case studies have been developed to form the basis for a *Guide for Accelerated Practices for Airfield Concrete Pavement Construction* for the Innovative Pavement Research Foundation. First, a comprehensive list of accelerated airfield concrete pavement projects was assembled. From this list, a shorter list of detailed case studies was developed. These case studies were developed through site visits and telephone and electronic mail interviews. Techniques that have been used to accelerate concrete airfield pavement construction include the use of high early strength concrete, the temporary use of precast panels, innovative contracting practices, design and construction innovations, and creative planning and phasing solutions. The case studies provide valuable documentation of the lessons learned in the implementation of these strategies. The *Guide* will be of interest and value to anyone who is contemplating either new PCC pavement construction or the maintenance, rehabilitation, or reconstruction of an existing PCC pavement under operational constraints.

Introduction

Portland cement concrete (PCC) has been the material of choice for pavement construction at many airports for many years. When it is used, PCC pavement is favored over hot-mix asphalt (HMA) for several reasons, including:

- Ability to carry heavy loads without deforming under temperature extremes.
- Greater resistance to environmental effects.
- Less need for maintenance.
- Longer life without rehabilitation.

Nonetheless, eventually PCC pavements do deteriorate and must be maintained, rehabilitated, and reconstructed. Many of the airports in the United States operate at or near capacity, however, and the maintenance and rehabilitation of PCC pavements, or even reconstruction of existing pavements with PCC, has become

¹ Applied Pavement Technology, Inc., 3010 Woodcreek Drive, Suite J, Downers Grove, IL 60515-5415, email: dpeshkin@pavementsolutions.com

² Associate Professor, Civil & Environmental Engineering Department, Stilwell Hall, Euclid Avenue at East 24th Street, Cleveland State University, Cleveland, Ohio – 44115, email: n.delatte@csuohio.edu

increasingly problematic at busy airfields due to the length of construction normally associated with PCC.

Over the years, a suite of tools and techniques has been developed to address this perceived shortcoming of PCC. Sometimes grouped under the general heading of “accelerated rigid paving construction and rehabilitation techniques,” these tools and techniques are more than just the use of modified concrete mixes materials with early opening times. Although they may include the use of rapid-setting, modified Type I and II cements, Type III cements, or even more exotic cementitious materials, there are many other strategies that are applied to accelerate a PCC paving or repair job, including improvements in planning and coordination of work activities, more efficient sequencing of construction steps, alternate pavement cross section designs, more effective methods of monitoring the in situ PCC strength, and the application of appropriate criteria for early opening to traffic.

While accelerated techniques have been developed and used for at least two decades, there has never been any attempt to collect and disseminate information on these techniques in a formal manner. With the support of the Innovative Pavement Research Foundation (IPRF), a *Guide* has been developed to address that gap. The *Guide* includes detailed case studies of completed projects, extending back to 1990. The selection and development of the case studies is discussed further below.

Research and Practical Significance

The eventual product of this research will be a guide for accelerated concrete pavement techniques for PCC airfield pavement. This guide, whose target audience includes airport owners and operators, planners, designers, and contractors, will be based on the actual experiences of that target audience, and will be of interest and value to anyone who is contemplating either new PCC pavement construction or the maintenance, rehabilitation, or reconstruction of an existing PCC pavement under operational constraints.

Methodology

In the first task of this project, the research team identified airports where potential “fast-track” or “accelerated construction” concrete projects have been undertaken. The initial data collection efforts involved a literature search utilizing available search engines (such as TRIS, the American Society of Civil Engineers [ASCE] database, and others) in order to obtain as much information as possible from publicized projects. Materials obtained in this search included Transportation Research Board records, proceedings from ASCE, Federal Aviation Administration (FAA), Airport Consultants Council (ACC), and American Association of Airport Executives (AAAE) conferences, and several industry guides (such as American Concrete Institute’s [ACI] *Accelerated Techniques for Concrete Paving* and American Concrete Pavement Association’s [ACPA] *Fast Track Concrete Pavements*).

Several aviation industry web sites were also searched during the literature review. Web sites included industry associations (such as ACPA, Portland Cement Association [PCA], Airports Council International – North America [ACI-NA],

AAAE, and others) and publications (such as *Concrete International*, *Roads and Bridges*, *Concrete Construction*, *Engineering News Record*, and others). The project team's experience with accelerated concrete paving projects provided several potential projects, as did the IPRF's technical panel and direct communication with other engineers in the aviation community.

The literature review and team members generated 42 potential airport concrete paving projects. This initial data collection effort was followed by a more comprehensive outreach. Using the resources of the IPRF and the project's Technical Panel, direct requests to identify projects that included accelerated techniques were e-mailed to the FAA, and to members of ACC, ACI-NA, and ACPA (contractor members).

These requests resulted in the identification of 26 potential accelerated airport concrete paving projects. Although several of these responses were duplicates of projects previously identified through the literature review, in most cases they provided valuable contact information and additional project information. Numerous initial contacts were made during this task to obtain preliminary project information.

