

An **IPRF** Research Report  
**Innovative Pavement Research Foundation**  
Airport Concrete Pavement Technology Program

Report IPRF-01-G-002-02-3

**Accelerated Practices for Airfield  
Concrete Pavement Construction—  
Volume II: Case Studies**



**Programs Management Office  
5420 Old Orchard Road  
Skokie, IL 60077**

**April 2006**

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The contents of this document reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented within. The contents do not necessarily reflect the official views and policies of the Federal Aviation Administration. This document does not constitute a standard, specification, or regulation.

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## EXECUTIVE SUMMARY

This research report, *Accelerated Practices for Airfield Concrete Pavement Construction*, presents information and experiences about accelerated or “fast-track” PCC paving projects from the airport pavement industry. It is based on detailed case studies that were developed from an extensive list of accelerated projects compiled from available resources in the airfield paving industry, including contractors, designers, owners, and industry representatives.

The key to applying accelerated paving techniques for rigid pavements lies in understanding the available strategies, and in knowing when and how these strategies should be applied. There is a range of materials that are available for accelerating pavement opening times; however, beyond the simple selection of appropriate materials lie many other strategies that can accelerate an airfield PCC paving or repair project, including thorough planning and coordination of work activities, efficient sequencing of construction steps, and application of appropriate criteria for early opening to traffic. While the materials and procedures are not necessarily new, there is very limited guidance on their integrated application in the aviation industry.

This report summarizes much of the experience that is known about accelerated airfield concrete pavement construction projects, based on case studies developed for some of the most important projects. Site visits, telephone and electronic mail interviews, and review of available documents were conducted to assemble as much information for each case study as possible. The information in Volume I of this report, *Planning Guide*, represents the “lessons learned” from the case studies and other reported experiences. Volume I also includes a “decision tool” that is developed based on project variables to help identify techniques that could be beneficial for other accelerated projects. The decision tool also provides information on what case studies are directly related to, or similar to, the selected project variables. The case studies themselves are presented in Volume II of this report, *Case Studies*; they offer detailed information about how the various projects were approached.

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## 1. INTRODUCTION

The primary goals of this project are to collect and document useful information and experiences about accelerated or “fast-track” PCC paving projects from the airport pavement industry (identified as case studies in this document). Volume I, *Planning Guide*, presents accelerated strategies so that a potential user can easily identify projects similar in scope and size and apply the lessons learned from those projects to their anticipated needs.



This document, Volume II, *Case Studies*, presents the detailed case studies themselves (in Appendix A). The projects included in the detailed case studies are selected from an extensive list of accelerated projects compiled from available resources in the airfield paving industry, including contractors, designers, owners, and industry representatives. This database of projects is included in Appendix B. Several key variables were considered in selecting projects for inclusion, including the following:

- **Airport Classification** – The case studies include a range of airport classifications, such as primary commercial airports, non-primary commercial airports, reliever airports, and cargo airports.
- **Facility Type** – Runways, taxiways, and aprons are all represented in the projects. With runways and taxiways in particular, the emphasis is on projects that are performed under time constraints due to the adverse impact of closures on operations. The intersection of two facilities is also a special situation that requires accelerated construction techniques and is represented in the case studies.
- **Climatic Region** – The case studies span a range of climatic regions, with variations in temperature, rainfall, and freezing index. FAA regions have been used to classify climate conditions in general terms.
- **Accelerated Phase** – Projects are selected to ensure that all phases of a project (planning, design, and construction) are represented. That is, some projects include accelerated strategies at all phases, while others may only be accelerated during specific phases, such as the planning phase or the construction phase.





- **Rehabilitation Method** – The case studies include a range of rehabilitation methods, such as major repair and pavement reconstruction projects, as well as new construction.

Site visits, telephone and electronic mail interviews, and review of available documents were conducted to assemble the information for each case study. The results are a compilation of the accelerated techniques that are available and how they have been implemented.

## 1.1. Research Approach

In this project the research team identified airports where potential “fast-track” or “accelerated construction” concrete projects have been undertaken. The initial data collection effort consisted of a literature search using 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. This search produced 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 input from team members resulted in identification of 42 potential airport concrete paving projects, summarized in Appendix B. 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 projects 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, such as by phone calls and e-mail follow-ups.

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

- Does the project demonstrate fast-track techniques? Was the construction 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 (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 projects included in Appendix A were ultimately selected for study and form the basis of this report.

Case studies included in this report are for projects at:

- Airborne Airpark (Ohio)
- Charleston (South Carolina) International Airport
- Cincinnati/Northern Kentucky International Airport
- Cleveland Hopkins International Airport
- Colorado Springs Municipal Airport
- Columbia Regional Airport
- Denver International Airport
- Detroit Metropolitan Wayne County International Airport
- Hartsfield-Jackson Atlanta International Airport
- Memphis International Airport
- Mineta San Jose International Airport
- Phoenix Sky Harbor International Airport
- Savannah Hilton Head International Airport
- Seattle-Tacoma International Airport
- Washington Dulles International Airport
- William P. Hobby Houston Airport

## **1.2. Disclaimer**

This document is based on data found in the published record and information collected from airports, consulting engineers, and contractors. To the extent that the provided information is correct, this document reflects the interpretation of the factual record by the research team. This document is not a specification, standard, or regulation, and should not be used as a substitute for project plans and specifications that are properly designed for any given project.

## **APPENDIX A – CASE STUDIES**

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## **Airborne Airpark (Wilmington, Ohio) Runway 4L – 22R Reconstruction**

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### **General Information**

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Airport: Airborne Airpark

Owner: Airborne Express/DHL

Airport Classification: Cargo

Climatic Region: Wet/Freeze

FAA Region: Great Lakes

Facility: Runway 4L-22R

Description of project: Partial runway reconstruction; addition of drainage system and filter fabric; total of 2,200 ft of runway replacement

Dates of construction: August 1999 to December 1999

Engineer/Designer: None (The Harper Company)

Project Manager/Construction Manager: ABX Air (Owner representative)

Prime Contractor: The Harper Company

### **Project Overview**

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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 as DHL's sole national hub serves as an air freight sorting and routing center. In its current configuration, this airport has two parallel runways that handle approximately 100 aircraft and 4 million pounds of freight per night. In the absence of alternate facilities, it is imperative to its owner that this airport operates at or near full capacity at all times.

At the time of this rehabilitation project, Runway 4L-22R was nearing 60 years old and was exhibiting severe deterioration. The owner hired an outside consultant to analyze all of the concrete surfaces at the airpark, and the results identified that areas of the runway and ramp were in need of immediate repair because of cracking and loss of load carrying capacity. Drainage problems were also noted, with water in runway light cans placing the lights at risk of deterioration.

It was determined that replacing 2,200 ft of deteriorated pavement in the middle of the runway was required. This middle section was performing more poorly than the rest of the runway, probably because it had at one time been the runway end (before a previous runway

lengthening). The owner was concerned about the continuing deterioration of the runway, and also noted that improvement to the runway surface would reduce aircraft maintenance costs.

This project was not a traditionally designed project. Although a consultant assisted with determining rehabilitation boundaries and evaluating rehabilitation strategies, the contractor was brought in early in the process to determine construction strategies and typical design details.

Reconstruction was performed with transverse paving strips using a pavement section based on the existing pavement structure. Reconstruction started with replacing one transverse row of slabs per closure but progressed to four lanes per closure by the end of construction. To address roughness concerns with paving in the transverse direction, diamond grinding and then grooving were performed at the end of construction to provide the final runway surface.

Although there was a higher construction cost associated with the weekend closures (compared to a full runway closure), delays in operations were avoided, which was the primary requirement of the rehabilitation.

## **Key Project Components**

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The key components that contributed to the success of this project are noted below:

- Sound planning and preparation, including development of an hour-by-hour schedule and a thorough prior analysis of all factors that could disrupt the schedule.
- Good communication at all levels.
- Including mechanics in planning meetings to anticipate possible equipment breakdowns.
- Design of an alternative pavement section, without a stabilized base layer.
- Use of a pavement breaker to removing existing concrete more rapidly.
- Use of high early strength concrete.
- Making key backup equipment available, such as an additional concrete plant and pavement breaker.
- Having an arrangement for backup cement delivery for the on-site batch plant.
- Using longitudinal grinding and grooving to attain a smooth surface following rapid concrete construction.

Each of these aspects is discussed in more detail in this case study.

## **Planning**

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As part of the initial pavement evaluation, the owner's consultant evaluated preliminary rehabilitation alternatives and determined appropriate work limits. Since delays at this facility would result in delays at other facilities, it was estimated that any loss in operations could result in a couple of million dollars of revenue loss just for one night of delay. Thus, any alternative that required a closure that would impact operations was dismissed immediately.

The final two alternatives considered were:

1. Extend Runway 22L/4R to provide safe landings and takeoffs of the fleet of aircraft while the work was done in the affected area.
2. Perform individual panel replacement on Runway 22L/4R beginning in the morning on Saturday, with the affected area cured and ready for aircraft by 10:00 pm Monday.

Some PCC panels had already been replaced, including the replacement of a single damaged panel in the runway using a high early strength proprietary concrete over the Labor Day weekend in 1995. This showed the owner that it was possible to replace a single panel in two or three days and reopen the runway to traffic immediately following a weekend closure. Thus, the second alternative was selected.

The owner brought in the contractor early in the project planning and began talking with the contractor in February 1999. In response to the owner's needs, the contractor proposed a 1-month total closure of the runway to do the work. However, as determined previously, the cost to the owner of such an extended closure was unacceptable; the owner's goal was to complete the required rehabilitation and keep the cargo moving at the same level of operations. Based on weekend closures, the contractor developed an alternate proposal that met the owner's needs. While reconstruction over the course of several weekend closures may have been more expensive than conventional construction, the \$4 million cost of the accelerated runway partial replacement was considered reasonable compared to a month's disruption of traffic.

Since any reduction in operations would have a ripple effect on DHL's operations, work occurred during weekend closures that were determined by the operations schedule. Most of the owner's flights occur overnight, and most of those are on weekday nights. The construction window agreed upon between the contractor and the owner was from 7:00 am Saturday through 10:00 pm Monday. This provided a 63-hour construction window each weekend without disruption to flight operations. Construction took place between August and December 1999.

The owner had a high degree of confidence in the contractor's ability to complete the project within the closure windows because they had a working relationship stretching back more than a decade.

## **Design**

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Based on the allowable 63-hour window using weekend closures, the contractor developed an alternate proposal that met the owner's needs. The general concept that the contractor developed was to pave a one-panel wide (25-ft) 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 every transverse joint becomes a construction joint and is likely to contribute to a very rough ride, but the contractor addressed the associated roughness by also including diamond grinding as part of the project. A plan view of a one-panel wide transverse strip is provided in figure A-1.

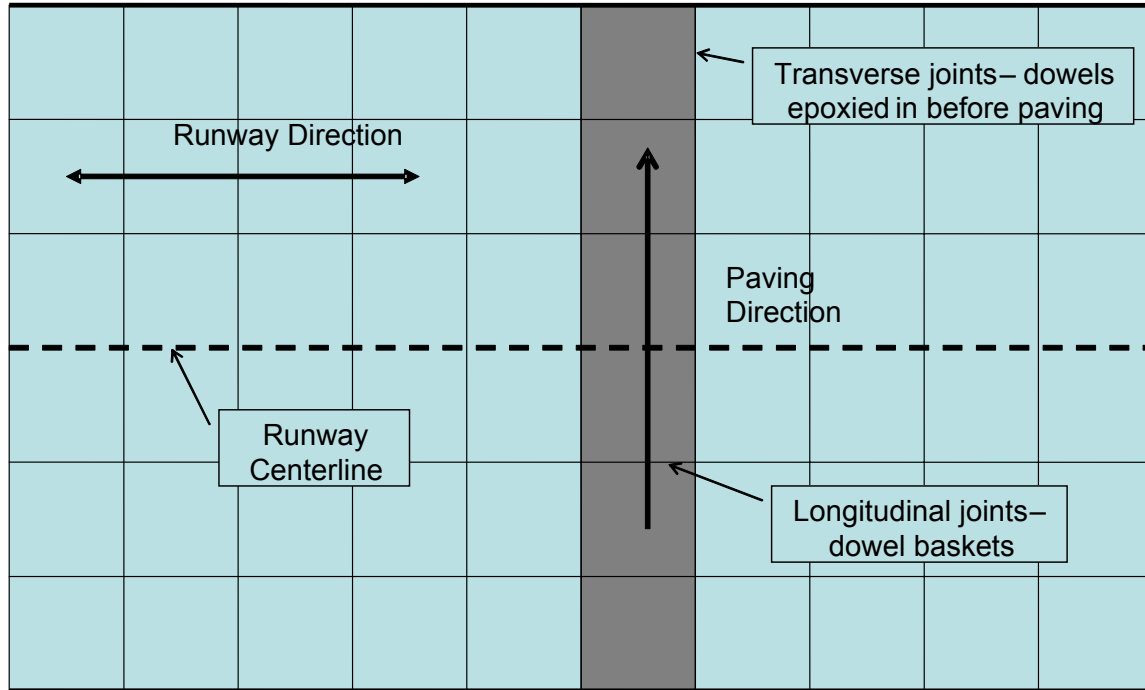


Figure A-1: Transverse Strip Paving

The original World War II-era runway was constructed as a trapezoidal cross section, consisting of approximately 20 to 21 inches of PCC at the centerline, with a taper to approximately 18 inches at the edge. There was some variation in thickness throughout the project. The existing runway consisted of 25-ft by 25-ft slabs, with no reinforcement or dowels. Upon excavation, the base appeared to be gravel, contaminated by the migration of the subgrade. The clogging of the base material had interfered with drainage, as evidenced by the standing water in light cans. The shoulders were constructed with gravel for drainage, but again subgrade migration over 30 to 40 years had made it behave more like compacted earth.

There was no specific design calculation to determine the new pavement thickness; instead, the new cross section was developed based on site and constructability constraints, as well as the performance of the original PCC. The new design developed by the contractor included placing 22 inches of PCC over 8 inches of P-209 crushed stone subbase. A conventional FAA design for this aircraft loading would have included a stabilized base; the replacement pavement used a thicker subbase and a thicker slab to compensate for the absence of a stabilized base. Nor was a design flexural strength a key part of the calculations. In this case it was recognized that the PCC would have a high ultimate strength if 650 psi flexural strength was achieved by the end of the weekend closure window.

Because the level of the subbase was lowered, an underdrain system was installed. A filter fabric was placed under the P-209 stone base to prevent the migration of fines that had clogged the existing base course.



One of the keys to the success of this project was developing a mix with fairly rigorous strength requirements that would also be workable. The 1995 panel replacement, while successful, had shown that the proprietary material used was difficult to work with. The contractor has its own ASTM C 1077 lab, and in planning for this project developed several mix designs, ranging up to 900 pounds per cubic yard of Type I cement. Admixtures from two different companies were tried. Most of the trial batches used a superplasticizer/high range water reducer, although one used a mid-range water reducer. In most cases the slump was 5 to 6 inches. The trial batches achieved 24-hour strengths of 525 to 795 psi and 48-hour strengths of 690 to 870 psi. The final mix design used to achieve 650 psi at 24 hours had 800 pounds of Type I cement per cubic yard.

During construction it proved possible to reduce the cement content by up to 33 pounds while still meeting the strength requirements. In most cases, the strength requirement was met a day early, providing a considerable margin of safety. The flexural strength reports from the project indicate 2-day (45- to 52-hour) flexural strengths of 655 to 715 psi, with cement content reduced to 767 to 783 pounds per cubic yard. The 28-day strengths ranged from 855 to 915 psi. Slump was 5.75 to 6.5 inches, with about 6 % air. The water/cement ratio was approximately 0.27, which is difficult to achieve without a superplasticizer.

## **Construction**

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Prior to the construction the contractor held meetings with crews to go through all possible “what ifs” that could delay the project. The contractor held these meetings since it was the contractor’s responsibility to guarantee the owner that the work would be completed within the window of time allowed, and that the pavement would have achieved the required strength to allow the large aircraft to land on the complete repairs at the end of the allotted time window. The contractor’s operations people had prepared the list of “what-ifs” to address breakdown of key equipment as well as backup supplies for necessary components required to complete the weekend’s work. 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. As part of the planning process, the project schedule was also prepared on an hourly basis.

Cement for the batch plant was the one critical material the contractor was most concerned with. Arrangements were made to take deliveries on Sunday if that became necessary. All other materials were stockpiled throughout the week.

The following are the specific construction steps followed on this project. They are discussed in greater detail below.

- Remove existing pavement.
- Excavate and install underdrains.
- Install a filter fabric.
- Place and compact base.
- Place concrete pavement.
- Saw joints.

### ***Remove existing pavement***

Two methods were considered for removing the existing pavement: sawing and lifting out and breaking up and cleaning out. The lift-out method is often used with accelerated repairs, especially when the base does not need reworking. On this project the contractor felt that sawing the slabs into sections and lifting them out with pins would be too slow, because it required extensive deep saw cutting and the cut pieces of pavement would still be large and heavy. The alternative (which was used) was to rubblize the pavement in place. First, isolation cuts were made around the removal area slab edges, 1 ft in from the edge, to keep from damaging the adjacent pavement. Then the slabs were broken up using a guillotine slab breaker, starting at the center and working toward the outer slab edges. Finally, a backhoe was used to pull the rubblized pavement from the edge toward the hole.

### ***Excavate and install underdrains***

Once the pavement was removed, the underdrain was installed in segments. Edge drains were also installed, and center drains in the light cans were used.

### ***Install filter fabric***

A filter fabric was placed on the subgrade to prevent clogging of the crushed stone subbase.

### ***Place and compact base***

The P-209 stone base was placed and compacted over the filter fabric.