In the case of certain highly publicized projects (such as runway construction at Memphis International Airport, Hartsfield-Jackson Atlanta International Airport, and Sky Harbor Phoenix International Airport.), the majority of preliminary information was taken from the available literature. For projects with less readily available information, more emphasis was placed on direct contact with individuals involved with the project. For these projects, information was obtained by discussing the project with the contact person by phone.

Once all potential projects were identified, the list was reviewed and projects were identified for more in-depth study. Several criteria were established for determining whether to include the project in the study:

- Does the project demonstrate fast-track techniques? Is the project faster than the "normal" construction process?
- What is the contribution of the identified project? What aspects of the project demonstrate that "accelerated" criteria are used? Does the project meet multiple criteria?
- Does the project meet the research study variables as established in the project variable matrix (such as airport classification, facility type, type of construction, and so on)?
- Does the project demonstrate proven techniques? Has the project been completed successfully?

The initial consideration is whether the project was completed faster than "normal." As might be expected, however, the distinction between "normal" and "accelerated" is not always clear-cut. In some cases, a project that is considered accelerated by one agency might not be considered accelerated by another. For example, Memphis International Airport reconstructed Runway 18R-36L in less than 9 months; however, Hartsfield-Jackson Atlanta International Airport reconstructed Runway 9R-27L in just over 33 days. Another example is that the Atlanta airport now uses a rapid setting concrete as their "standard" mix specification, so this is now "normal" construction for that agency.

Project phasing turned out to be an important consideration for several accelerated construction projects. Phasing has allowed concrete construction to take place where it may not have been considered a viable option due to time constraints. For example, Detroit Metropolitan Wayne County International Airport has performed extensive apron construction, but with a complex phasing plan was able to follow conventional concrete construction practices. The phasing requirements didn't accelerate the construction, but did help make it possible. Although several projects similar to this were identified, the research team tried to select projects that demonstrated a fast-track construction process compared to conventional practices.

From the project list developed, a shorter list of projects was selected for site visits. Each site visit team generally comprised two investigators. Subsequently, additional projects were selected for telephone and electronic mail interviews. The projects investigated are listed in Table 1. Only a few of these projects are discussed in this paper, but all will be documented in the *Guide*.

For each project, representatives of the owners, contractors, engineers, or consultants were contacted. Once the interviews were completed, detailed case studies were written for the *Guide*. Case studies and project findings are discussed further in the following sections reviewing high strength concrete, temporary use of precast panels, and planning and scheduling solutions.

High Early Strength Concrete

The use of high early strength concrete for airfield paving is becoming increasingly common. Examples and typical flexural strength requirements include:

- 4,500 kPa (650 psi) in 3 days for Hartsfield-Jackson Atlanta International Airport, Runway 9R-27L (1999)
- 4,500 kPa (650 psi) in 48 hours for Airborne Airpark in Wilmington, Ohio (1999)
- 4,800 kPa (700 psi) in 3 days at Cincinnati-Northern Kentucky during construction of Taxiway M tie-ins to existing runways (2002)
- 5,200 kPa (750 psi) in 3 days for slab replacement at Indianapolis International Airport (2002)
- 3,100 kPa (450 psi) for opening to traffic and 4,500 kPa (650 psi) at 3 days for JFK International Airport (1998) (Jansen, 2001)
- 5,200 kPa (750 psi) in 6 hours for Washington Dulles International Airport, Runway 12-30 slab replacement (2003)

Table 1. Airfield Projects Investigated

Airport	Project Name
Airborne Airpark	Runway Reconstruction
Charleston International Airport	Reconstruction of intersection of Runways 15-33 and 3-21
Cincinnati/Northern Kentucky International Airport	Taxiway M Reconstruction
Cleveland Hopkins International Airport	Runway 6L-24R
Colorado Springs Municipal Airport	2001 Runway and Taxiway Patching
Columbia Regional Airport	Runway 2-20 Repairs
Dallas-Ft. Worth International Airport	Runway 17L Extension
Denver International Airport	Runway 16R-34L
Detroit Metropolitan Wayne County International Airport	Deicing Apron
Hartsfield-Jackson Atlanta International Airport	Runway 9R-27L Reconstruction
Hartsfield-Jackson Atlanta International Airport	Reconstruction of Taxiways F and L
Indianapolis International Airport	FedEx Apron Repairs
John F. Kennedy International Airport	Taxilane L-A Reconstruction
Louis Armstrong New Orleans International Airport	Runway 1-19 Rehabilitation
Memphis International Airport	Runway 18R-36L Reconstruction
Miami International Airport	Runway 8-26
Mineta San Jose International Airport	Runway 12L-30R Extension
Phoenix Sky Harbor International Airport	Runway 8-26 Reconstruction
Savannah Hilton Head International Airport	Reconstruction of intersection of Runways 9-27 and 18-36
Seattle-Tacoma International Airport	Runway 16R-34L Repairs
Washington Dulles International Airport	Runway 12-30 Repairs
William P. Hobby Houston Airport	Reconstruction of intersection of Runways 12R-30L and 4-22

Airborne Airpark. One example of the use of high early strength concrete for airport runway reconstruction is the 1999 Airborne Airpark Project. Airborne Airpark/DHL in Wilmington, Ohio is a World War II-era airport that has passed through several owners since it was decommissioned in the 1960s. The airport is currently owned by

DHL (formerly Airborne Express) and is used as an air freight sorting and routing center. In the absence of alternate facilities, it is imperative to its owner that this airport operate at or near full capacity at all times. Runway 4L-22R, on which this project occurred, was nearing 60 years old and was exhibiting severe deterioration.

The construction window agreed upon between the contractor and the owner was from 7 a.m. Saturday through 10 p.m. Monday, with construction between August and 1 December 1999. The contractor developed several trial mixtures, with up to 530 kg/m^3 (900 pounds per cubic yard) of cement. The trial batches achieved 24-hour flexural strength in a range from 3,600 to 5,500 kPa (525 – 795 psi) and 48 hour strength from 4,800 to 6,000 kPa (690 – 870 psi).

The general concept that the contractor developed was to pave a one-panel wide (7.6-m, 25-foot) strip transversely to the pavement centerline during each closure. The existing pavement would be removed, the base would be reworked, and the new pavement would be constructed one “row” at a time. Paving transversely is generally not recommended because of the roughness associated with each construction joint, but the contractor addressed the associated roughness from every transverse joint being a construction joint by also including diamond grinding as part of the project. A plan view of a one-panel wide transverse strip is provided in figure 1. After the first weekend of work was completed without any problems, the contractor decided that he could complete two “rows” or strips in a single closure. Eventually up to four strips were paved in a single weekend.

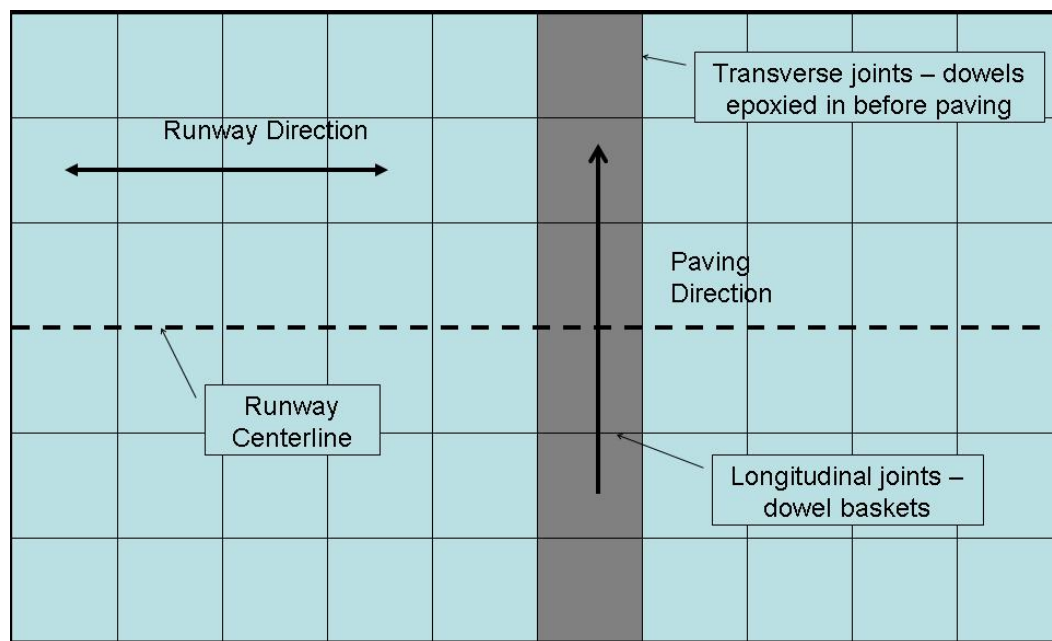


Figure 1. Transverse paving at Airborne Airport.

Prior to the construction the contractor held meetings with crews to go through all possible “what ifs” that could delay the project. As part of the planning process, the project schedule was prepared on an hourly basis. Mechanics were included in the planning sessions, to help anticipate what equipment problems could

be expected and what back up equipment would therefore be necessary. Because of all of the weekend work, one of the contractor's concerns was the availability of replacement equipment in the event of a breakdown. The contractor decided to keep backup equipment on site, including a second concrete plant and a second guillotine paving breaker. Arrangements were even made for backup cement supply for Sunday work in case the concrete plants ran low on cement.

Cincinnati-Northern Kentucky. The Cincinnati/Northern Kentucky International Airport was constructed during World War II as a military training airfield and later converted to civilian use. In its current configuration, it has two North-South runways and one crosswind runway. Runway 18L-36R and Runway 18R-36L are 3,050 and 3,350 m (10,000 and 11,000 feet) long, respectively. The crosswind runway, Runway 9-27, is 3,050 m (10,000 feet) long. The airport is served by ten national and international commercial airlines, and is a Delta Airlines hub as well as a DHL package-sorting hub.