### ***Place concrete pavement***

All joints were doweled, and no tie bars were used. Dowel baskets were used in the line of paving, forming the longitudinal joints as contraction joints. Dowels were drilled and epoxied into adjacent concrete to tie in for transverse joints; thus, the transverse joints were constructed as construction joints. In most cases a four-gang drill was used, with single drills used when necessary to fill in gaps. After the dowels were installed, 1-inch thick Styrofoam was placed against any old concrete to protect the new concrete during demolition. Because of the Styrofoam, some of the slabs were either 1 inch shorter or longer than the standard 25 ft.

Nearly all construction took place on Saturday: all concrete was placed by Saturday night, leaving only control joint sawing for Sunday. Placement of the 22-inch thick concrete pavement required hand work and a large number of vibrators.

Each panel strip had 125 linear ft of sawing. With the high early strength concrete, timing the sawing was important. The saw cut depth was  $T/4 + 0.5$  inch, or 6 inches. Although the contractor uses early entry saws for highway construction, he did not use them on this project because of their sawcut depth limitations.

Because of the high cement content, there was concern about thermal shock and cracking. The use of insulating blankets was considered, but blankets were not found to be necessary. Instead of blankets, a resin-based curing compound was used. Beams were cast to verify opening strength, and broken before opening the pavement to traffic. In many cases the strength was reached by Sunday night, 24 hours ahead of the required opening time. The contractor considered using maturity meters to monitor strength gain, but did not, mostly due to questions about their accuracy at very early ages. The contractor did use FHWA's HIPERPAV software to identify potential curing problems, and found it to be very useful (for more information on this PCC construction analysis software, see [www.hiperpave.xxx](http://www.hiperpave.xxx)).

The contractor's original plan was to pave one section strip per weekend. 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, and the owner and contractor considered paving six strips if weekends were lost to weather. Because of the difficulty of screeding across a 50-ft long double strip, when multiple strips were constructed in a single weekend they were not adjacent to each other.

At the end of October, once all the paving was completed, 0.25 inches of the pavement surface was removed by diamond grinding. This was followed by 0.25-inch grooving, spaced 1.25 inches on center. As noted previously, this sequence allowed the rapid construction of the strips without worrying about achieving smoothness at the transverse joints.

## **Other Issues**

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The contractor undertook this project for a private entity which demonstrated a good deal of flexibility. For example, during negotiations the owner accepted the need to pay overtime for some of the weekend work, and to have backup labor and equipment available. The owner also exhibited a high degree of confidence in the contractor, allowing him to modify the design to meet the operational constraints.

The method of paving in transverse strips developed by the contractor would be applicable to any runway reconstruction, especially with the planned use of diamond grinding to achieve smoothness. The technique would not have worked with an asphalt stabilized base, however, since the hot mix asphalt would not have had a chance to cool prior to placing the PCC; the thicker pavement placed over a crushed stone subbase facilitated the expedited construction. Another aspect to consider would be placing the concrete thicker in anticipation of the diamond grinding.

Lights had previously been retrofitted to the airfield by coring and trenching with conduit. New lights were put in the concrete with a base and cage and steel can, and spliced back into the circuit with flexible couplings.

The contractor was fortunate not to find any problems with the subgrade during pavement removal serious enough to cause delays. If the subgrade was too soft, he was able to undercut it

and replace it with P-209 aggregate and still drain the bottom of the base to keep it from trapping water. This problem was rare.

Obviously, the contractor was concerned with the potential for inclement weather. Fortunately only one weekend was lost when the forecast was highly probable for weather that would potentially create a problem with making the repairs. In any case, once the breaker began to take the existing pavement apart, the contractor was committed to work through any rain in order to have the runway open again by the specified time on Monday evening. While there were some rain showers during some of the work, there were not any big rainstorms, nor did the weather get cold enough to cause problems with concrete curing.

## **Summary**

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This project is considered a success by both the owner and the contractor. The owner's concerns about loss of service and slowed or cancelled deliveries never materialized due to the project's progress. The contractor showed that he could do the work as planned, and moreover, that his productivity could be increased fourfold over original projections.

There is no good way to measure the financial savings associated with this project. However, since the contractor had originally estimated a 1-month closure for conventional construction methods the potential losses could have been enormous; or, put another way, since all of the work was performed over the weekend when it did not adversely impact operations, the potential savings were enormous. If the work had been done in a single, month-long closure, it is likely that the owner would have had to relocate ground operations to a different facility to minimize the impact of delays. The costs of such a move would also have been substantial.

The airfield operations could not be impacted at all since that is the sole business of the airfield. Maintaining the same level of operations was a requirement. Work-arounds helped with the decision made by management. Cost was also a major factor. Even though the business incurred increased cost for material and weekend work, risk to the operation mitigated that factor. Delays in arrivals or departures would cause delays in Wilmington and that would cascade throughout the network causing even larger delays. This would mean late deliveries and lost revenue, which could have easily cost a couple million dollars just for one night of late operations.

Once demolition of the existing pavement began, the contractor was committed to opening the pavement by 10:00 pm the following Monday. 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. As stated previously, arrangements were even made for backup cement supply for Sunday in case the concrete plants ran low on cement.

While long-term performance can not yet be assessed, the pavement is performing very well after 6 years of service. The same contractor adopted some of the techniques used here for the extension of Taxiway "M" at Cincinnati/Northern Kentucky International Airport two years later.

## **Available Sources of Information**

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The project team would like to acknowledge the valuable input and assistance provided by the following individuals:

- Mike Shayeson, The Harper Company (Contractor)
- Dan Schlake, ABX Air (Owner's representative)

The following documents also provided valuable information used in this summary:

- Mix designs and test data provided by The Harper Company

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## **Charleston International Airport Reconstruction of the Intersection of Runways 15-33 and 3-21**

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### **General Information**

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Airport: Charleston International Airport

Owner: Charleston County Aviation Authority/U.S. Air Force

Airport Classification: Small Hub

Climatic Region: Wet/No Freeze

FAA Region: Southern

Facility: Runway/Intersection

Description of project: Reconstruction of the intersection of Runways 15-33 and 3-21 in 67 days, using overnight closures, very high early strength concrete, and temporary pre-cast panels. Removed and replaced 9,500 yd<sup>2</sup> with 3,600 yd<sup>2</sup> using a proprietary PCC mix.

Date of construction: 1990

Engineer/Designer: HNTB

Project Manager/Construction Manager: N/A

Prime Contractor: Scruggs Company

### **Project Overview**

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The original Charleston Airport was located on a former phosphate mine leased from South Carolina Mining and Manufacturing Company. In 1928, the Charleston Airport Corporation was formed to lease approximately 700 acres which was cleared and graded to provide landing strips for aircraft. The privately-owned airport officially opened on August 10, 1929, and in 1931, the City of Charleston floated a \$60,000 Bond Issue to obtain a portion of this property and continue further development of the airfield.

Throughout the 1930s, facility development continued with significant assistance from the Works Projects Administration (WPA). Runway 3-21 was paved to a distance of 3,500 ft; Runway 15-33 was paved to a distance of 3,000 ft; Runway 10-28 (now Taxiway 5) was paved to a distance of 4,000 ft. All runways were lighted with floodlights for night operations.

In 1942, Charleston Municipal Airport was given to the United States Army as part of the Eastern defense program. Full control of the field was vested in the Army Air Corps; however, commercial flying was allowed to continue. During the war, the Army purchased more land and drained and reclaimed other portions of the surrounding real estate. Charleston Army Base was

closed in 1946 as part of the peacetime transition and released its 2,050 acres and \$12 million in improvements to the City.

The Korean War led to the reactivation of a military air base at Charleston. In 1952, the City of Charleston and the United States Air Force (USAF) reached an agreement on control of the Base and joint use of the runways. On January 1, 1979, the Charleston County Aviation Authority assumed control of Charleston Municipal Airport and immediately began the expansion of the civil aviation facilities. Today the airport is situated adjacent to Charleston Air Force Base and uses the airfield facilities at the Air Force Base jointly with the USAF. The airport is one of the country's largest joint use facilities, with the military comprising almost 25 percent of the approximately 100,000 annual operations in 1990. Forty percent of the military's C-141 cargo aircraft capacity is connected to this facility. In 2002, a total of 791,341 passengers were enplaned on the scheduled commuter and charter airlines serving the airport.

The airfield has a main instrument runway (Runway 15-33) which is 9,000 ft long and 200 ft wide, and a crosswind runway (Runway 3-21) which is 7,000 ft long and 150 ft wide. Each runway is equipped with high intensity runway lighting and one runway has category II instrument landing systems to permit all-weather operations. The airport diagram is shown in figure A-2.

Runway 15-33 and Runway 3-21 form an intersecting "V," and by 1989 the intersection was showing significantly more distress than adjacent areas, including slab cracking and faulting in the concrete keel section, and asphalt cracking in the outer section. The USAF decided to shift training missions to other airfields and repair the intersection. However, options for maintaining commercial airport capacity during construction were limited. The intersection of the two runways is approximately 1,100 ft from the Runway 21 threshold and approximately 3,000 ft from the Runway 33 threshold. Due to runway lengths and taxiway system layouts, virtually all aircraft taking off or landing cross the intersection.

Given the many previous changes in stewardship, the exact history of the design and construction of the runways was not available. Cores of the existing pavement found that the controlling pavement section included a 12-inch jointed PCC pavement over 6 inches of crushed aggregate base for the 75-ft wide keel section, with the remainder of the runway 12 to 15 inches of asphalt over granular subbase. The existing PCC pavement was divided into 12.5-ft square panels.

## **Key Project Components**

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Key components of the project included:

- Planning – phasing and scheduling planned and coordinated with Air Force and Charleston County Aviation Authority, coordination with stakeholders, relocation of military aircraft.
- Design – use of thicker section to eliminate requirement for base course and dowels.
- Materials – proprietary rapid setting cement.

- Construction – using a proprietary rapid set cement to cast pre-cast panels to validate mix designs and construction methods, use of temporary pre-cast panels, use of a sacrificial asphalt overlay, surface grinding to produce a smooth profile.
- Other – preparations for adverse weather.
- Innovative construction staging within an 8-hour window.

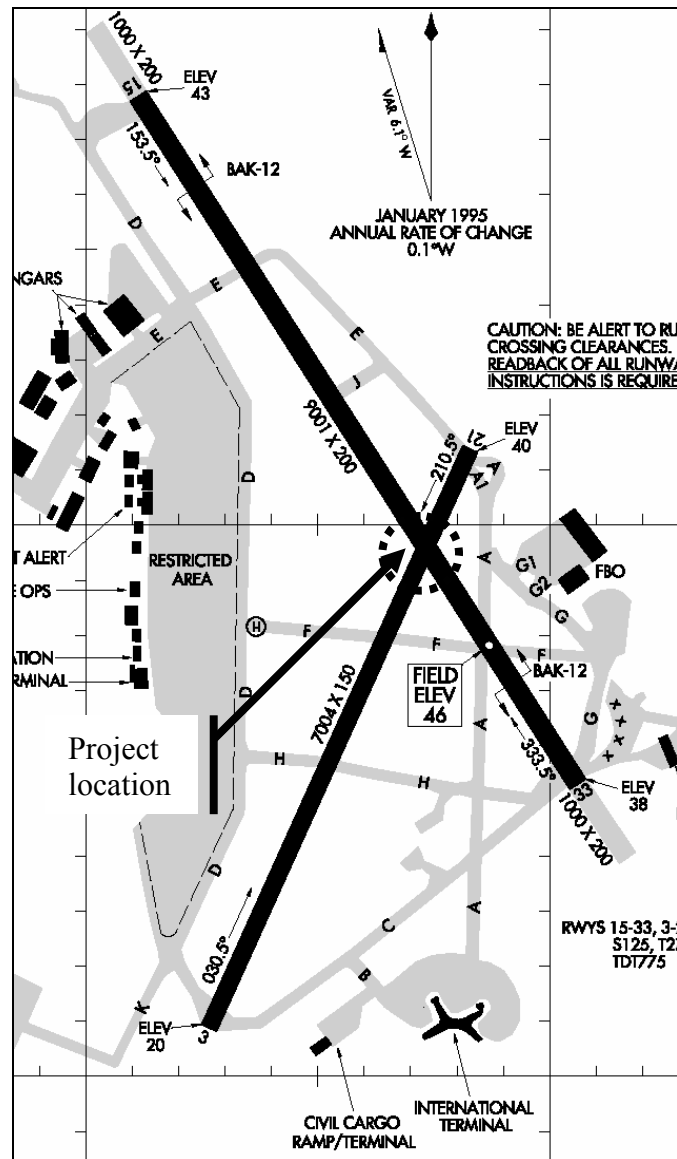


Figure A-2. Charleston International Airport diagram (from [http://www.naco.faa.gov/ap\\_diagrams.asp](http://www.naco.faa.gov/ap_diagrams.asp)).



## Planning

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The Charleston County Aviation Authority and the USAF both favored concrete for the reconstruction because of its durability. However, with PCC it was originally estimated that a 60-day shutdown would be necessary to replace the intersection's 3,600 yd<sup>2</sup>. This would reduce the operable lengths for Runways 15-33 and 3-21 to 5,400 ft and 5,350 ft, respectively.

A complete closure of the intersection would have required the military to halt C-141 training missions and made it harder for civilian air carriers to operate economically. The economic effect of such a shutdown was estimated at over \$100 million. Both civilian and military users rejected the shutdown alternative, but agreed that the runways could be closed for 8 hours each night, opening promptly at 6:45 am the following morning. This would keep one runway open every day for 16 hours, accommodating most of the commercial and military operations (although some C-141 and fighter aircraft were relocated to reduce military use of the airfield during the closure). Based on these constraints, the general consultant for the airport developed a design and construction system that could develop a durable, lasting reconstruction within the closure window. In case of adverse weather or an aircraft emergency, it was also important to be able to quickly reopen the runway.

## Design

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Both the FAA and Department of Defense (Army and Air Force) criteria were considered in developing the pavement design. In order to speed construction, a design that required neither elaborate subsurface preparation nor dowels for load transfer was favored. The FAA design was based on forecast departures through 2008, varying modulus of subgrade reaction values from 150 to 250 psi/in, and 28-day concrete flexural strengths varying from 500 to 1,000 psi. The Air Force design procedure for heavy-load type airfields was checked using the same variables. On the basis of this analysis, the designers found that a 19- to 20-inch full depth concrete thickness would be adequate. Although dowels were originally specified, the thickness design assumed no dowels and the pavement was constructed without them.

The designers worked directly with potential contractors during the design process to address the following potential problems.

- There was not enough time to place base course and shape subgrade if the concrete pavement were to have a minimum cure time of 4 hours before opening the runway each morning. This was solved by specifying a uniform concrete thickness of 24 inches on top of the compacted subgrade, substituting an additional 4 inches of concrete for the specified base course.
- In case of an emergency, such as unexpectedly poor subgrade, weather, or an emergency requiring immediate opening of the runway, the contractor was required to have pre-cast concrete units on site with lifting equipment. This would allow rapid closure of openings in the pavement, allowing the runway to be put back into service quickly. The lifting

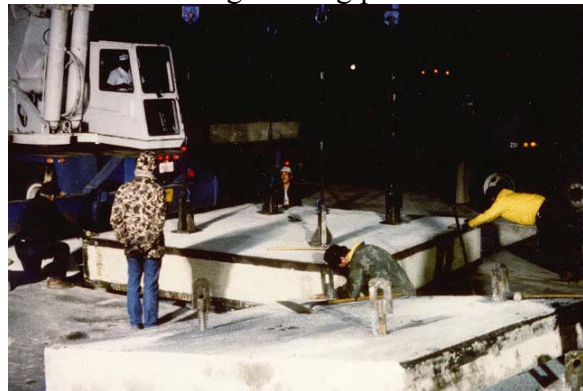
equipment and its use to remove existing pavement and to place the pre-cast concrete slabs is shown in figure A-3.



Crane with spreader bar



Removing existing pavement



Placing pre-cast pavement sections

Figure A-3. Lifting equipment and pre-cast panels.

- It was clear that the slab-by-slab replacement would not produce a smooth surface profile. Therefore, a sacrificial asphalt overlay up to 4 inches thick would be used to set the new grade. Grinding of the concrete pavement would be performed to provide a smooth surface at the end of construction.
- A series of longitudinal underdrains was installed in the runway intersection area in case water was encountered in the subgrade. These were to be installed by trenching through the existing pavement before the slab replacement program began.

Planning focused on the use of a proprietary, rapid-setting blended cement with a 90 to 120 minute set time, achieving a flexural strength of 500 psi within 6 hours after batching. Although this cement was more expensive than ordinary portland cement, the extra cost could be justified by the time savings. The contractor was also required to have a backup concrete plant available, as well as on-site backups for all critical equipment to help ensure the runway was reopened on time each morning.

There are several challenges to using proprietary cements, including the following:

- There are a relatively narrow blend of mix variables which will produce satisfactory strength, workability, and setting time.
- Chemical reactions between the cement and locally available aggregates and water may be unpredictable, and concrete properties need to be verified in the laboratory

The high early strength, quick-setting cement specified was typically used only for small patches and repairs. Therefore, it was necessary to thoroughly investigate the concrete properties before using it on a project of this scale. Based on the laboratory testing, a mix design was developed, consisting of the following:

- Minimum cement content – 752 pounds/yd<sup>3</sup>; specified 90-minute set time. The proprietary cement was available with several different set times.
- Water/cement ratio – 0.22 to 0.26.
- Slump – 5 inches  $\pm$  2.
- Ratio of Grade 67 coarse aggregate to natural sand fine aggregate: 55/45 to 50/50
- Minimum of 6 minutes mixing time

The laboratory tests of this concrete mixture resulted in 500 psi flexural strength ( $\pm$  50 psi) at 5 hours.

One problem that had been previously noted by the proprietary cement manufacturer was a very high degree of bond to steel, which prevented dowels from working normally. Therefore, the designers eliminated the load transfer devices. Eliminating the dowel bars also decreased construction time.

The pre-cast slabs to be used in case of emergency were approximately 12.33-ft squares, designed so that four would fit into a 25 ft by 25 ft hole in the pavement with enough clearance for placement and removal. These slabs were constructed on site using the proprietary blended hydraulic cement concrete, allowing the batching and transporting issues to be worked out in advance of paving. Each slab unit was 24 inches thick with # 10 bars at 6-inch spacing at the top and bottom. Threaded couplers were cast into the slabs for removable lifting devices. Steel angles were cast in to protect the slab edges against impacts from aircraft traffic. Eight pre-cast units were made, enough to close two holes in the pavement.

## **Construction**

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The construction sequence included the following steps:

- Install underdrains.
- Place sacrificial asphalt overlay for grade correction and control.
- Remove existing pavement in 25 ft by 25 ft sections (removing four 12.5-foot square panels).

- Replace pavement using high early strength quick setting concrete in a 25 ft by 25 ft joint pattern.

The first two steps were completed prior to any pavement replacement. The excavation and concrete placement are shown in figure A-4.



Excavating



Concrete placement

Figure A-4. Overview of slab excavation and concrete placement.

The contractor eventually was able to replace two slabs per overnight closure, using the following schedule:

- Close runway (10:45 pm).
- At the start of each closure, one section already had pre-cast panels installed from the previous night's work. These pre-cast panels were lifted out (10:45 pm – 11:45 pm).
- Concrete was placed for the first of two slabs (12:00 am – 12:45 am).
- One set of four 12.5 ft by 12.5 ft panels of the existing pavement was deep sawed and removed. Existing PCC pavement was lifted out with a 75-ton hydraulic truck crane, and existing asphalt pavement was excavated with a track backhoe (12:00 am – 1:15 pm).
- Place second 25 ft by 25 ft slab (1:15 am – 2:00 am).
- Excavate second 25 ft by 25 ft hole and fill with four pre-cast panels to prepare the runway for reopening (2:00 am – 6:00 am).
- Clean up construction area (6:00 am – 6:45 am).
- Re-open runway (6:45 am).

An illustration of the typical condition of the runway intersection following an overnight closure is shown in figure A-5.

The field concrete consistently achieved 500 psi 5 hours after batching, with 7-day flexural strength exceeding 1,000 psi. On the first night, the concrete set in 20 minutes, so a slower setting blend was substituted. This new cement extended the concrete set time to 90 minutes. The proprietary cement concrete was batched in a conventional batch plant offsite and placed using traditional procedures. Special attention was paid to adequate vibration of the concrete,

and use of evaporation retardants to avoid loss of moisture. Of the total area of 9,500 yd<sup>2</sup>, 3,600 yd<sup>2</sup> (52 slabs) were constructed using the proprietary blended hydraulic cement.

Fortunately, the subgrade was in excellent condition and no undercut and backfill was required. The finished pavement was ground to correct surface imperfections and provide a smooth surface profile. The grinding also provided macrotexture to improve surface friction. Joints were sealed by oversawing the joint area, installing a backer rod, and cold-pouring a silicone sealer.



Aerial view of runway intersection



Precast pavement sections in place

Figure A-5. Overview of runway intersection with two slabs replaced; precast panels in place.

## Other Issues

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Outside of the critical intersection area, improvements were made to each runway with traditional high early strength concrete. The main runway (Runway 15-33) was kept open during the construction except for the overnight closures, and the cross runway (Runway 3-21) was closed throughout construction. Since the cross runway was closed, work on it was not limited to the overnight closures. This often left a pavement drop-off near Runway 15-33 within the 200-foot runway safety area, which normally would not have been allowed under Federal Aviation Administration guidelines, but was permitted under an allowance made by the USAF.

Several in-pavement lights were installed during paving. The can assemblies were secured with steel bar hoops. PVC ducts connecting the cans were placed in a subgrade trench.

The project was carried out in early spring, so there was a risk of thunderstorms. Project documents required the contractor to furnish a tent-like structure, 25 ft by 25 ft, capable of protecting a completed panel in the event of a heavy downpour. However, while construction was cancelled on several nights when rain was forecast, in general weather did not affect operations. The tent was never used, and it would probably not have been practical to deploy it in the face of a thunderstorm anyway.

## Summary

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The project was completed in 67 days, which was 9 days ahead of schedule. The 6:45 am opening was achieved after every closure. One B-727 landed on the new pavement 4 hours after set with no incident.

The pavement was inspected at 3 and 7 months after construction. Pavement performance appeared excellent, with no signs of distress. Some small imperfections were observed, mostly problems with consolidation and joint treatment. No early maintenance was required, although over time, the joint seals have required some maintenance.

In a telephone conversation on November 17, 2004, the Director of the Charleston Airport, confirmed that the intersection was still in excellent shape after 14 years of service and had required virtually no maintenance. Both of the runway users, the USAF and the Charleston County Aviation Authority, have been pleased with the performance of the intersection. The engineer and contractor both considered the project a success.

Although the proprietary blended hydraulic cement concrete cost three to four times as much as conventional concrete, in this instance the much greater cost of a runway closure was avoided. The project included very high liquidated damages/penalties, which were never applied. Overall, the project was judged to be successful and similar methods were used a few years later at the nearby Savannah/Hilton Head International Airport.

## Available Sources of Information

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Interviews with several key individuals involved in this project were held by telephone and email. The following individuals provided much of the information presented in this case study document:

- Gary Skoog, HNTB
- Sam Hoerter, AAE, Director of Airport, Charleston
- Brian Summers, Summers Concrete Contracting, Inc. (formerly with Scruggs Company)

The following documents also provided valuable information used in this summary:

- Drinkard, J.L., "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, 1991.
- Photographs provided by Gary Skoog, HNTB.

The following web sites also provided valuable information used in this summary:

- <http://www.chs-airport.com/aphist.htm>
- <http://www.chs-airport.com/facilities.htm>



## Contacts

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## **Cincinnati/Northern Kentucky International Airport Taxiway M Extension**

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### **General Information**

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Airport: Cincinnati/Northern Kentucky International Airport

Owner: Kenton County Airport Board

Airport Classification: Large Hub

Climatic Region: Wet/Freeze

FAA Region: Great Lakes

Facility: Taxiway

Description of project: New Taxiway M extension with tie-ins to existing Runways 9-27 and 18R-36L; time limits on two critical phases of the project

Dates of construction: July 2002 to November 2002

Engineer/Designer: Kenton County Airport Board

Project Manager/Construction Manager: Cincinnati/Northern Kentucky International Airport

Prime Contractor: The Harper Company

### **Project Overview**

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The Cincinnati/Northern Kentucky International Airport (CVG) was constructed during World War II as a military training airfield. After the war, the airport was converted to civilian use and later the Kenton County Airport Board (KCAB) assumed control of it. In its current configuration, CVG has two North-South runways (Runway 18L-36R and Runway 18R-36L, 10,000 and 11,000 ft long, respectively), and one crosswind runway (Runway 9-27, 10,000 ft 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. The airport diagram is shown in figure A-6.

Runway 9-27 is used by larger aircraft, including cargo planes, and is the airport's preferred nighttime arrival runway because of noise constraints. Prior to the extension of Taxiway M, aircraft landing on the Runway 27 end and taxiing to the south airfield area had to cross the runway, causing an increased risk of runway incursions and reducing capacity because of the need to increase aircraft separations. A new cargo facility in the south airfield area opened in 2003, which substantially increased the number of aircraft landing on Runway 9-27 and taxiing to the south. Initially, 20,000 annual operations were predicted for the south airfield area, increasing to 22,700 by 2011.

Extending Taxiway M west across Runway 18R-36L would provide aircraft arriving on Runway 27 with an exit to the south, without crossing an active runway. The new taxiway would also



allow 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. Accordingly, in 2002 Taxiway M was extended 4,200 feet to the west, parallel to Runway 9-27.

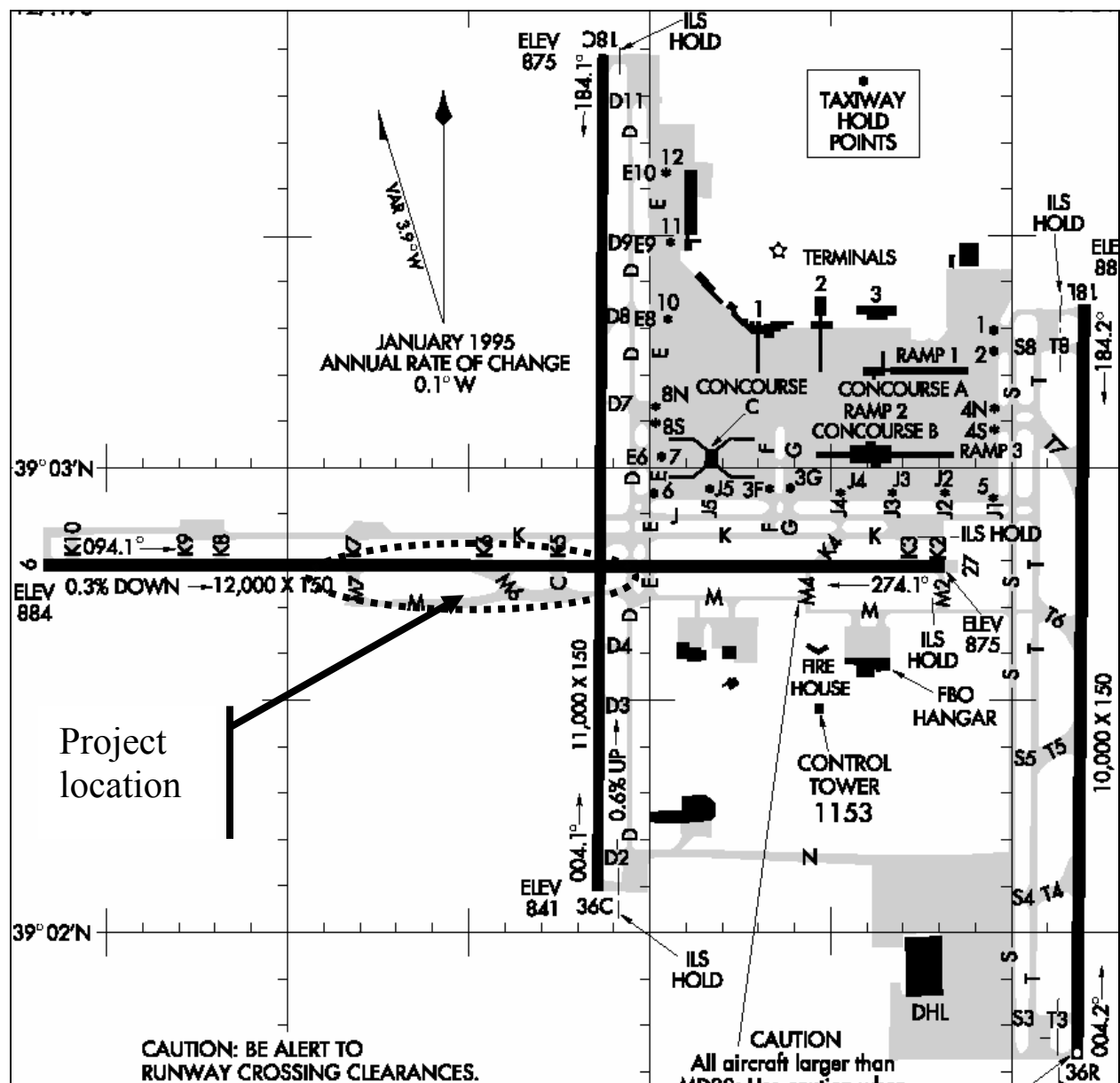


Figure A-6: Airport Diagram (from [http://www.naco.faa.gov/ap\\_diagrams.asp](http://www.naco.faa.gov/ap_diagrams.asp))

In addition to the taxiway extension, connecting Taxiways M6, M7, and C were added, and Taxiway M4 was widened to provide adequate fillets to allow aircraft landing on Runway 9 to exit to the south. Connecting Taxiway M6 is designed as a high-speed exit, for use once the planned 2,000-ft extension to Runway 9-27 is constructed.

The specific accelerated aspect of the project was the four tie-ins between Taxiway M and the runway because of working in the runway safety area and because the runway pavement outside

of the keel section had to be reconstructed for the tie in. The runway pavement had to be reconstructed because the keel had a thicker section (16 inch PCC) than the outer edge (10 inch PCC) and additional thickness was needed to provide sufficient structure. The existing PCC pavement was also covered with an 8-inch hot-mix asphalt overlay.

## **Key Project Components**

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The overall project was fast tracked, with a maximum duration of 4.5 months. However, the phases of the project outside the safety areas of the runways were constructed using conventional techniques. Two phases that impacted the use of Runways 9-27 and 18R-36L had shorter durations. The key accelerated components of this project are noted below:

- Phasing and scheduling to provide time limits for the critical phases of the project.
- Bonus/incentive for opening the runways ahead of schedule.
- Use of an alternative pavement cross-section, eliminating the stabilized base layer and increasing the PCC pavement and aggregate subbase thicknesses to speed construction.
- Use of two concrete mixtures, one for the majority of the construction and one for the accelerated phases.
- Accelerated schedules, with the contractor working 24 hours a day when necessary.

## **Planning**

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Because the construction of the connecting taxiways interfered with the use of Runways 9-27 and 18R-36L, the Airport Board limited the duration of these construction phases and emphasized the importance of adhering to the tight construction schedule through the use of penalties and bonuses.

The interference of the Taxiway M construction with the runways was a key planning consideration. Originally, KCAB planned to avoid closures and use displaced thresholds to keep at least one side of each runway in service. However, the Taxiway C intersection with Runway 9-27, near the midpoint of the runway, did not leave enough room on either side for a usable runway. Therefore, a phasing plan was selected to separate the work within the runway safety area from the other taxiway construction.

The resulting project consisted of five separate phases, as described below:

- Phase 1 (and entire project): extension of Taxiway M, all paving outside of the 250-foot safety area 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.

Phases 2 and 3 impacted runway operations 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. KCAB selected the duration of critical closures based on internal estimates of how quickly a contractor could perform the work.

The project was scheduled to take advantage of projected dry weather. The owner would not have tried to do the accelerated phases in the spring or fall, but the July to September period typically has little rain. Some drainage improvements were also planned in conjunction with the paving project.

There was considerable coordination between the owner, tower, airlines, cargo carriers, and the FAA. Runway 18R-36L was not closed during construction. To minimize the impact on traffic operations, the threshold was displaced to the north by 4,600 ft, leaving 6,400 ft of usable runway. The temporarily shortened runway was then used for smaller aircraft.

## **Design**

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The taxiway pavement design thickness was determined using FAA Advisory Circular 150/5320-6D. A subgrade modulus of reaction (k-value) of 100 (based on a CBR of 3) was used for the design. For the outer sections of the rebuilt runway and the Taxiway M4 widening, the PCC was overlaid with 6 to 8 inches of P-401 asphalt. Most of the existing Runway 9-27 has an 8-inch asphalt overlay on top of 16 inches of concrete.

The new PCC joint pattern was 25 by 25 ft, except for the area to be overlaid with asphalt, which matched the existing joint patterns. Dowels were installed at all longitudinal and transverse joints. The PCC was not reinforced, except for welded wire mesh used in panels with an aspect ratio exceeding 1.25 to 1. A 6-inch perforated underdrain was installed along the edges of the new pavement.

The taxiway pavement cross section was designed as 18 inches of P-501 PCC pavement, 6 inches of P-306 or P-401 stabilized base, and 6 inches of P-209 aggregate subbase. For the outer section of runway 9-27, the original design called for 4 to 8 inches of P-401 bituminous leveling and surface courses over 16 inches of PCC pavement, 6 inches of P-306 or P-401 stabilized base, and 6 inches of P-209 aggregate subbase. This design was used on the runway to remain consistent with the existing pavement structure.

Criteria for acceptance were unchanged, with a requirement for 700 psi flexural strength at 28 days. For drilling dowels, the concrete had to achieve 75 percent strength at about 3 days. The two accelerated phases were constructed with high early strength concrete, with 700 psi at about 3 days required for opening. The main change to QC/QA procedures was that more beams were cast for early breaks.

## Construction

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The contractor proposed eliminating the stabilized base layer in the taxiway pavements within the runway safety area in order to speed construction, and proposed increasing the PCC pavement from 18 to 20 inches and the aggregate subbase from 6 to 8 inches. The stabilized base provided a good working platform for slipforming but was less useful for hand placement, and the contractor used hand placement for much of the accelerated portions of the project.

The contractor made a similar proposal for the runway pavement: increasing the PCC pavement from 16 to 18 inches and the aggregate subbase from 6 to 8 inches, again eliminating the stabilized base.

The contractor presented the alternative designs for the taxiway and runway to the owner, who then checked the design using the FAA AC 150/5320-6D procedure and drafted the correspondence for FAA approval. The cost savings was only about \$10,000, but the time savings, which was estimated as 2 to 3 days per critical phase (for a total of 4 to 6 days) was much more important.

As noted previously, only specific phases involving disruption to operations were fast-tracked, and not the entire project. During the two accelerated periods (phases 2 and 3) the contractor worked around the clock. The phase 2 taxiway tie-ins were finished in 21 days, and phase 3 was finished in 6 days. Projected and actual durations are summarized in table A-1.

Table A-1. Scheduled and actual construction phase durations.

Phase	Duration allowed	Actual duration
1	Entire project – July 1 to November 15, 2002	Substantial completion one day early
2	24 days	21 days (July 20 – August 10)
3	10 days	6 days (September 8 – 13)
4	15 days	6 days (September 8 – 13)
5	30 (48*) days	47 days (August 14 – September 30)

\* A change order added 18 days to Phase 5

Lights were installed after the accelerated construction window, and joints were also sealed later, as opportunities permitted. As a result, this work did not delay the re-opening of the runways.