Runway 9-27 is used by larger aircraft, including cargo planes, and is the airport's preferred nighttime arrival runway because of noise issues. Extending Taxiway M west across Runway 18R-36L provided arriving aircraft with an exit to the south, without crossing an active runway. The new taxiway also allowed greater flexibility for aircraft arriving on Runway 18L, making it easier to avoid congested areas in the east terminal area when taxiing to the terminal apron. Taxiway M was extended 1,280 m (4,200 feet) to the west, parallel to Runway 9-27.

The specific accelerated aspect of the project was the four tie-ins between Taxiway M and the runway, because on one side of the runway the entire pavement outside of the keel section had to be removed for the tie in. The runway had a thicker keel section (400 mm, 16 inches) and a thinner edge (250 mm, 10 inches) of PCC pavement which had to be removed and replaced to provide sufficient thickness for the taxiway connection.

The interference of the Taxiway M construction with the runways was a key planning consideration. Therefore, the project consisted of five separate phases, as follows:

- Phase 1 (and entire project): extension of Taxiway M, all paving outside of the 76 m (250-foot) safety areas of Runways 9-27 and 18R-36L.
- Phase 2: tie ins with Runway 9-27
- Phase 3: tie in with Runway 18R-36L
- Phase 4 (starting simultaneously with phase 3): connection to existing Taxiway M
- Phase 5: realignment of a short existing portion of Taxiway M

The second and third phases impacted traffic and had to be accelerated. Because the runway had to be closed to build the tie-ins, the contractor was only allowed 24 days for phase 2. A \$10,000 per day bonus/penalty for specific phases was established. Penalties for the entire project and for phases 4 and 5 were \$1,000 or \$2,500 per day, with no bonus.

The taxiway pavement cross section was designed as 450 mm (18 inches) of P-501 PCC pavement, 150 mm (6 inches) of P-306 or P-401 stabilized base, and 150 mm (6 inches) of P-209 aggregate subbase. The contractor proposed eliminating the

stabilized base layer within the runway safety area in order to speed construction, and proposed increasing the P-501 PCC pavement to 500 mm (20 inches) and the P-209 aggregate subbase to 200 mm (8 inches) for the taxiway within the runway safety areas.

For the outer section of Runway 9-27, the original design called for a 100 to 200 mm (4 to 8 inches) overlay of P-401 bituminous leveling and surface course over 400 mm (16 inches) of PCC pavement, supported by 150 mm (6 inches) of P-306 or P-401 stabilized base and 150 mm (6 inches) of P-209 aggregate subbase. Again the contractor proposed a revised pavement section, increasing the P-501 PCC pavement to 450 mm (18 inches) and the P-209 aggregate subbase to 200 mm (8 inches), eliminating the stabilized base. Removing the stabilized base layer from the pavement structure made it possible to speed construction.

Houston Hobby. In some cases the use of high early strength concrete has led to premature deterioration of the pavement. A runway intersection was constructed in 16 days at Houston Hobby Airport in 1994 (Godiwalla, 1997), but by the end of the 1990s the intersection was deteriorating significantly. The deterioration was attributed to secondary ettringite crystal formation (Godiwalla et al., 2004), and a decision was made to replace the entire intersection. Because of the negative experience from the 1994 intersection replacement, the Houston Airport System and the other stakeholders required proven technologies that would ensure the long-term durability of the pavement.

The basic strategy for the intersection replacement had six elements:

- Closure of the runway intersection: that is, no operations on either Runway 4-22 or 12R-30L.
- Use of PCC capable of attaining a 3,800 kPa (550 psi) flexural strength in 3 days.
- Paving 11.4 m (37.5-ft) wide lanes rather than 7.6 m (25 ft). This reduced the number of paving passes from six to four. The 11.4-m (37.5-foot) paving passes were sawn longitudinally to make panels 5.7 by 6.1 m (18.75 by 20 feet).
- Elimination of the 40-mm (1.5-inch) bond breaker layer that had been used in the 1994 reconstruction. This simplified construction and allowed a thicker replacement concrete pavement.
- Reuse of existing base and subgrade layers.
- Use of adjustable light bases and extensions for the in-pavement lighting.

The intersection reconstruction project was carried out in October 2001. The project goals were met, allowing opening of the intersection with a durable concrete pavement following a tight, 19-day closure window. Using proven materials and techniques had two benefits. First, they reduced the tendency of contractors to add contingencies to their bids to account for unfamiliar techniques. Second, they gave the airport stakeholders confidence that the reconstruction could be completed within the 19-day window, and that this work would last longer than the failed 1994 repair.

Temporary Use of Precast Panels

Precast concrete panels have been used in two ways for accelerated airfield concrete pavement rehabilitation. These are:

- Temporary replacement for removed panels until concrete can be placed during the next scheduled closure, and
- Permanent pavement (selective panel replacement)

Only the temporary use of panels will be discussed in the *Guide*.