## Other Issues

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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 contractor earned a \$30,000 bonus for finishing phase 2 three days early, and a \$40,000 bonus for finishing phase 3 four days early. Although this was an FAA-funded project, the bonus was paid by the KCAB since bonuses are not an FAA-allowed expense.

The closure of Runway 9-27 during phase III was another unusual aspect of this project. Due to the short duration of the closure (5 to 6 days) and the fact that temporary markings cannot be permanently removed, the airport used sand to cover markings. Lights that could not be switched off were covered with sand bags.

No weather problems were encountered during construction.

## **Summary**

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The owner considers the project to be a success and expects the performance of the accelerated construction pavement to be the same as that of conventional construction. So far (2 years after construction) there have been no cracking or joint deterioration problems. All project goals for quality and time of completion were met or exceeded.

The contractor also considers the project to be a success and to have been a routine project in most respects, except for the short timeframe for the tie-ins. The contractor's experience with the Airborne Airpark runway replacement project a few years earlier increased his confidence in his ability to complete the accelerated portions of this project.

## **Available Sources of Information**

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Interviews with several key individuals involved in this project were held at Cincinnati/Northern Kentucky International Airport. The project team would like to acknowledge the valuable input and contributions of the following individuals for providing much of the information presented in this case study document:

- Michael J. Sherman, Civil Engineer, Cincinnati/Northern Kentucky International Airport
- Jim Thomas, The Harper Company

The following documents also provided valuable information used in this summary:

- Kenton County Airport Board, Engineer's Report for Taxiway M Extension, FAA AIP No. 3-21-0010-39, Cincinnati/Northern Kentucky International Airport, June, 2002.
- KCAB Planning & Development Department, Project Closeout Manual for Taxiway M Extension, KCAB Project No. 01-09, AIP Grant No. 3-21-0010-39, Cincinnati/Northern Kentucky International Airport, February, 2004.
- Letter to Mr. Jerry Bowers, FAA, Re: Taxiway M Extension (Project No. 01-09), July 10, 2002.
- Letter to Mr. Jerry Bowers, FAA, Re: Taxiway M Extension (Project No. 01-09), August 2, 2002, with enclosures.
- Blueprints – dated 4-2002, by Michael Sherman, sheets 3, 6 – 10, 15 – 20.

## Contacts

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## **Cleveland-Hopkins International Airport Runway 6L-24R Construction**

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### **General Information**

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Airport: Cleveland-Hopkins International Airport

Owner: City of Cleveland, Department of Port Control

Airport Classification: Medium Hub

Climatic Region: Wet/Freeze

FAA Region: Great Lakes

Facility: Runway 6L-24R

Description of project: Construction of a new Runway 6L-24R Stage 1 & 2, tie-ins to existing runways and taxiways

Dates of construction: May 2001 to October 2004

Engineer/Designer: Michael Baker Co.

Project Manager/Construction Manager: Program Management Team, Parsons – Tyler – Choice

Prime Contractor: Anthony Allega Cement Contractors

### **Project Overview**

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Cleveland Hopkins International Airport (CLE) began operations in July 1925 as the first municipal airport in the United States. Today the airport, which is owned by the City of Cleveland, is a hub for Continental Airlines, and in 2002 saw close to 11 million passengers, with 58 percent of those Continental Airlines travelers. International destinations from CLE include Canada, the Caribbean, Mexico, Puerto Rico and London. In 1997, the airport developed an expansion plan to meet projected future demand. This master plan was based around the need for a new parallel runway that could facilitate electronically aided simultaneous take-off and landing operations.

Prior to this project, the airport had two parallel runways (6-24) and one cross runway (10-28). The two parallel runways were used the most, with Runway 10-28 used when wind direction and velocity made the other two unsafe. As part of a \$1.5 billion expansion and renovation program, the airport added a third parallel runway, 6L-24R, 9,000 ft long, equipped for category III approaches and designed for Group V aircraft. The new runway was built in two stages: the first 7,000 ft of the runway (Stage 1) became operational in December 2002, and the full 9,000-ft length was opened early in August 2004 (with projected final completion in October 2004). The project justification was that the existing parallel runways did not allow for adequate aircraft spacing.

The new runway, plus a new radar, increased the airport's overall capacity from 80 to approximately 120 takeoffs and landings per hour. The need for aircraft to taxi and maneuver across runways was also reduced, improving safety by reducing the likelihood of runway incursions.

## **Key Project Components**

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Nearly all of the Runway 6L-24R project was conventional PCC construction. However, in both project phases it was necessary to tie in to existing taxiways and Runway 10-28. Therefore, two concretes were specified for the project: a fairly conventional mixture and a high early strength mixture for closure strips. The fast track components of this project are noted below:

- Multiple classes of concrete.
- Use of high early strength concrete.
- Use of conventional concrete in accelerated tie-in construction.
- Coordination and scheduling to reduce need for high early strength concrete.
- Coordination with stakeholders for best timing for critical closures.

## **Planning**

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Over 20 sub-projects were identified to overcome the many obstacles facing the construction of the new runway in the existing area, including the relocation of some NASA buildings and several surrounding businesses on Brookpark Road. Many roads surrounding the airport also required either rerouting or upgrading to provide room for the new runway and also to handle the proposed increased passenger traffic. As such, the overall project included more than the runway construction. The airport is bordered by the Rocky River Reservation Park and environmental impacts on streams and wetlands were also an important consideration. Other elements of the project included:

- Installation of a Surface Movement Guidance Control System (SMGCS).
- Ramp replacement.
- Taxiway reconstruction.
- Relocating thresholds for existing runways.
- Glide slope improvements.
- New Taxiway G between the center and outboard 6-24 runways.

The project was scheduled in two stages: in the first stage, from May 2001 through December 2002, the first 7,000 ft of the new runway were constructed and opened to traffic. Between the first and second stages, 3.5 million yd<sup>3</sup> of fill were placed to prepare for the runway lengthening. In the second stage, which began in July 2003 and ended in October 2004, Runway 6L-24R was extended to 9,000 ft. The location of Runway 6L-24R is shown in figure A-7.



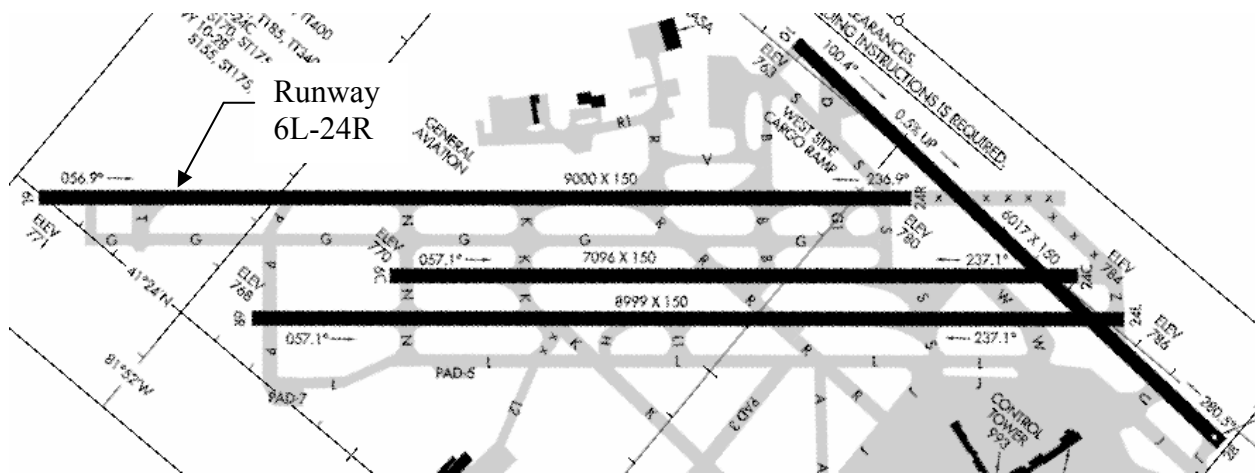


Figure A-7. Cleveland-Hopkins International Airport layout  
(from [http://www.naco.faa.gov/ap\\_diagrams.asp](http://www.naco.faa.gov/ap_diagrams.asp)).

An important planning element was the need to expedite the tie-in between the new runway, the existing Runway 10-28, and taxiways. During Stage 1, several of the tie-ins were planned to be constructed within 10-day closure windows.

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 second stage of the construction. The goal was to have two operational runways at all times, with at least one end of each runway with an instrumented approach. Once the matrix was developed, weekly meetings were held to update the stakeholders on changes to the schedule.

One important result of this planning process was the consolidation of a 20-day closure and two 10-day closures into a single 30-day closure, saving 10 days. These closures involved the center parallel runway, as well as Taxiways K, R, and S. The single 30-day closure also made it possible for the new concrete pavement to achieve at least 14 days of maturity before opening to aircraft, eliminating the need for high early strength concrete during this phase. Based on input from the airlines, after the initial planning this closure was postponed from August until September 2004.

## Design

The new runway pavement consisted of 16 inches of PCC, 8 inches of stabilized base, and 10 inches of aggregate subbase. A pervious concrete drainage layer was placed under the aggregate subbase, between two layers of filter fabric. The joint pattern was 18.75 ft by 20 ft, which allowed paving 37.5 ft wide with a transverse joint in the middle of the paving lane. For the majority of the project, the stabilized base layer was P-306 Econocrete Subbase Course. For two critical tie ins, an asphalt subbase layer was specified. It was believed that construction would be faster by using an asphalt material in these time-critical areas.

The pervious concrete layer provided pavement underdrainage. In addition, the light cans were drained into the storm sewer system.

Project specifications called for a 28-day flexural strength of 725 psi, with 550 psi achieved at 7 days. The pavement could be opened to traffic once it achieved a flexural strength of 550 psi or an age of 14 days. Type I cement was specified for the conventional concrete, with Type III cement allowed as an option for high early strength concrete.

The contractor developed two mix designs; both used Type I cement with 25 % Grade 120 Ground Granulated Blast Furnace Slag (GGBFS). The contractor's conventional P-501 PCC used 423 pounds of Type I cement and 141 pounds of GGBFS per cubic yard, with a w/c ratio of 0.47. This concrete achieved an average flexural strength of 990 psi at 7 days and 1,170 at 28 days. The P-501 MS 800 had 800 pounds of cementitious material per cubic yard, with 600 pounds of cement and 200 pounds of GGBFS. The MS-800 concrete achieved an average flexural strength of 1,140 psi at 7 days and 1,480 at 28 days. Both mix designs used air entraining and mid-range water reducing admixtures for slipforming at a slump of 1.25 inches. For hand work, a superplasticizer was used to increase slump to 5.25 inches.

## **Construction**

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In order to enable a continuous pour across the runway area, 6,000 yd<sup>3</sup> of concrete would be needed (the equivalent of 700 ready mix concrete trucks). The contractor chose to erect concrete plants at the airport even though it was not a project requirement. Use of the high early strength concrete was limited. The main reason was that the conventional concrete generally achieved the needed strength at 2 to 3 days (measured with beam breaks). The contractor cast multiple beams in order to determine when the flexural strength had reached 550 psi and construction equipment could be allowed onto the pavement.

During the first phase, three intersection closures were made between taxiways and the existing runways. There were two problem areas with extensive cracking when using the high early strength concrete over asphalt base course at Taxiways N and S. Some cracks appeared next to joints at the ends of dowel bars. The contractor believed that the cause of the cracking was the permeable asphalt base course with high friction. A third closure strip, with an Econocrete base, did not crack. Although the asphalt base had been intended to speed construction, the Econocrete proved to be as fast, and the performance proved to be better for this project.

## **Other Issues**

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The previously cracked concrete from high early strength mix was repaired with routing and sealing of cracks. A surface sealer was also applied to repair surface imperfections.

## **Summary**

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Overall the project has been a success. The contractor achieved 106 % pay on Percent Within Limits for strength, smoothness, and thickness. Because this project was recently completed, there is no long-term performance data available yet.

## **Available Sources of Information**

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Interviews with several key individuals involved in this project were held in Cleveland. The project team would like to acknowledge the valuable input and contributions of the following individuals for providing much of the information presented in this case study document:

- Mark Vilem, City of Cleveland, Department of Port Control
- Duane L. Johnson, Michael Baker Co.
- Jeffrey D. Kyser, Program Management Team
- Joseph Allega, John Allega, Gary Thomas, and Fred Knight, Allega Companies

The following web sites also provided valuable information used in this summary:

- <http://www.clevelandairport.com/>
- <http://www.airport-technology.com/projects/cleveland/index.html>

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## Colorado Springs Municipal Airport Runway 17L-35R and Taxiway Patching

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### General Information

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Airport: Colorado Springs Airport

Owner: City of Colorado Springs

Airport Classification: Small Hub

Climatic Region: Dry/Freeze

FAA Region: Northwest Mountain

Facility: Runway 17L-35R and parallel taxiway

Description of project: Slab repairs during overnight closures

Dates of construction: June to October 2001

Engineer/Designer: URS Corporation

Project Manager/Construction Manager: URS Corporation

Prime Contractor: T. L. Smith, Inc.

### Project Overview

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Repairs were needed on Runway 17L-35R and its taxiway system at Colorado Springs Airport due to continued alkali-silica reactivity (ASR) resulting in spalling of the portland cement concrete (PCC) pavement. In order to limit the impact to operations at this busy airport (the airport received 220,739 operations in 2000), all work had to be performed during night closures and the runway had to be restored to active status by 5:00 am each morning.

A new, permanent, ultra-fast setting concrete repair material was used to help the contractor complete the repairs. The material sets within 30 minutes, allowing the contractor to work right up to the time of re-opening the runway. It can set as fast as 10 minutes with the application of water and/or ice. The material is also advertised to last 10 years.

### Key Project Components

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The accelerated components of this project and the keys to its success are noted below and discussed in more detail in this case study:

- Fast-setting repair material.
- Nighttime construction to minimize impact to operations.
- Sound planning and preparation.

- Good communication between all parties before and during repairs.

## Planning

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In 2000, Colorado Springs Airport handled 220,739 operations, which included approximately 2.4 million commercial passengers on about 100 average daily arrivals and departures. So when repairs were needed to repair Runway 17L-35R, the airport's primary runway, sound planning was required to ensure minimal impact to the airport's operations.

The pavement was experiencing a large number of spalls due to slab movement from continued alkali-silica reactivity (ASR) issues and environmental changes. In addition, the silicone joint sealant was coming out of the joints because the slabs were so tight, which was likely the result of the expansive ASR creating compressive forces at the joints. It was scheduled to be replaced in 2005 or 2006, so the airport was only looking for about a 5-year fix.

The City of Colorado Springs wanted all repair work to be performed at night, when the reduced number of operations allowed one runway to handle traffic while other runways were shut down for repairs. All work had to be completed during night closures, and the runway had to be re-opened to traffic each morning. The material selected for the project was a new, fast-setting, proprietary product for PCC pavement repair. The material sets up quickly, typically within 30 minutes. However, if an airplane needed to use the runway in an emergency, they could spray cold water on the patch and it would be set up in 10 minutes.

The project focused on repairs to the primary runway, but any remaining funds would be used to address distresses on the parallel taxiway. The project also included sealing all longitudinal joints and transverse joints on connecting taxiways.

## Design

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One of the conditions of the project was to provide repairs that would last 10 years. Most materials are too brittle to meet this criterion, especially for use with slabs that continue to move. The material used for the project was a fast-setting, proprietary product called TechCrete (Circle 922). This material stays flexible over time and is designed to provide 10 years of service. The material is mixed and heated in an oil-lined kettle (i.e., the "pot") similar to a hot-pour machine. The airport's current equipment is shown in figure A-8 (the airport did not own the equipment at the time of this project). The material is poured out while hot and hardens as it cools. The material results in a permanent repair in less than hour, but often sets up faster than that. It can set up in as little as 10 minutes with the application of water and/or ice.

The fast-setting material enables the contractor to spend more time performing repairs and less time sitting idle waiting for the material to harden/cure. The contractor is able to work through the entire shift, whereas typically they would need to reserve a 2-hour to 4-hour window to allow the material to cure before opening to traffic.



Figure A-8. Patching equipment.

## Construction

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The contractor worked weeknights, under flood lights, over a 3-week period. Work began each night at 7:00 pm, when air traffic was shifted to one runway, and the crews would work through the night until 5:00 am the next morning. The project involved the repair of over 200 square yards of airfield pavement.

To accomplish the repairs, the contractor would make a square edge sawcut about 1 inch deep and about 3 inches beyond the spalled area. The crews would then chip out the damaged concrete down to sound material using 60-lb air hammers. The patch area was then cleaned out and airblasted to remove moisture and fines.

Meanwhile, the pre-measured units of the repair material were melting in the pot. Immediately before placing the material, the hole was heated with a torch. A supplied primer was placed on the patch area, and after a 5- to 10-minute wait, the material was spread in the patch with buckets, or for large patches, placed directly in the patch from the pot. The material was placed in lifts about 1 inch deep. For areas greater than 1 square yard or where the deterioration extended too deep, a full-depth repair or slab replacement was performed instead.

No vibration or floats were required for the finishing process, but the crew did use a hot iron to minimally flatten or move the patch material for final finish. Finally, a specified, high-performance aggregate was placed over the patching material before the material had cooled down to a firm consistency. Figure A-9 shows a repair in progress.



Figure A-9. Pavement repair in progress.

The contractor described the material as “error-proof and easy to use for your employees” and further stated that “error-proof products are valuable to a contractor.” [*Roads and Bridges Magazine*]

Opening requirements were left to the construction inspector to monitor since it was a new material, and they did not have much experience with it. The inspectors were always in touch with operations.

Requests for Information (RFI) and change orders were processed through the Construction Manager and then sent to the engineering office. They were reviewed by the Engineer and the issue was raised at a construction meeting. There was no specific timeframe for addressing these requests, but it was usually resolved within a day.

## **Other Issues**

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Security was not a major issue on this project. Only a few people—including the construction inspector and airport operations—were badged. They provided oversight to the contractor’s staff.

One issue with this material is its high initial cost. The material is fairly expensive compared to other products, but its cost is competitive with other rapid-setting patch materials. The equipment alone costs about \$30,000 to \$35,000. However, the airport had tried concrete patches in the past, and they would typically only last about 6 months. These patches have already lasted 3 years without any replacements. Thus, even with the higher initial cost, the airport feels it was cost effective. The airport has since purchased the equipment themselves, so they can perform repairs using in-house maintenance forces.

## Summary

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The airport was so pleased with the outcome that they released the contractor's 10 percent retainage fee from progress payments within 60 days, even though the airport had the option of holding it for up to 1 year to ensure performance.

The airport reports that the patches have been in place for over 3 years and are performing well. They have not had to replace a single patch.

The airport has been so pleased with the material that it has since purchased the equipment to allow them to do repairs using their own maintenance crews, a \$30,000 investment. The airport reports that the material works really well for night work, and they have not had any problems with moisture. They are now using the same material on the taxiway. Their maintenance crews often pour ice water on the patch so they can open it back up to traffic quickly.

## Available Sources of Information

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The project team would like to acknowledge the valuable input and contributions of the following individuals for providing much of the information presented in this case study document:

- Sam Schneider, City of Colorado Springs, Colorado Springs Airport
- Dale Brock, City of Colorado Springs, Colorado Springs Airport

The following documents also were used in preparing this summary:

- "Tons Riding On It," published in Volume 40, Issue 8, *Roads and Bridges Magazine*.
- Project plans and specifications.

## Contacts

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## **Columbia Regional Airport Runway 2-20 Repair**

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### **General Information**

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Airport: Columbia Regional Airport

Owner: City of Columbia, Missouri

Airport Classification: Small Hub

Climatic Region: Wet/Freeze

FAA Region: Central

Facility: Runway 2-20

Description of project: Rehabilitation of Runway 2-20 under a weekend closure; reconstruction of a 200-foot by 50-foot keel section of the runway.

Dates of construction: September 21-23, 2001

Engineer/Designer: Crawford, Murphy, & Tilly, Inc.

Project Manager/Construction Manager: Crawford, Murphy, & Tilly, Inc.

Prime Contractor: Emery, Sapp & Sons, Inc.

### **Project Overview**

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The primary runway at Columbia Regional Airport, Runway 2-20, was originally constructed in 1968 with a 9-inch portland cement concrete (PCC) pavement. An area approximately 500 feet from the Runway 2 approach was experiencing heaving and associated pavement deterioration, which caused a potential concern for aircraft traffic. Thus, the Federal Aviation Administration (FAA) and Columbia Regional Airport initiated a project to repair this area and to improve the profile of the runway.

The project included the removal and replacement of 200 feet of pavement in the keel section of the runway and milling and grinding on the outer portions of the runway. The work was accomplished over a weekend closure.

One of the primary issues on this project was to minimize the impact to airport operations. Although the Airport does have a cross-wind runway, it does not provide the necessary structural capacity or length to handle the larger aircraft in use at the Airport, most importantly commercial service and air cargo operations.

## Key Project Components

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The accelerated components of this project and the keys to its success are noted as follows:

- Construction over a single weekend closure.
- Use of high-early strength concrete.
- Liquidated damages for failure to meet opening requirements.
- Sound planning and preparation involving all stakeholders.
- Redundant equipment and contingency plans.
- Good communication between all parties before and during construction.

Each of these aspects is discussed in more detail in this case study.

## Planning

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The Airport wanted a solution that had the least impact on users, which included a commercial airliner (Trans State Airlines) and a cargo airliner (Airborne Express). Trans State Airlines had scheduled flights 7 days a week, whereas Airborne Express only operated on weekdays. Both of these major stakeholders were involved in discussions during the planning stages.

A preliminary study was conducted to determine the cause of the swelling and the most appropriate design, which is discussed in the following section. Based on the final design selection, a weekend (55-hour) runway closure was planned, starting on Friday evening at 11:00 pm (immediately after the last Airborne Express departure) and extending to Monday morning at 6:00 am. The designer developed a construction schedule and then verified the schedule through meetings with local contractors before the bidding process.

The next critical step in the planning process was to determine the date for the weekend closure. The project was planned for the fall of 2001, but since Columbia is home to the University of Missouri, a constraint during planning was that the runway not be closed during a weekend of a football game (home or away) due to the increased traffic volumes experienced on such weekends. The stakeholders collectively selected first and second alternative dates for the weekend closure and the project ended up being switched to the alternate weekend based on the contractor's other work commitments and ability to mobilize the required equipment from another project.

The commercial airliner was most affected by the weekend closure and did not immediately accept it. They also experienced some internal communication issues in terms of getting approval for the weekend closure, pointing out the need to have the key decision makers elsewhere involved in the discussions. But with advance planning, they were able to take their weekend flights out of schedule with 2 ½ months notice. In addition, this project convinced them of the benefits associated with accomplishing the work in such a short timeframe, and they were more accepting of the concept for a major repair project performed in 2005.

Another key was cooperation from the FAA, which considered this a unique project, evaluated their guidelines, and made concessions whenever possible. The FAA ended up being a vital part of the project team. Another important factor during planning was that the designer had recently performed a similar project at Spirit of St. Louis Airport and was able to apply the lessons learned from that project.

The Airport and the design team made a conscious effort to award the contract in June, 3 months prior to construction. They wanted to allow enough time for up-front planning by the contractor and did not want any surprises during construction. The contract also included provisions for constructing a full test section and for providing redundant equipment on site during the construction phase (which proved beneficial when one of the concrete pumping trucks broke down). A second operational concrete plant was also specified for the construction phase.

## Design

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An initial study was performed to assess the cause of the problem and to identify the most appropriate rehabilitation alternative. That study determined that this area of the runway was a cut section and that removal of the soil overburden pressure allowed the subgrade to swell and the pavement to heave. The study further concluded that the pavement was no longer experiencing this movement (95 percent of the soil had achieved maximum swell potential), meaning removal and replacement of the existing subgrade was not required as part of the pavement rehabilitation effort.

This preliminary study identified the preferred rehabilitation option as a hot-mix asphalt (HMA) overlay, which could be constructed during nighttime closures. However, this option would have taken 2 months to construct under nighttime-only closures. Therefore, the designer investigated a PCC alternative that was ultimately selected as the desired option. The PCC alternative included replacement of the keel section (center 50 feet) with a new PCC pavement and milling/grinding the outer portions of the runway, and could be completed over a single weekend closure. The PCC alternative offered the following advantages over the HMA overlay option:

- Reduced overall construction cost.
- Reduced overall construction time.
- Flexibility when considering future rehabilitation projects.

The project, which is illustrated in figure A-10, consisted of the removal and replacement of the PCC pavement over 200 feet in the keel section (center 50 feet) and milling/grinding of the outer portions of the runway. Within the keel section, both the original 9-inch PCC pavement and base course were removed and replaced with a 15-inch PCC pavement. Because pavement strength was not as important in the less critical area outside the runway keel, the pavement was allowed to be milled down to a minimum thickness of 6 inches. The Airport accepted that aircraft loadings in this area may result in some distress, but would not cause a catastrophic failure. Where the runway profile required milling such that less than 6 inches of PCC pavement would remain, the slabs were removed and replaced (required for five slabs).

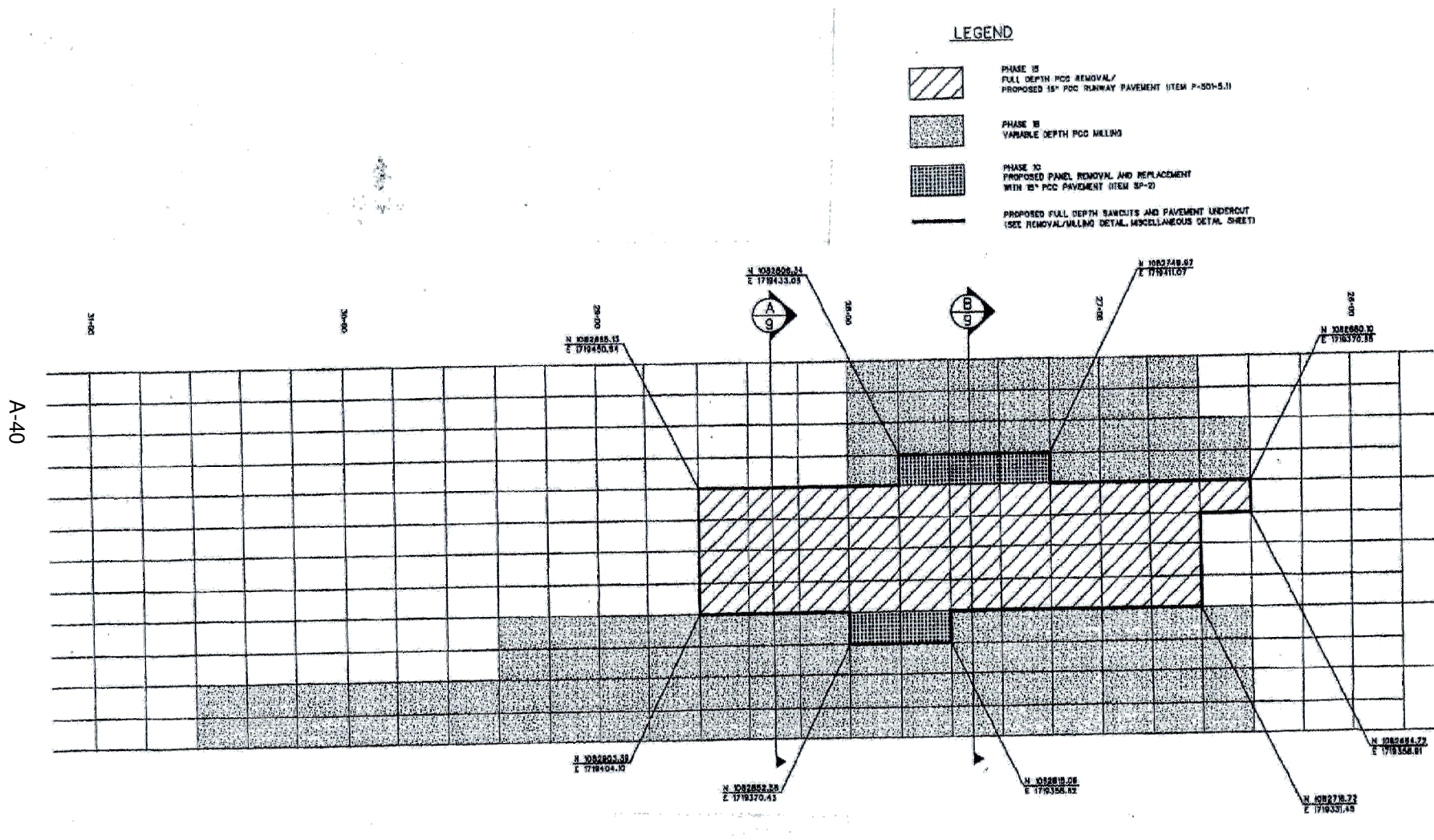


Figure A-10. Runway rehabilitation plan.

The transverse joints on the original PCC pavement were spaced 20 feet apart, while the longitudinal joints were spaced 12.5 feet apart. The transverse joint spacing was reduced to 10 feet for the replaced slabs to accommodate the thinner pavement in the outer portions of the runway, which were also cut in half (even if they were not being replaced) to avoid sympathy cracking from the adjacent slabs.

Around the perimeter of the replacement area, the adjacent 9-inch thick slabs were undercut and filled with PCC pavement to a depth of 15 inches (see detail in figure A-11). Dowels were not placed across the joint because in some cases the adjacent slabs were only 6 inches thick. However, 5/8-inch deformed bars were placed at 18-inch centers beneath the joint (within the undercut area) to help maintain the integrity of the pavement.

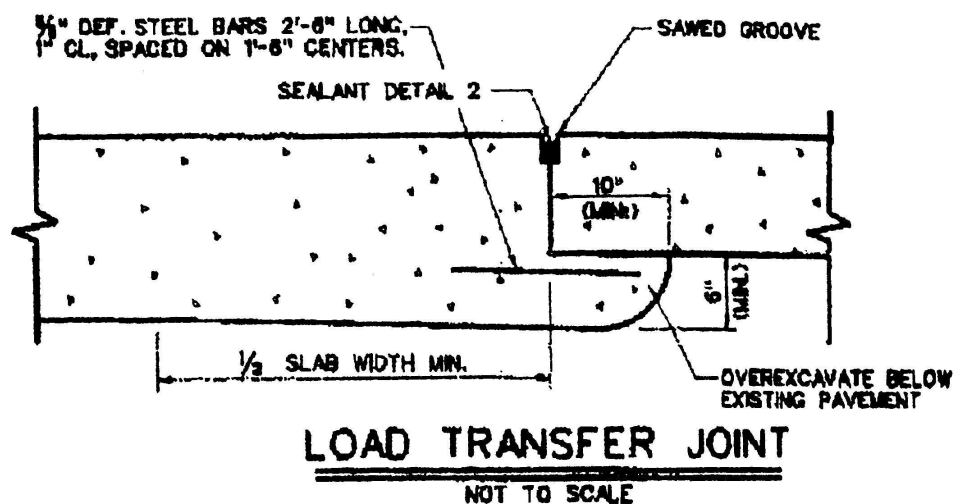


Figure A-11. Jointing detail at perimeter of replacement area.

There was a lot of discussion about the PCC mix design and required strength. The designer originally planned to use 550 psi in 8 hours, but eventually settled on using 550 psi in 12 hours, understanding that there was no need to use a faster setting material than needed for the specific job. There was also a 28-day strength requirement of 700 psi, which was used for payment in accordance with the P-501 specification. A higher cement content was specified (8 1/2 bag mix), but no other special admixtures were employed. The mix design was also required to be submitted well in advance of construction. In addition, the contract required the construction of a test section using the same equipment and construction techniques as would be used in the actual construction. This step enabled the placement and finishing crew to gain experience working with the atypical mix and help eliminate surprises during the runway closure.

## Construction

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As mentioned, good communication was vital to the success of this project. A pre-construction meeting was held within 1 week after award of the contract to discuss the logistics of the project. Another meeting was held prior to the scheduled runway closure. The prime contractor organized and coordinated a detailed work schedule, in conjunction with its subcontractors, which included several contractors and covered several concurrent operations during the weekend closure.

Approximately 1 week prior to the scheduled weekend closure, the perimeter of the pavement removal areas was sawcut and grades were marked during a nighttime closure. Thus, at the start of the weekend closure, the contractor immediately started breaking up the pavement using two hoe-mounted jack hammers, while a third trackhoe removed the broken pieces (construction inspectors reported that they thought a guillotine breaker would provide better productivity). Meanwhile, a milling machine started milling on the outer portions of the runway. A temporary stringline was established for the milling machine, with different sets of stringlines set up for the different construction operations.

Demolition was completed by 7:00 am Saturday morning, at which time a small bulldozer was used to clean up the broken concrete, and a small roller ran over the subgrade to provide density and smoothness. The equipment used resulted in some disturbance to the existing subgrade; the designer indicated they would specify the type of equipment to remove the material on future projects. Figure A-12 illustrates the prepared site ready for paving.

The five extra slabs outside of the runway keel were poured on Saturday morning, followed by paving of the keel. The contractor used a 50-foot wide bridge deck paver to allow paving to be accomplished in a single pass (see figure A-13), and paving was completed by 5:00 pm on Saturday. A curing compound was applied and joints were sawed overnight. The concrete achieved the 550 psi strength required for opening, and the runway was re-opened on Sunday at 6:00 pm, 12 hours ahead of schedule. Grooving, joint sealing, painting, and seeding were completed later under separate overnight closures.



Figure A-12. Prepared site ready for paving operations.



Figure A-13. PCC placement using bridge deck paver.

## Other Issues

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For security, a mobilization area was established, and the contractor was required to tend the gate. A security guard was dedicated solely to the project.

The contract also included liquidated damages of \$5,000 per hour for re-opening the runway past 6:00 am on Monday morning. No incentives were used for the project.

## Summary

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By all accounts, the project was a success. The project resulted in a smoother runway that provided a higher degree of safety to the general public and was accomplished with minimal interruptions to airport operations. In addition, the project was completed for \$500,000 (as compared to \$1.2 million for the HMA overlay option), and the runway was re-opened to traffic 12 hours ahead of schedule. Furthermore, 4 years later, there have not been any issues with performance. The project was a national finalist for the ACPA Award for Concrete Paving Repair and won the Missouri/Kansas regional award. With so many entities involved and working under a compressed schedule, the project is a testament to the benefits of sound planning and teamwork.

## Available Sources of Information

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Telephone interviews were held with several key individuals involved in this project from both Columbia Regional Airport and the design team. The project team would like to acknowledge the valuable input and contributions of the following individuals for providing much of the information presented in this case study:

- William (Bill) Boston, Columbia Regional Airport (Airport Manager)
- Chuck Taylor, Crawford, Murphy, & Tilly, Inc. (Design/Construction Project Manager)
- Ty Sander, Crawford, Murphy, & Tilly, Inc. (Design Engineer)

The following documents also provided valuable information used in this summary:

- Executive Summary of the application for the ACPA Paving Award.
- *Partial Rehabilitation of Runway 2-20*, presentation from Missouri/Kansas ACPA Conference, Crawford, Murphy & Tilly, Inc. and Emery, Sapp & Sons, Inc.
- Project plans and specifications.