Charleston and Savannah. Temporary precast panels were used for reopening to traffic during runway intersection reconstruction at Charleston (S.C.) International Airport in 1990 (Drinkard, 1991) and Savannah/Hilton Head International Airport in 1996 (McGovern, 1998). In each case, the airport had two runways that crossed, and the intersections needed to be repaired (Drinkard, 1991, McGovern, 1998). The Charleston runway intersection is shown in figure 2. Since both runways had to be closed for the repairs, the work was limited to 8-hour night time closure windows. Both pavement intersections were reconstructed during multiple 8-hour overnight closures, using concrete with proprietary high early strength cement. A different type of cement was used for each project.



Figure 2. Charleston runway intersection (photo provided by Gary Skoog, HNTB).

During each closure, two 7.6 by 7.6 m (25 by 25 feet) sections were excavated and two were filled with concrete. Precast panels approximately 3.8 m (12.5 feet)

square (4 per section) or 3.8 by 2.4 m (12.5 feet by 8 feet) (6 per section) were cast before construction, to fulfill several functions:

- Producing the precast panels allowed the contractor to gain experience with and verify the properties and workability of the high early strength concrete
- Panels could be used to open the runway to traffic in the event of an emergency
- Panels were used to speed production—following each overnight closure, one section was filled with precast panels. On the next closure, the panels were removed and the new concrete was placed as two more panels were removed.

The contractor for the Savannah project was able to observe the Charleston project and made improvements to the process.

- Smaller precast panels (3.8 by 2.4 m or 12.5 by 8 feet, 13,600 kg or 15 tons) were used, which were faster and easier to install and remove than the larger, heavier Charleston panels (3.8 m or 12.5 feet square, 20,900 kg or 23 tons). Lighter lifting equipment could be used. These smaller panels are shown in figure 3.
- The contractor used more precast units—enough to close four 7.6 x 7.6 m (25 x 25 feet) panels rather than two. This made it possible to double the production rate per overnight closure.



Figure 3. Precast panels in place, Savannah photo provided by Gary Skoog, HNTB).

Seattle-Tacoma. In 1994, the Port of Seattle (POS) started a fast-track program to replace deteriorated slabs on Runway 16R-34L at Sea-Tac Airport. With only two runways, Runway 16R-34L is critical to operations, particularly during poor weather, so all work had to be completed during temporary closure of the runway from 11:00 pm until 6:30 am the following morning.

The original pavement section consists of 350 mm (14-inch) PCC with 450 mm (18-inch) thickened edges at alternate longitudinal joints (5.7 m long by 6.1 m wide, 18.75 ft long by 20 ft wide), and the existing base is 250 mm (10-inch) thick crushed aggregate. The rehabilitation design called for a 450 mm (18-inch) thick slab, which required the removal of 100 mm (4 inches) of the base aggregate. All joints for replaced slabs are dowelled with 38 mm (1.5-inch) diameter dowels placed 380 mm (15 inches) on-center.

One key consideration during the design was the expected life of the repair. The replacement of slabs on Runway 16R-34L was considered to be a temporary repair. With each night's time constraints, it was determined that the work required the use of rapid setting materials. However, the long-term durability of these materials was uncertain. Since POS had plans for adding a new runway it was anticipated that major, more permanent rehabilitation (or reconstruction) of Runway 16R-34L could be performed after the new runway was operational. Thus, the potential for reduced long-term durability was an acceptable risk to use rapid setting materials and maintain runway operations.

The specifications for the concrete mix required a 3,800 kPa (550 psi) flexural strength in 5 hours and a 4,500 kPa (650 psi) flexural strength at 28 days. There was no specified slump, water/cement ratio, or minimum cement content, but the POS does require an approved mix design and demonstration of the construction methods prior to beginning work on the runway.

Several contingency plans were considered in this work. Temporary pre-cast panels were used to provide a quick pavement surface in case of the need for emergency re-opening of the runway or an inability to place the new concrete slab within the allowed closure (due to a plant breakdown, for example). The contractor is also required to have additional equipment on standby in case of any equipment failures. The POS also established guidelines for allowing reduced aircraft weights if the concrete repairs did not meet the full specified strength by the required opening time.

Full-depth sawcutting was typically conducted the night prior to slab removal, but was not allowed to precede slab removal by more than 72 hours. Once the existing pavement was removed an additional 100 mm (4 inches) of the base material was excavated to make room for the 450 mm (18-inch) pavement. If unsuitable material was exposed during excavation, undercutting was performed. Once the base material was compacted, the contractor either placed temporary panels for reopening the runway or continued the preparation work for placing the concrete.

The temporary pre-cast panels were 450 mm (18 inches) thick with a double mat of reinforcing mesh. Lifting anchors were cast in and recessed so that no protrusions extended above the surface of the slab. Angle iron was also placed along all of the edges to assist with the durability of the panels. Each panel covered one-quarter of a typical slab, and for non-standard slab sizes, temporary filler material

(usually wood) was placed to provide a uniform riding surface with no gaps. A unique feature of the pre-cast panels was the use of adjustable screw jacks to adjust the elevation of the panels and provide a smooth riding surface.

Concrete testing included air content, slump, and temperature. Although slump testing was performed, its applicability with the rapid-set material is questionable. The concrete has a very high initial slump, but the slump changed so rapidly that the time of the test had the greatest effect on the measured slump. The temperature of the mix was used more to assist with quality control for the rapid-set concrete.

Final acceptance and payment for the slab replacement work was made on a per slab basis. Payment factors were based 70 percent on the flexural strength at the time of opening and 30 percent for the flexural strength requirement at 28 days, using the factors in Table 2 and the following formula:

$$\text{Pay Factor} = 0.70 \times \text{Opening Time Factor} + 0.30 \times 28 \text{ Day Factor}$$

Table 2. Strength and Time Factors.

Flexural Strength (psi)	Opening Time Factor	Flexural Strength (psi)	28-Day Factor
550 psi min.	1.00	650 psi min.	1.00
540 – 549 psi	0.90	640 – 649 psi	0.90
530 – 539 psi	0.80	630 – 639 psi	0.80
520 – 529 psi	0.70	620 – 629 psi	0.70
510 – 519 psi	0.60	610 – 619 psi	0.60
500 – 509 psi	0.50	600 – 609 psi	0.50
Below 500 psi	0.00	Below 600 psi	0.00

Note: 1 psi = 6.89 kPa

If the average flexural strength for opening was below 3,800 kPa (550 psi), placement was suspended until the deficiency was investigated and corrections were made. If the average flexural strength was less than 3,400 kPa (500 psi), the contractor would be required to remove and replace the concrete at his own expense. If the 28-day flexural strength was less than 4,100 kPa (600 psi)—regardless of the opening strength—the contractor would be required to remove and replace the concrete at his own expense.

If the runway was not reopened at the required time, liquidated damages of \$10,000 per hour or any portion thereof would be assessed. Additionally, a penalty of \$3,000 per day was established for not completing work within a 50-day schedule. Since this work was first undertaken, there has only been one time that the runway was not reopened near the required time.

The use of accelerated materials and innovative construction methods has resulted in successfully replacing over 400 slabs during nighttime closures and reopening Runway 16R-34L to operations at 6:30 am. However, quick setting materials can be problematic and hard to use. Some of the earliest placed slabs have been replaced due to cracking. Other slabs exhibit cracking similar in appearance to

durability or "D" cracking, with the cracks extending full-depth. There have also been some observations of expansion of the material. Since the repair work was always approached as a temporary repair measure, overall the project has been a success. Replacing deteriorated slabs that pose a safety concern while providing uninterrupted air traffic has been the primary goal, and it has been achieved by using accelerated materials and innovative construction methods.

Planning and Phasing Solutions

For large projects, the techniques discussed above may not be necessary or desirable. Overall reductions in project duration, as well as reductions in the length of critical phases, can be achieved through careful and innovative planning and scheduling.

Memphis. Unlike many other fast-track runway reconstruction projects, the Memphis project required complete reconstruction of all components of the runway. That is, it included reconstruction of the pavement section, reconstruction of the drainage system, addition of an underdrain system, modifications of the approach lighting system and Surface Movement Guidance Control System (SMGCS) lighting and marking, construction of a new electrical vault, construction of a new perimeter road, and the addition of three high-speed connecting taxiways.

In light of the complexity of the project, careful planning, organization, and communication were necessary. These were fostered through constructability and partnering sessions as well as regular meetings. The Airport Authority, designers, and construction managers all had senior and experienced staff—and people very familiar with the project—in the field at all times throughout the project. The FAA also had personnel on site. The key components to the success of this project are noted below:

- Sound planning and preparation.
- Development of contingency plans.
- Good communication at all levels.
- Quick decision-making process.
- Positive attitude and teamwork.
- Strong leader/champion willing to make decisions and accept responsibility.
- FAA cooperation and flexibility.
- Bonus/incentive for re-opening runway ahead of schedule.
- Scheduling flexibility during construction.
- Identifying utilities in advance of construction.

Several projects had to be undertaken and completed well in advance of the runway reconstruction project. Two major projects were completed on the airside pavement system. First, Taxiway M, the parallel taxiway to Runway 18R-36L, was upgraded to function as a runway capable of handling Boeing 727 aircraft. It was designated as Runway 17-35 to avoid potential confusion with pilots. A localizer was installed at each end, a glide slope antenna provided vertical guidance for Runway 35 approaches, and a PLASI provided vertical guidance for Runway 17 approaches. No approach or touchdown lights were provided on the temporary runway. Then,

taxiway traffic was diverted to Taxiway N, which had also been upgraded under a previous contract.

The decision to convert the parallel taxiway to a temporary runway did not come about easily. There was no specific plan in place when the initial discussions to reconstruct the runway commenced, which encouraged innovation and creativity while developing a solution. During this process, there were arguments and conflicts, which in hindsight proved to be instrumental in the process.