## Contacts

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## **Denver International Airport Runway 16R-34L Construction**

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### **General Information**

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Airport: Denver International Airport

Owner: City and County of Denver

Airport Classification: Large Hub

Climatic Region: Western plains/Rocky Mountain foothills

FAA Region: Northwest Mountain Region

Facility: Runway 16R-34L (Sixth Runway)

Description of Project: New runway construction, Group VI, 16,000 feet long and 200 feet wide, parallel taxiway, connector and crossfield taxiways

Dates of Construction: January 2001 to September 2003

Engineer/Designer: CH2M HILL

Construction Manager: DMJM, with City and County of Denver

Prime Contractor: Interstate Highway Construction

### **Project Overview**

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The new Denver International Airport (DIA) was constructed from 1990 through 1993 and officially opened in early 1995. When it was opened, DIA had five, 12,000-ft long runways, but it was always intended that a sixth runway (16R-34L) would be constructed soon after the 1995 opening. In fact, in anticipation, during the original construction, some of the backbone drainage system and some of the deep fill material were placed for the sixth runway. However, the sixth runway did not get political support immediately after the airport opened, and over the years some additional fill material was placed in the footprint of the sixth runway. With the airlines continuing to express the need for the sixth runway for flights to Europe and Asia with large aircraft, support and funding were secured in 2000 and project design started in mid 2000.

Once the funding was secured and approval to proceed with the project was granted, there was some urgency to get the construction started due to environmental and weather issues. At that time, earthwork for about one quarter of the runway was somewhat complete. The Earthwork and Drainage project design was expedited to allow the bidding and award of the project for this portion of the project to be completed in advance of the concrete paving. The earthwork and drainage project was completed in a phased manner to allow the concrete paving to proceed promptly after the earthwork and drainage were completed.

## **Key Project Components**

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This project did not employ fast track construction methods in the traditional sense, but many elements of the project were planned and executed to allow the project to be completed at least one year faster than a normal project. Sound planning and direction from the management team were part of a process that made this project a success; it opened on the scheduled day, which was determined approximately 3 years earlier.

The key factors that allowed this project to be completed are:

- Early involvement of the outside utility agencies.
- Established intermediate milestones.
- Commitment of FAA to design and complete the NAVAIDs.
- On-site construction management team and testing laboratory.
- Airport security flexibility.
- Contractor's responsiveness to schedule.

## **Planning**

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Extensive up-front planning was the key to this project's success. It was realized early that for this project to be completed in two construction seasons, the earthwork and drainage portion of the project would have to be designed, advertised, bid, and awarded on a fast-track basis. There was also a major high-pressure fuel line that had to be relocated before the earthwork could begin. This was accomplished by issuing an early purchase order under an existing contract. The local power company, Xcel Energy, was given early purchase orders to begin the design of their system so construction could be accomplished prior to other portions of the project.

Initially, the FAA was not sure that they could meet the schedule with the design and construction of their NAVAIDs. However, in the end they committed to accomplishing their design on a fast-track and expediting their construction. The result was that they were ready when needed, prior to the start of the paving.

Another planning decision that involved coordination with the FAA for NAVAID approval was to schedule the paving of the center lane of the runway first. This allowed the airport to schedule the NOAA survey crew to measure the length of the runway prior to the runway being completed. This was an important time-saving step that allowed the runway to open on time, because the survey crew has to be scheduled 3 to 6 months in advance. The FAA was also able to start their NAVAIDs surveys and calculations early because the concrete paving had been completed in the areas that were required. This step saved 2 months in the NAVAIDs certification process.

An additional planning decision was made to pave the future connector taxiways beyond the runway safety area so that future connections would not affect the runway operations. The connector taxiways that were in the glide slope critical area were also paved beyond the critical area, so the runway instrument landing system would stay operational when the connector

taxiways are constructed. A 48-inch conduit was installed in numerous locations under the runway, so the runway would not have to be closed for any future utility crossings.

Discussions were held with concrete paving contractors prior to the bidding in order to begin the process of evaluating the mix design, additives, strength requirements, testing requirements, and production rates for the concrete paving. This proved valuable during the construction of the pavement, as realistic expectations were developed during the planning process and incorporated in the contract provisions.

One key element of the planning phase that contributed to the success of this project was the establishment of eleven significant schedule milestones that had to be met to keep the project on schedule, including the following:

1. Complete the mass earthwork and drainage for the southern 1/3 of the runway.
2. Complete the mass earthwork and drainage for the northern 2/3 of the runway.
3. Complete all earthwork, full strength paving, blast pads, drainage, grooving, temporary painting, and jointing from E56,160 to N 72,960 and between E83,500 to E83,700.
4. Complete all earthwork, paving, lighting, drainage, grooving, painting, jointing, and any other work on Taxiway WA from E86,450 east to existing Taxiway F.
5. Complete all earthwork, paving, lighting, drainage, grooving, painting, jointing, and any other work on Taxiway WB from E86,450 east to existing Taxiway F.
6. Complete all earthwork, paving, lighting, drainage, grooving, painting, jointing, and any other work on Taxiway WC from E 85,560 east to existing Runway 16-34 at night between the hour of 11:00 pm and 7:00 am.
7. Complete all earthwork, paving, lighting, drainage, grooving, painting, jointing, and any other work on Taxiway WD from E85,560 east to existing Runway 16-34 at night between the hours of 11:00 PM to 7:00 AM.
8. Complete all earthwork, paving, lighting, drainage, grooving, painting, jointing, and any other work on Taxiway WE from E 85,500 east to existing Runway 16-34.
9. Existing Runway 16-34 pavement marking removal, and Runway 16-34 remarking.
10. Replace all Taxiway guidance sign panels associated with existing Runway 16-34.
11. Complete FAA duct bank, manholes, and cans. Complete blast pad asphalt, grading, and paving, at both the north and south ends of runway.

On-time completion of these milestones required close interaction with the affected utility companies, the FAA, and the other contractors working on site; it also required coordination with Operations on the existing active runways and integration with the airfield lighting control system. The milestones were clear to everyone working on the project from the beginning, which helped to ensure that they were met.

To facilitate continued communication and coordination, a project team meeting was held every 2 weeks. These meetings included the design firm, airport design manager, airport construction manager, airport operations, airport electrical, airport communications, airport environmental, FAA project manager, Xcel Energy project manager, and other technical experts. This team discussed all design issues and tracked all open action items in meeting minutes, and was very effective in resolving issues on the spot, so the design phase could stay on schedule. The sort of

communication was continued into the construction phase by holding weekly construction meetings with all of the key project staff, including the FAA. There was also a separate QC/QA meeting every week.

## **Design**

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Many alternatives were discussed and developed for the design of this project. The previously completed portion of the runway earthwork had been constructed to Group VI (200 feet wide) criteria, but the earthwork for the taxiways was constructed to Group V (75 feet wide) criteria. So one of the major issues to resolve was whether to upgrade the taxiways to Group VI or downgrade the runway to Group V. The “downgrade” option involved determining if the runway could be constructed to Group V (150 feet wide) criteria, with provisions to upgrade it to Group VI in the future. In the upgrade option the taxiways were evaluated for full Group VI (100 feet wide) criteria. The analyses showed that at very little extra cost, the runway and parallel taxiway could be constructed to full Group VI criteria, and so it was decided to construct the runway, parallel taxiway, all connector taxiways, and two crossfield taxiways to Group VI criteria. The construction to Group V criteria would have required significant pavement and other infrastructure to be removed and reconstructed later to convert to Group VI. The earthwork for the remaining taxiways would also be constructed to Group VI criteria, but paved to Group V criteria. The length of the runway was also re-evaluated to determine if the initial planning length of 16,000 feet was still valid. It was determined that the 16,000 feet was required.

Since operations at DIA require significant aircraft deicing, the benefits of an additional deicing fluid collection system were evaluated for the south end of the runway and taxiway complex. This system was incorporated into the project and includes edge drains along the outside edge of the shoulder pavement that collect most of the storm drainage from the crown section of the runway and taxiways and discharges the runoff into the deicing collection ponds. It also collects deicing fluid that drips off of aircraft or shears off during takeoff.

Because the in-pavement airfield electrical systems (cables, connectors, transformers, and light base cans) on the existing airfield were being severely damaged by the pavement deicing fluids, the decision was made to upgrade the corrosion resistance of the new lighting system. Accordingly, the lighting system for this new project included the following: epoxy-coated light base cans, insulated electrical cable, and rubber-coated transformers. The electrical manholes were constructed with fiberglass cable racks and non-corrosive cable tags. A new airfield lighting vault was also evaluated. While the existing airfield lighting vault would have handled the electrical loads from the new runway, there would have been no room for future expansion. The evaluation resulted in the construction of a new lighting vault.

The entire design process was accelerated, which required more coordination during the construction phase due to the fact that some changes (such as the new electrical vault) were added relatively late in the design process. The overall quality of the project was not compromised and the project ended up with less than 2 percent change orders, far below industry standards.

The requirements for the material Quality Control/Quality Assurance program were modified during the design process to require that the contractor do all of the Quality Control material testing and that the owner repeat one hundred percent of the testing for Quality Assurance and acceptance. While this is a higher level of testing than called for in the typical P-501 specification, this program was very successful and eliminated any problems with conflicts between the QC and QA testing results.

## **Construction**

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In addition to having regularly scheduled meetings to facilitate communication throughout the construction process, constant communication was facilitated by housing the construction management staff right next to the contractor's staff. This arrangement also provided a means for issues to be addressed immediately and for disputes to be resolved in a timely manner. Requests for information were generally answered in 7 days.

Both the Quality Control and the Quality Assurance laboratories were in the same building on site and both testing subcontractors used the same equipment to do the tests. This reduced the potential of the laboratories having different results and having to resolve those differences. An owner's inspector was assigned full-time to the batch plant to monitor the concrete production.

The contractor requested that the center paving lane for the 100-foot wide taxiways be allowed to be paved in one pass. This required that the paving machine have a break in the center of the slab to install the crown. The contractor was required to perform a demonstration proving that this would work, by paving a test section on the actual taxiway footprint in an area that included centerline in-pavement lights. The test section was then checked for grade tolerances, straight edge requirements, light location, and tolerances; all parameters met the project criteria, and this method was subsequently approved and successfully used.

## **Other Issues**

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To ensure security, a new, separate manned gate for construction access was installed at a convenient location. All of the worker's private vehicles were parked outside of this gate and the workers were bused into the site. Survey stakes were installed near the new electrical vault building during construction with height restrictions identified for the FAA Part 77 surfaces, so the active runway near the vault could remain operational.

The weather did not present very many challenges, as there was a winter shutdown during which all temperature-sensitive activities were suspended. The subgrade was stabilized with lime and this allowed a stable working platform for work to continue immediately after any significant moisture. Any cement-treated base course was required to be covered with pavement prior to the winter shut down.

## **Summary**

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All components of the project were designed on a fast-track basis and this allowed the bids to be opened on time; responsive bids were received that allowed the projects to be awarded and funded. The acceleration of the airfield concrete pavement was a critical element in this project being completed approximately one construction season earlier than it would have been had this technique not been used. Because of its success, this technique will be used on future projects at DIA. The key to the project's success is that the up-front planning has to be done early and has to have the right parties involved. The project's goals were met, as the project was completed on the date which was established over 3 years earlier.

## **Available Sources of Information**

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Interviews were conducted with several key individuals involved with the project:

- Don Smith, Denver International Airport Project Manager and Design Manager
- Pete Stokowski, Denver International Airport Construction Manager
- Dean Rue, CH2M HILL Project Manager

## **Contacts**

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## **Detroit Metropolitan Wayne County International Airport Fourth Deicing Pad Construction**

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### **General Information**

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Airport: Detroit Metropolitan Wayne County International Airport

Owner: Wayne County Airport Authority (WCAA)

Airport Classification: Large Hub

Climatic Region: Wet Freeze

FAA Region: Great Lakes

Facility: Fourth Deicing Pad

Description of project: Construction of deicing apron and extensive collection system; 7-week design period and 45-day construction period

Dates of construction: September to October, 2002

Engineer/Designer: Reynolds, Smith & Hills, Inc.

Program Manager/Construction Manager: Program Management Team

Prime Contractor: John Carlo, Inc.

### **Project Overview**

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Mandates by the Michigan Department of Natural Resources (DNR) required the Wayne County Airport Authority (WCAA) to construct a fourth deicing apron with an extensive glycol and stormwater collection system at Detroit Metropolitan Wayne County International Airport (DTW) in 2002. The new deicing pad was 1,400 feet long by 275 feet wide, as shown in figure A-14. Delays in getting the project out to bid increased the need for accelerating the design and construction phases of the project, as it had to be completed before the upcoming deicing season began. As a result, the \$10-million project was designed in 7 weeks and constructed in 45 days to meet the tight schedule.

The project involved removal of portions of the Terminal Concourse C foundation and jet bridges, as well as removal of the existing pavement and utilities surrounding the concourse. The existing pavement included both 10-inch and 17-inch portland cement concrete (PCC) pavement on top of a 6-inch asphalt-treated base (ATB) and a 12-inch crushed stone subbase.

The pavement structure is Detroit's standard 42-inch cross section, consisting of a 17-inch thick PCC pavement (reinforced with wire mesh), a 4-inch ATB, and a 21-inch crushed stone subbase (see figure A-15). An extensive glycol and stormwater collection system was also installed on the project and a five-position lighting system and placement of an electrical system across the apron to the deicing operations building were included.



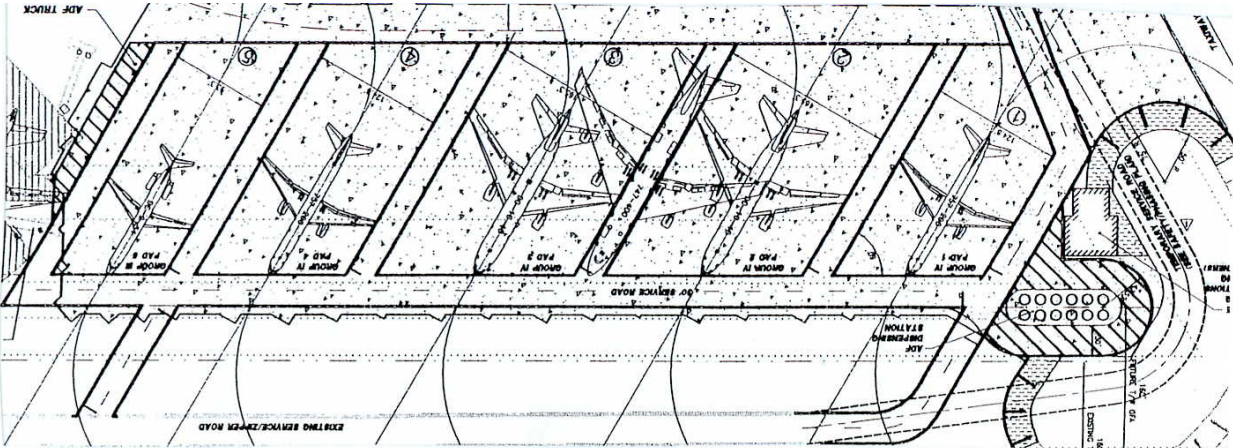


Figure A-14. Site layout plan.

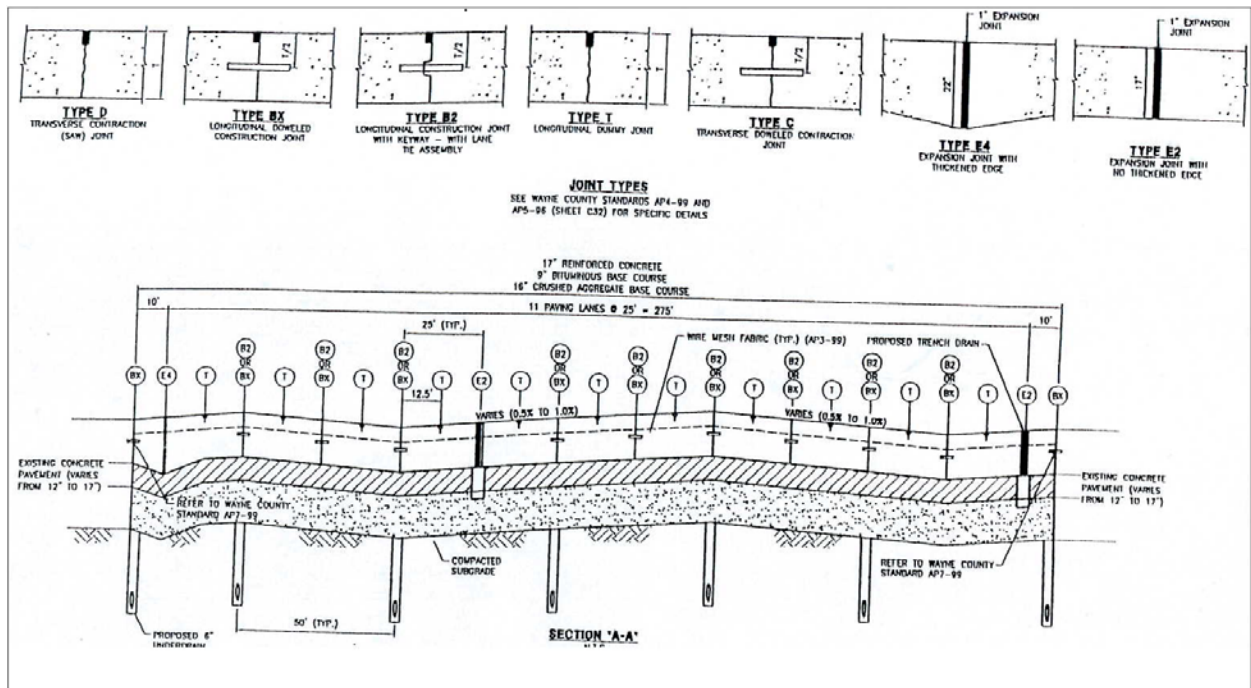


Figure A-15. Typical pavement cross section.

## **Key Project Components**

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The accelerated components of this project and the keys to its success are noted below and discussed in more detail in this case study:

- Coordination of planning and phasing with all parties involved with the project from beginning to end.
- Expedited contract award process.
- Accelerated schedules for both design and construction.
- Contractor's commitment in manpower to stay on schedule.
- Flexibility in operations to adjust phasing to maintain construction schedule.
- Team commitment to address all issues in a timely manner.

## **Planning**

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Due to the need for an expedited project, the planning process included alteration of the bid procedures. To expedite the award of the contract, a special session of the WCAA Board was scheduled to make selection immediately after the construction bids were received.

In light of the tight project deadlines, the project construction sequence was worked out in advance. The planning and phasing were coordinated with the airlines, FAA, air traffic control, FBOs, and operations, and the various phases were coordinated to minimize impacts on operations. Several critical aspects of this project were coordinated through numerous meetings in which plans were presented, input received, and appropriate modifications made, including issues associated with aircraft and ground vehicle operations and layout of the collection system and its components.

A critical factor in terms of planning and phasing was that the service road for airline baggage carts and other vehicles, which cut across the entire project area, had to remain open at all times during construction. The phasing plan included the construction of a temporary road to be used during various phases of the project. The temporary road was built and used during one phase of the project, but during construction, when the project was starting to fall behind schedule, a portion of the inner apron taxiway was closed, aircraft traffic was rerouted, and the taxiway was used as a service road. This coordination effort and revision in plans during construction completely eliminated a construction stage, allowing the project to get back on schedule.

During the planning stages, weekly meetings were held with all involved parties. The airport provided input into the glycol and stormwater collection system, such as the location of the pumps and other components. Likewise, Operations provided input regarding the sequence of aircraft and ground vehicle movements during construction. Direct input from the airlines was also obtained for the temporary pavement marking layouts to help avoid having vehicles travel behind aircraft, which was a concern to the airlines.

Weekly meetings were also held during the design and construction phases of the project, which are discussed in more detail in their respective sections of this case study.

## Design

The design team consisted of a lead consultant and four subconsultants. During the design stage, the work was divided up between the design team members so that it could be completed as quickly as possible. The lead consultant took several measures to ensure consistency between all the drawings and deliverables. At the beginning of the project, the lead consultant developed a list of each plan sheet and miniature plans on a “story board.” They also developed the base layout map, scales, templates, and so on.

Weekly meetings were held with all members of the design team—including the design consultant, owner, construction manager, and other involved parties—to keep the project moving forward. Each meeting started with an agenda and ended with a list of action items. Holding weekly meetings helped with obtaining design decisions and avoiding delays with waiting for responses.

As noted previously, the designed pavement section was the typical 42-inch cross section used at DTW. Although the design team needed to verify subgrade strength and adequacy of the pavement section for the project, the use of the standard design section did expedite the development of the plans and specifications. The jointing details for the apron are illustrated in figure A-16.

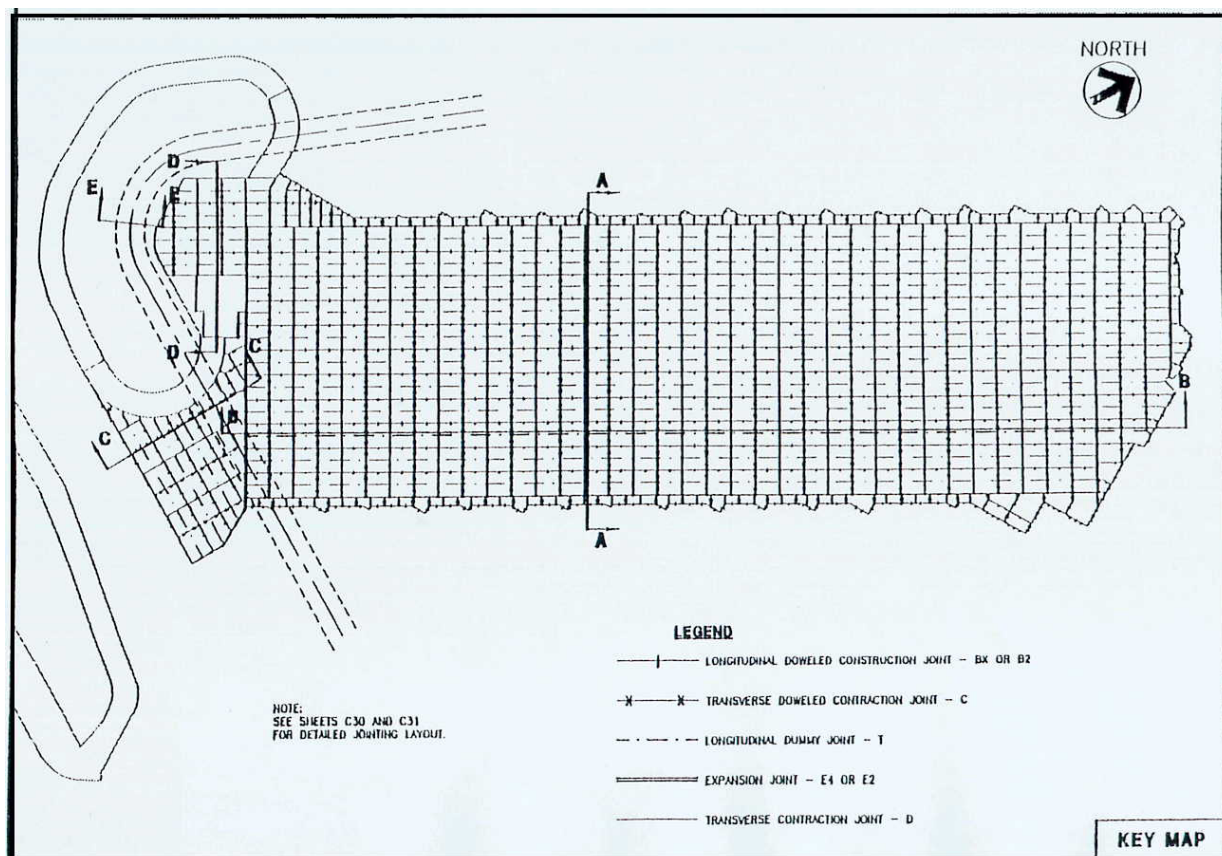


Figure A-16. Jointing layout and configuration.

The necessity of getting the project completed before the next deicing season did not allow the paving work to be planned during optimal weather; the planned construction schedule resulted in paving occurring in the fall months, which in Detroit can be wet and cold. In anticipation of potential cold weather, the project specifications included provisions for cold-weather concreting. However, paving was performed during the day and temperatures did not necessitate the use of the provisions. Nonetheless, it is always best to address such issues ahead of time, especially on a fast-track project.

Although this was a complex project requiring matching surrounding grades and maintaining drainage internally (i.e., no glycol on the deicing pad could be allowed to drain off the pad), the design was completed a week earlier than required.

## Construction

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As with the planning and design phases, construction proceeded on an accelerated schedule. Figure A-17 shows an overview photo of the site. To meet the project deadline, the contractor worked 24 hours per day, 7 days a week during the demolition and pavement removal stage. During this stage, the contractor used two crews working 12-hour shifts. The removal stage, which included removal of the concourse foundation and existing utilities in addition to pavement removal, was completed in about 3 weeks.



Figure A-17. Overview of project site.



Removal of the 17-inch PCC pavement proved to be one of the major challenges during construction. The contractor tried several methods unsuccessfully—drop ball, vibratory, and small guillotine—which did not impart enough energy to crack the existing pavement. Finally, a large guillotine was employed that worked well.

The pavement removal included the existing P-209 base aggregate. However, the existing material still met P-209 requirements and thus was reused in the new pavement section. The P-209 specification for the project was modified slightly to reduce the amount of fines passing the No. 200 sieve to allow better drainage through the material. This was accomplished by blending the existing base material with virgin material containing fewer fines.

All paving work was performed during daylight hours. A major challenge for the project was paving around the extensive trench drain system, which is shown in figure A-18. There were a series of longitudinal and transverse trench drains, which caused frequent starts and stops of the paver. The contractor included two crews on the project during paving: one crew concentrated on the main paving and the second crew concentrated on finishing around the drains and at other header locations. The type of trench drain system used on this project was difficult to work with, as seen by the extensive forming requirements shown in figure A-18, and the contractor suggested that a different type of system be used on future projects.

Paving was completed in two lifts, with the reinforcing mesh being placed on top of the initial lift and the second lift being placed immediately after the first lift (see figure A-19). The concrete material was a standard mix design with a required 28-day flexural strength of 750 psi. A compressive strength of 4,000 psi was required before opening the pavement to aircraft traffic. However, the biggest strength issue affecting construction was obtaining adequate strength to support the paver and to limit damage from its track; a compressive strength of 3,000 psi was required for mechanical equipment to operate on the new pavement. Concrete cylinders were made and broken at 1, 2, and 3 days as needed to determine when sufficient strength was obtained to allow the paver on the newly placed PCC. The contractor also placed rubber matting on the newly placed PCC to avoid damage from the paver tracks. In addition, the contractor used a maturity meter to monitor strength gain; although it was not used for acceptance, it nonetheless provided valuable information.



Figure A-18. Trench drain system.



Figure A-19. Reinforcing mesh placed between two lifts.

The construction manager provided quality assurance (QA) for the construction work and hired a local firm for materials testing. The lead design consultant provided services as the construction administrator and assisted with inspections. However, inspections by the design consultant were limited to one day per week (plus during critical paving times) during the 2-month construction process. The design consultant felt that additional experienced inspectors being on site full time would have helped this project proceed more smoothly, as they typically encountered problems during their visits. For a fast-track project, having a member of the design team as part of the inspection team would ensure that quick decisions or changes, which are often required on a fast-track project, do not adversely affect the intentions of the design.

Weekly meetings with all project members were held on the day the design engineer was on site for inspections to keep everyone informed of progress and to address any questions. Also, a memo summarizing each day's inspection was developed. This memo outlined any deficiencies, which went immediately to the contractor to address.

To minimize delays during construction, a process to address change orders and requests for information (RFIs) was established. All change orders and RFIs were first sent to the construction manager and then to the design team, with a commitment to have all of them resolved within 3 days; most were addressed the same day.

## **Other Issues**

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As discussed previously, the trench drain system used for this project created a challenge for paving operations and required additional work crews. Based on the experience with the system used on this project, it was recommended that an alternate trench drain system should be considered on future projects, particularly when the project is on a short schedule, and the impacts of the drainage system on completing construction should be thoroughly reviewed before the project.

With the heightened security at airports, access to the project site is almost always a factor on airside construction projects. Several steps were taken to try to minimize the influence of security measures on the construction schedule:

- A single gate at the north end of the airfield was used for construction access.
- All construction vehicles were inspected and escorted by operations; the contractor had to reimburse the airport for escorts.
- Not every worker was required to get badged, but all foremen, supervisors, and inspectors were badged and provided oversight of the rest of the crew.

Liquidated damages of \$1,500,000 per day were also used on the project, which is standard for Detroit International Airport.

## **Summary**

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Overall, the project exceeded WCAA's goals: the project came in under bid, the design was completed a week ahead of schedule, and only one minor change order was approved during construction (resulting in a \$2,500 credit to the airport).

Although the drainage system created challenges during paving, the glycol system also exceeded expectations. For example, it satisfied Michigan DNR requirements and has the highest collection ratio of the four deicing pads. Both the pavement and collection system are currently performing well, and the financial benefits to the success of the project have become clear. Major fines and penalties have been avoided by achieving environmental compliance, and treatment costs have been significantly reduced.

## **Available Sources of Information**

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The project team would like to acknowledge the valuable input and contributions of the following individuals for providing much of the information presented in this case study document:

- Stephen Moulton, Reynolds, Smith & Hills, Inc. Design Engineer

The following documents also were used in preparing this summary:

- Project plans and specifications.

## **Contacts**

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## **Hartsfield-Jackson Atlanta International Airport Runway 9R-27L Reconstruction**

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### **General Information**

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Airport: Hartsfield-Jackson Atlanta International Airport

Owner: City of Atlanta, Department of Aviation

Airport Classification: Large Hub

Climatic Region: Wet/No Freeze

FAA Region: Southern

Facility: Runway 9R-27L

Description of project: 33.5-day runway reconstruction; conversion of parallel taxiway to a temporary runway

Dates of construction: May 1999 to November 1999

Engineer/Designer: Aviation Consulting Engineers, Inc.

Project Manager/Construction Manager: Aviation Consulting Engineers, Inc.

Prime Contractor: APAC-Mathews-Swing-Mitchell, A Joint Venture

### **Project Overview**

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The Hartsfield-Jackson Atlanta International Airport (Hartsfield) is the world's busiest passenger airport. As part of a four parallel runway layout, Runway 9R-27L plays a vital role in maintaining Hartsfield's operations by handling a quarter of the airport's daily flights. Runway 9R-27L was originally constructed in 1972 and by the late 1990's it was obvious to Hartsfield that it had outlived its design life. Pavement evaluations in 1997 and 1999 indicated an accelerating rate of deterioration, with extensive map cracking and joint spalling identified as the predominant distresses in those studies. A materials evaluation identified the presence of alkali-silica reactivity (ASR) and concluded that ASR had contributed to the deterioration of the pavement to the point that replacement of the runway was necessary.

In addition to the critical role of this in Hartsfield's overall operations, decisions about the reconstruction of this runway were even more important because Runway 9R-27L was also one of two Category IIIB-certified runways. As such, a prolonged closure would significantly impact operations at Hartsfield during severe weather. In 1998, during the replacement project's early conceptual planning, a conventional construction schedule of 6 to 7 months was deemed unacceptable due to the operational impacts of such a lengthy closure. Eighteen months of planning resulted in the fast-track alternative discussed in this case study: reconstruction of the runway pavement in 33.5 days.

## Key Project Components

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The following are the key components to the success of this project:

- Extensive planning and phasing.
- Good communication at all levels, positive attitude, and teamwork.
- Key personnel with authority to make decisions immediately and accept responsibility.
- Preserving the existing base layer.
- Sufficient manpower, equipment, and materials with emergency backup plans.
- Security fencing and guard location.

Each of these aspects is discussed in more detail in this case study.

## Planning

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Coordination and communication early in the planning and throughout the project were critical parts of the success of the project. An attitude of teamwork was fostered early in the project's planning phase by Hartsfield, the engineers, the airlines, and the FAA working together closely. Logistical input from contractors who were not yet onboard was also obtained early in the planning.

Early planning estimated that closing the runway for a conventional construction schedule would have a financial impact of approximately \$475,000 per day. In addition to deciding on a fast-track schedule to minimize the length of runway closure, it was decided that the use of a parallel taxiway as a temporary runway would provide near normal operations and reduce delay costs. Figure A-20 presents the layout of construction area, including the parallel taxiway.

Rehabilitation work on Taxiway R—the parallel taxiway south of Runway 9R-27L—was already underway, so the decision was made to modify the taxiway rehabilitation plans in anticipation of using this taxiway as a temporary runway during the Runway 9R-27L reconstruction. This change in the project required realignment of portions of the taxiway and strengthening the shoulder to obtain the required pavement width. Also, the taxiway edge light cans were paved over so that the shoulder could be used as part of the temporary runway.

The notice-to-proceed for this project actually consisted of two separate notices. The first was issued after contract award and was 70 days long. During this phase, materials were stockpiled, equipment was brought to the site, haul roads were built, batch plants were assembled, and Taxiway R was painted and lighted to become the temporary runway. Once the mobilization had progressed to the point of readiness, a second notice-to-proceed was issued which officially started construction on the runway. The contract documents allowed progress payments for stockpiled materials and also made allowances for weekly invoicing during the peak work effort of runway construction.