The field trailers for the owner's representatives, the engineers, and the contractors were deliberately placed together to facilitate teamwork and communication (and manned continuously during construction). The designers and construction managers were required to assign their project managers to the trailers so that all questions, decisions, new ideas, etc. could be resolved within 24 hours.

The FAA assigned a full time representative to the project and made several key contributions to the project. They allowed construction work to occur within 180 feet of an active runway, instead of the specified 200-feet requirement, in rolling increments of 2,300 feet. This restriction waiver allowed construction of the connecting taxiways without a special closure of an active runway and was instrumental to ensuring the project was completed within the tight schedule. A video camera placed on an arriving aircraft showed that the construction would not interfere with a safe landing.

The contract was awarded 5 months prior to construction to allow the contractor plenty of preparation time. During those 5 months, the contractor was able to finalize agreements with subcontractors and suppliers, move all required equipment to the job site, construct the concrete batch plant, stockpile aggregate, submit all required documents, and participate in the partnering process. While this additional time came at an additional cost to the Airport Authority, since timing was essential on this project the benefits were realized when demolition began on schedule at 4:00 am on the first day of the planned runway closure and the new runway was opened over a month earlier than scheduled.

One of the biggest contributors to the success of the project was the use of a bonus or incentive. It was critical that the runway be restored to full operation by October 31, before Federal Express's Christmas rush. There were no provisions for extensions, including weather, labor disputes, civil unrest, and so on. As further insurance, the Authority offered a bonus of \$1.5 million if Runway 18R-36L was ready for flight check by October 1. An additional \$1 million bonus would be awarded to the contractor if Runway 18R-36L and associated taxiways were re-opened in fully operational condition by November 1. On the other hand, liquidated damages would be assessed if the contractor failed to perform services within the times specified in the contract. If multiple milestones were missed, liquidated damages would be imposed concurrently. This bonus was completely funded by the Airport Authority and was believed to be money well spent.

The entire project was accelerated in comparison to conventional projects through careful planning and scheduling, innovative contracting and cooperation, and ongoing communication throughout all phases. The runway was completely reconstructed and cleared for use a full 39 days ahead of the October 31 deadline, thus avoiding a major impact to operations during Federal Express' busiest time of

the year. In addition, the project cost about \$14 million less than was initially estimated, which was believed to be largely due to allowing a full runway closure rather than reconstructing the runway in phases (Polk and Mitchell, 2003).

Cleveland-Hopkins. As part of a \$ 1.5 billion expansion and renovation program, the airport constructed a new 2,700 m (9,000 foot) parallel runway equipped for category III (CAT III) approaches and designed for Group V aircraft. The new Runway 6L-24R was built in two stages. The first 2,100 m (7,000 feet) of the runway (Stage 1) became operational in December 2002, and the full 2,700 m (9,000 foot) length was opened early in August 2004.

In Stage 2, a number of airfield improvements were added. As a result of these project additions, it was necessary to accelerate Stage 2 construction to adhere to the original schedule. The added items increased the scope to the point where it would have been difficult to meet the original schedule. However, if the work could not be completed during the 2004 construction season, it would be necessary to continue into 2005, with substantial increases in cost and disruption to operations.

In March 2004, a meeting was held between the project management team, the owner, all carriers, and the FAA to coordinate and develop a matrix of forecasted runway and taxiway closures for the Stage 2 construction. The goal was to have two operational runways at all times, with at least one end of each runway with an instrumented approach. The original plan had six separate tie-ins planned, which would have taken 50 or 60 days unless combined. The coordination involved considerable communication and creativity among the City, the contractor, and the consultants.

The combined work reduced costs by improving equipment utilization and providing economies of scale. Coordination made it possible to cancel some weekend closures while adhering to the schedule, reducing costs. Once the matrix of forecasted closures was developed, weekly meetings were held to update the stakeholders on changes to the schedule. With construction complete, this project is deemed a success. The contractor achieved 106 percent pay on Percent Within Limits (PWL) for strength, smoothness, and thickness. The project was also completed on time and \$500,000 under budget.

Early in Stage 1 of the project, the use of high early strength concrete was considered for putting critical taxiway connections into service earlier, but was discontinued for two reasons. The first was that two of the first taxiway connections completed exhibited considerable cracking. The second, and most important, reason was that the use of high early strength concrete was found to be unnecessary. The contractor found that the conventional concrete used for the project usually attained adequate strength in two or three days, so that construction was not delayed.

San Jose (Warren, 1996). In 1991 the San Jose airport decided to extend a runway to handle trans-Pacific flights. The project to extend Runway 12R-30L by 395 m (1,300 ft) consisted of adding 120 m (400 ft) to one end and 275 m (900 ft) at the other. This presented two challenges: pedestrians and motorists needed to be protected from the jet blast from departing aircraft, and the FAA navigational aids at both ends of the runway had to be relocated.

Detailed schedules were prepared to identify critical activities during construction, and bonuses and liquidated damages were specified. The City's construction management staff coordinated activities carefully with the contractor, other City staff, consultants, FAA Airports and Air Traffic personnel, and airlines.

The City of San Jose made an early identification of the critical staff members to manage the construction process. A carefully sequenced program of construction was developed and identified in the bid documents, including seven separate notices to proceed. The City's construction management staff reviewed contract documents and provided further review for constructability throughout the project.

Specifications required the concrete to be produced by an onsite batch plant and placed with a slipform paver. The onsite batch plant avoided the risk of concrete delivery delay due to traffic jams. Monitoring included inspection of plant operations and materials as well as material testing.

Summary and Conclusions

These case study summaries demonstrate that a variety of strategies and techniques are available for accelerating concrete airport pavement construction for either new facilities or rehabilitation of existing facilities. High early strength concrete has been used on a variety of projects and is often associated with accelerated concrete paving, but is just one of many techniques that are available. Another technique discussed here is the temporary use of precast panels to complete repairs in several stages.

Innovative planning and scheduling, alternate pavement cross sections, and innovative contracting and cooperation have also proven to be valuable, particularly for larger projects. The *Guide* that is being developed based on these and other case studies will document the techniques, tools, materials, and other strategies that are currently being used to successfully accelerate PCC airfield pavement projects. It will include guidance on strategies for different types of airport projects (e.g., intersections, panel replacements, runways, and connectors), and different lengths of available closure time.

Acknowledgements

This research was funded by the Innovative Pavement Research Foundation under Project 01-G-002-02-3, *Accelerated Practices for Airfield Concrete Pavement Construction*. The project panel was chaired by James Lafrenz of the American Concrete Pavement Association, and includes Mike DeVoy, Gary Garlow, Earl Gowder, Gary Mitchell, and Jack Scott. The following individuals provided information and documents for the case studies selected for inclusion in this paper:

- Joseph Allega, John Allega, Gary Thomas, and Fred Knight, Allega Companies
- John Bush, DMJM Aviation
- Thomas Clarke, Manager of Engineering Administration, Memphis-Shelby County Airport Authority
- George Fidler, Director of Engineering, Savannah/Hilton Head International Airport

- Adil Godiwalla, City of Houston, Houston Airport System
- Sam Hoerter, AAE, Director of Airport, Charleston
- Duane L. Johnson, Michael Baker Co.
- Jeffrey D. Kyser, Program Management Team, Cleveland-Hopkins
- Mark Manning, Kimley-Horn & Associates, Inc.
- Joseph Polk, Construction Administration Manager, Memphis-Shelby County Airport Authority
- Dan Schlake, AVX Air
- Mike Shayeson, The Harper Company
- Michael J. Sherman, Civil Engineer, Cincinnati/Northern Kentucky International Airport
- Gary Skoog, HNTB, Denver, Colorado
- Jim Thomas, The Harper Company
- Mark Vilem, City of Cleveland, Department of Port Control
- David Webb, Allen & Hoshall
- Michael Zimmermann, Mineta San José International Airport

References

Drinkard, J. L., (1991). "A Concrete Alternative to Runway Reconstruction," *Aircraft/Pavement Interaction: An Integrated System, Proceedings of the Specialty Conference* held in Kansas City, Missouri, September 4 – 6, 1991, ASCE, New York, N.Y.

Godiwalla, A. M., Wengler, F. R., and Bush, J. E., (2004). "Pavement Reconstruction of Main Runway Intersection at William P. Hobby Airport," *Airfield Pavements: Challenges and New Technologies*, Proceedings of the 2003 Airfield Pavement Specialty Conference held in Las Vegas, Nevada, ASCE, Reston, Va., pp. 484 – 506.

Godiwalla, A. M. (1997). "Reconstruction of a Major Intersection of Two Runways Using High Performance Concrete at Hobby Airport," *Aircraft/Pavement Technology: In the Midst of Change*, Proceedings of the 1997 Airfield Pavement Conference held in Seattle, Washington, ASCE, Reston, Va., pp. 313 – 319.

Jansen, M. C. (2001). "Reconstruction of Apron Taxiway Lima-Alpha, JFK International Airport," *Advancing Airfield Pavements*, Proceedings of the 2001 Airfield Pavement Specialty Conference held in Chicago, Illinois, ASCE, Reston, Va., pp. 336 – 345.

McGovern, M.S. (1998). "Smooth landing for runway intersection replacement," Publication #R980124, *Publication Three*, The Aberdeen Group, April.

Polk, J. M., and Mitchell, G. L. (2003). "Fast Track Reconstruction of Runway 18R-36L At Memphis International Airport A Case Study," *Airfield Pavements: Challenges and New Technologies*, Proceedings of the 2003 Airfield Pavement Specialty Conference held in Las Vegas, Nevada, ASCE, Reston, Va., pp. 507 – 524.

Warren, L. (1996). "Extending the Limits San Jose Runway," *Meeting the Challenge: Rebuilding Inner City Airports, Proceedings of the 24th International Air Transportation Conference* held in Louisville, Kentucky, June 5 – 7, 1996, ASCE, Reston, Va.