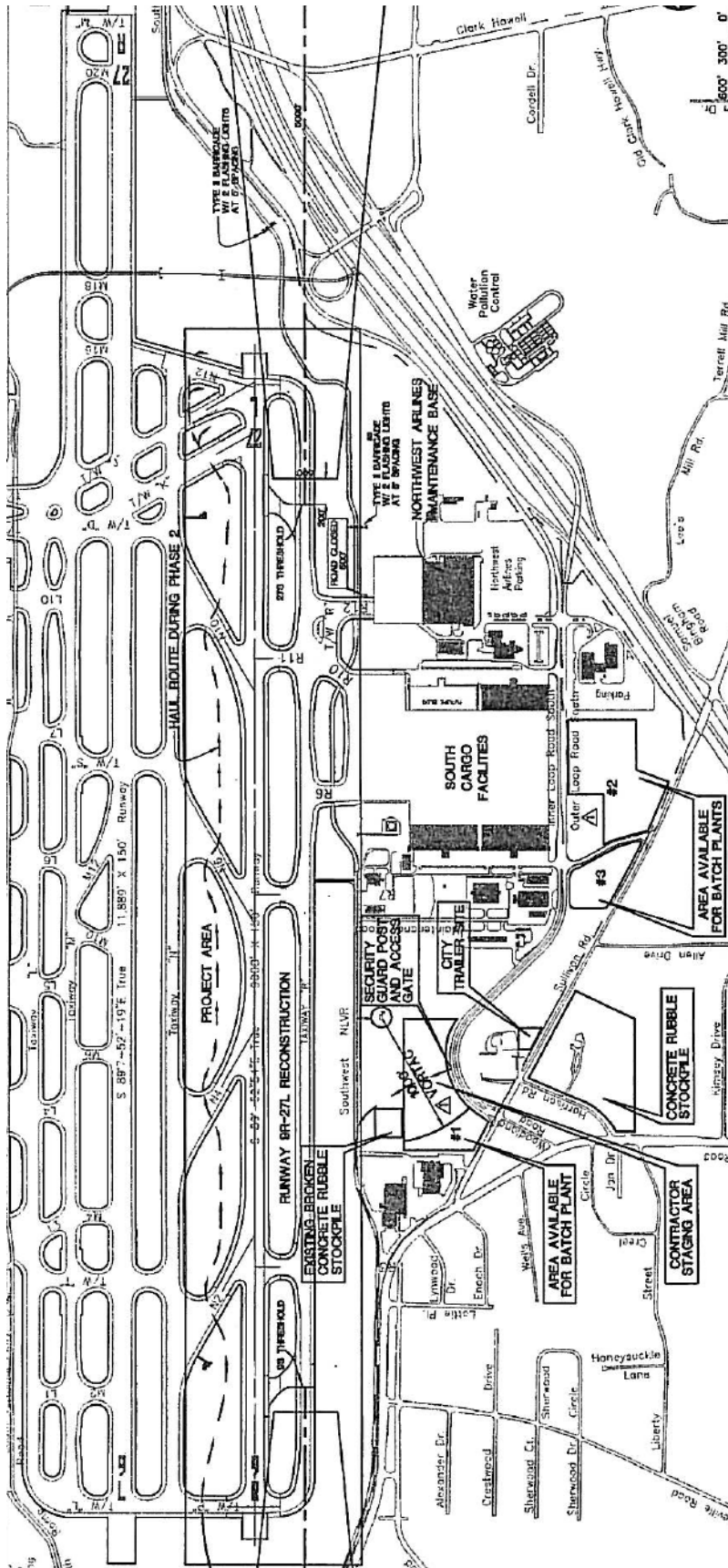


Figure A-20. Project Area

Several important factors were considered during planning for the scheduling of the work. The runway closure was scheduled for the historically drier months of the year, it was scheduled to begin on the slowest day of operations of the week, and the runway was scheduled to reopen for the busiest day of operations of the week. Part of the selection of a 36-day closure for this project was based on past experience at Hartsfield; Runway 8R-26L had been constructed in 40 days. Thus, it had previously been shown that the work could be accomplished within the proposed timeframe. In addition to allowing an extended mobilization period, Hartsfield assisted by providing light cans for the project with allowances for the contractor to replace them as part of the project.

Another step taken during planning to help ensure completion of the project was the inclusion of a "Miscellaneous Modifications" allowance in contract documents. Nearly \$2 million were provided in this allowance to cover work consistent with the project that might be necessary to complete the project successfully. The project team felt that having sufficient funds and having the "get it done" attitude driving the project were important factors.

## **Design**

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The initial design called for the removal of the existing PCC pavement (average 18-inch thick) and cement treated base (CTB) down to the stabilized subgrade. The replacement pavement consisted of an 18-inch PCC pavement and asphalt treated base (ATB) with an average thickness of 6 inches. The existing stabilized subgrade was to provide a suitable platform for construction. Analysis of the section using LEDFAA indicated a design life in excess of 20 years for the anticipated traffic.

Two modifications to the design were actually made during the bid process. Based on the results of previous coring, it was determined that the existing CTB layer was intact and did not require removal and replacement, so the decision was made to use the existing CTB and not require full pavement section reconstruction. This change resulted in several savings. First, the expense and time to remove and replace the CTB was saved. Asphalt cement had been applied to the stabilized base as a curing compound during the original construction and it acted as a bond breaker during pavement removal. The second savings was also one of time. Despite scheduling the project during the historically drier months of the year, the project started with 5 days of rain over the first 10 days. By saving the existing CTB, the project was not delayed due to wet subgrade conditions.

The second modification made during the bid process was to change the slab dimensions from 25-ft by 50-ft reinforced slabs to 25-ft by 25-ft non-reinforced slabs. Although this resulted in additional dowel baskets and joint work, the deletion of the reinforcing mesh resulted in a net cost savings.

There were essentially three main phases to the planning for the project: Phase I was associated with the modification of Taxiway R for use as a temporary runway and contractor mobilization for the runway closure; Phase II was the actual runway reconstruction; and Phase III was the conversion of the temporary runway back to a taxiway. Stages within each phase were designed

to provide cross-over routes for aircraft and still allow the greatest possible area for the contractor to work and were coordinated with the airlines and Hartsfield to maintain operations.

## **Construction**

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As with other phases of the project, the ability to quickly make decisions was a key element of the construction phase. 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. Furthermore, one person assumed responsibility for all decisions, which was key to expediting the decision-making process. By the time many of the issues would have gone through the process for approval or resolution on a typical project, days or even weeks would have been lost.

As noted above, the contract was purposely awarded with two notices-to-proceed to allow the contractor time to have sufficient manpower, equipment, and materials on site. During the initial 70 days, the contractor was able to move all required equipment to the job site, erect the concrete batch plants, stockpile the required materials, and build up the necessary project workforce. The contractor had a massive mobilization effort: five paving machines were on-site (3 actually paved and 2 served as back ups), 3 batch plants were erected with an off-site plant on stand-by, 45 side-dump trucks were brought in to haul concrete, 7 gang drills were brought in for drilling dowel holes, and 700 to 1,000 workers were involved in the work at any given time. The “contractor” for Atlanta was actually a joint venture of four contractors for the massive amount of effort to reconstruct the runway, including two paving contractors who had a history of working together. Everyone had a vested interest in the project and took on ownership of problems and getting them solved instead of passing them on.

During the last couple of weeks of the mobilization phase, sawcutting of the existing pavement began during nighttime closures. To facilitate slab removal the existing slabs were sawcut into 7.5 by 12.5 foot pieces. Once the runway work began the slab pieces were removed with an excavator equipped with a “slab crab.” Equipment generally worked from the existing pavement to minimize damage to the base layer, loading the slab pieces onto flatbed trailers which then hauled them to a designated stockpile yard.

Although the design allowed the existing CTB to remain in place, adjustments to the pavement grades were still required. Grade adjustments were made prior to paving by either milling high spots in the stabilized base or placing an asphalt overlay in low areas.

The concrete materials used for this project were conventional mixes. The main difference between this project and others is the massive equipment and manpower mobilization. Three paving sites were often in progress at one time: two working on main line paving and one working on tie-ins and taxiways.

## Other Issues

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From the beginning, those responsible for the project promoted teamwork, forward thinking, and a "will do" attitude through all aspects of the project. Key personnel with the authority to make decisions were available 24 hours a day so that responses to questions and field actions would be immediate. Plans were reviewed to anticipate any potential problems ahead of time and the project team was open to innovative ideas to facilitate completion of the project.

Liquidated damages were specified in the contract documents, and tied to a number of specific milestones as outlined in Table A-2 (the liquidated damages section of the project specifications has been included at the end of this case study). It was made clear to the contractor that these damages would be assessed if the contractor failed to perform services within the times specified in the contract. However, the runway was completed and reopened 2 days ahead of the 36-day deadline and liquidated damages were not incurred.

Table A-2. Summary of liquidated damage penalties.

Milestone	Liquidated Damages
Completion of stockpiling materials and mobilization requirements	\$75,000 per day for first 10 days; consideration of Termination for Default after 10 days
Open temporary Runway 9S-27S (completion of Phase I, Stage II)	\$200 per minute
Completion of Phase I, Stage II Taxiways R7 and N6 cross-over	\$25,000 per day
Completion of Phase II, Stage II Taxiways R3 and N2 cross-over	\$25,000 per day
Completion of Phase II, Stage II Taxiways R11 and N10 cross-over	\$25,000 per day
Completion of work within 200-ft of Runway 9R-27L and reopen to traffic (all Phase II work)	\$175,000 per day
Completion of all work under Phase III	\$10,000 per day

As with many projects of this scale and scope, close cooperation and coordination with the FAA were critical to the project's success. One of the issues requiring input and cooperation from the FAA was maintaining the glide slope antenna for operations on the taxiway serving as the temporary runway. Temporary runway lighting (PAPIs) was also placed in the grass area for visual approaches.

A significant issue with this project, as well as with most others, is the need for strict airport security. Accommodating the manpower, equipment, and materials mobilized for this project would have required an enormous effort following standard practices of badging and security check points. To reduce the badging requirements and hauling delays, a security fence was established around the work site, which was then considered outside of the airport operations area. Guards were posted at openings in the fence and the taxiway crossings were manned by air traffic control employees. The use of air traffic control people at the taxiway crossings greatly simplified the transport of materials: depending on the position of the guard vehicle the route

was either a taxiway or haul route. The mobilization section of the project specifications is included at the end of this case study.

## Summary

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By all accounts, this project was a success. The runway was reconstructed and reopened for use in 33 days, two days ahead of schedule. Extensive planning, the right people, innovative ideas, and continuous communication made what seemed impossible to many a reality. In the end, over 150,000 yd<sup>2</sup> of runway pavement were removed, 110,000 yd<sup>3</sup> of concrete were placed, 832 in-pavement lights were paved around, and over 60,000 dowel bars were drilled and epoxied.

Given all of the organizational and procedural changes that were put in place to ensure that this project was completed on time, it might be assumed that this project was delivered with a premium price tag. However, both the designers and the owner believe that the final project actually cost less than it might have if constructed under a more conventional schedule. During the design phase, a conventional project was estimated to cost around \$15 to \$20 million, take approximately 6 months, and have an impact of approximately \$475,000 for every day that the runway would be closed. The initial construction bid for the fast track project was \$52 million and the total project came in \$5 million under budget. Additionally, the use of a temporary runway was estimated to have reduced delay costs by over 60 percent.

## Available Sources of Information

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Interviews with several key individuals involved in this project were held at Hartsfield-Jackson Atlanta International Airport. The project team would like to acknowledge the valuable input and contributions of the following individuals for providing much of the information presented in this case study document:

- Frank Hayes, Aviation Consulting Engineers, Inc. (Project Manager)
- Quintin Watkins, Aviation Consulting Engineers, Inc. (formerly with Trinidad Engineering and Design, Quality Control Engineer)
- Talley Jones, Aviation Consulting Engineers, Inc. (Project Engineer)
- Subash Reddy Kuchikulla, Accura (formerly with R&D Testing & Drilling, Quality Assurance Engineer)
- Robert McChord, APAC-Southeast, Ballenger Division (Contractor)

The following documents also provided valuable information used in this summary:

- "Reconstruction of Runway 9R-27L at Hartsfield Atlanta International Airport, the 33 Day Wonder – A Case History," developed by S.R. Kuchikulla, et. al.
- "Hartsfield International Airport, Atlanta," *Concrete Pavement Successes*, American Concrete Pavement Association.
- Article entitled "33 Days ..." developed by GOMACO.
- Project plans and specifications.
- QC-QA test reports.

- 16.1.1 The Goods or part thereof is first identifiable as being appropriated to this Contract,
- 16.1.2 When CITY pays for the Goods or part thereof in accordance with this Contract, or
- 16.1.3 When the Goods or part thereof are dispatched to or from CONTRACTOR's fabrication yard or to the Jobsite.

**16.2 CITY's Right to Reject Goods.** However such transfer of title in the Goods will be without prejudice to CITY's right to reject the Goods in case of non-conformity with the requirements of this Contract. Irrespective of transfer of title in the Goods, CONTRACTOR shall remain responsible for risk of loss or damage to work in progress and all Goods until Final Acceptance. CONTRACTOR shall ensure that the above provisions are imposed upon its suppliers and subcontractors of any tier and shall execute all documents and take all steps necessary to vest title in accordance with this Clause.

**16.3 Title to Bulk Goods.** Title to standard Goods of the type usually bought in bulk such as reinforcement bars, piping materials, non-tagged instruments and instrument installation material, cable and similar items which are not incorporated into the Work shall revert to CONTRACTOR upon agreement by the CITY that such Goods are not required for the Work.

## **SC-17 COMPONENT WARRANTIES**

In addition to the Clause titled "WARRANTY" CONTRACTOR shall obtain or provide, for the benefit of CITY, warranties or guarantees for the equipment, materials and work furnished by lower-tier suppliers and subcontractors. Such warranties or guarantees are to run for the period set forth in the applicable specification of this Contract or, when not specified, that period customarily provided by the supplier. CONTRACTOR shall provide warranty documentation at the time of Final Acceptance or as otherwise required by this Contract.

## **SC-18 APPLICABLE LAW**

This Contract shall be governed by and interpreted under the laws of the State of Georgia. The parties fix venue and jurisdiction for any actions brought in connection with this Agreement or with the Project in Fulton County, Georgia.

## **SC-19 LIQUIDATED DAMAGES**

**19.1 Estimated Liquidated Damages.** The parties hereby agree that the damages which CITY will sustain as a result of CONTRACTOR's failure to meet Contract Milestones are difficult or impossible to determine with certainty and, therefore,



have in good faith estimated as fair compensation the liquidated damages as set forth below. If CONTRACTOR fails to deliver the equipment or materials or perform the services within the times specified in this Contract for the established Milestone Dates, or any extensions granted in writing, the CONTRACTOR shall pay to CITY as fixed, agreed and liquidated damages for each calendar day or minute of delay the sum(s) specified below.

- 1) Failure to complete the mobilization phase, stockpiling of materials and equipment, marshaling labor within sixty (60) days of the first Notice to Proceed: Seventy-Five Thousand Dollars and Zero Cents (\$75,000.00) per day for the first ten (10) days that the Mobilization Phase is not complete; thereafter, consideration will be given **to proceed in accordance with Section GC-41**.
- 2) Failure to open Runway 9S-27S on time at the completion of Phase 1, Stage 2, Drawing G-8: Two Hundred Dollars and Zero Cents (\$200.00) per minute.
- 3) Failure to complete the work required to open the area of Runway 9R-27L between E-10625 and E-11125 as required in Phase II, Stage I, Drawing G-9: Twenty-five Thousand Dollars and Zero Cents (\$25,000.00) per day.
- 4) Failure to complete the work required to open the area of Runway 9R-27L between E-7625 and E-8225 as required in Phase II, Stage 2, Drawing G-9: Twenty-five Thousand Dollars and Zero Cents (\$25,000.00) per day.
- 5) Failure to complete the work required to open the area of Runway 9R-27L between E-12475 and E-13025 as required in Phase II, Stage 2, Drawing G-9: Twenty-five Thousand Dollars and Zero Cents (\$25,000.00) per day.
- 6) Failure to complete the work required within 200 ft. of the Centerline of Runway 9R-27L and reopen the completed Runway within the specified **thirty-five days, thirteen and one-half hours (35 days, 13 1/2 hours)** time-frame as required in Phase II, Stages **1, 2 and 3**, Drawing G-9: One Hundred Seventy-five Thousand Dollars and Zero Cents (\$175,000.00) per day.
- 7) Failure to complete the work required under Phase III, all Stages, Drawing G-10: Ten Thousand Dollars and Zero Cents (\$10,000.00) per day.

**19.2 Application of Liquidated Damages not a Change.** The application of liquidated damages shall not effect a change in the Contract Milestone Dates or relieve CONTRACTOR of its obligation to improve its progress, pursuant to the Clause titled "COMMENCEMENT, PROGRESS AND COMPLETION OF THE WORK," to achieve, or to mitigate the failure to achieve, the Contract Milestone Date or stated Area reopenings.

**Addendum #2, March 16, 1999**

**19.3 Payment of Liquidated Damages.** Payments of liquidated damages shall become due immediately upon failure to achieve the Contract Milestone Dates or stated Area reopenings. CITY shall be entitled to withhold from payments due, offset against other obligations, deduct from Retainage, and draw down on letter(s) of credit or performance securities any and all liquidated damages due from CONTRACTOR.

**19.4 No Restriction of Rights and Remedies.** Nothing in this clause shall operate to restrict any other rights and remedies available to CITY at law or under this Contract.

## **SC-20 KEY PERSONNEL**

CONTRACTOR shall not reassign or remove the key personnel listed below without the prior written authorization of CITY:

<u>Name</u>	<u>Title/Position</u>
Robert W. McCord	Project Manager
Roy H. Jump, Jr.	Assistant Project Manager
Michael F. Durham	Project Engineer

## **SC-21 DRUGS, ALCOHOL AND WEAPONS**

**21.1 Policy.** CONTRACTOR's personnel shall not bring onto the Jobsite, or any other location where the provisions of this Contract apply:

- 21.1.1** Any firearm of whatsoever nature, knife with a blade exceeding four (4) inches (100 millimeters) in length or any other object which in the sole judgment of ENGINEER is determined to be a potential weapon.
- 21.1.2** Alcoholic beverages of any nature.
- 21.1.3** ILLEGAL or CITY prohibited non-prescription drugs of any nature without exception.

## SECTION 1F

### MOBILIZATION

#### 01 DESCRIPTION

- (a) This item shall consist of preparatory work and operations, including, but not limited to, those necessary for the movement of personnel, equipment, supplies, and incidentals to the project site; and for all other work and operations which must be performed or costs incurred prior to beginning work on the various items on the project site.
- (b) This item is also intended to compensate the Contractor for all costs incurred in providing security as set forth in these specifications; for providing all necessary warning devices; for providing all flagmen; for providing all radios as set forth in these specifications and plans; for providing all temporary fencing, barricades, gates, temporary detour roads, and access routes into the job site and the removal of the same at the completion of the work; for providing runway and taxiway closure markings as necessary; and to provide final clean-up and restoration of the area.
- (c) When the Contractor is working in the Aircraft Operations Area (AOA) adjacent to or on live runways, taxiways, aprons, traveling along the NLVR, or performing work requiring the crossing of any of the above facilities, the Contractor will be required to provide an escort vehicle with two (2) double flash high intensity strobe lights to escort vehicles and equipment to and from the non-AOA, and the work site. A maximum of two (2) vehicles can be escorted by the escort vehicle. The Contractor will be required to set up a security checkpoint at the entrance to the AOA, and will be required to provide flagmen at each side of each taxiway or apron throat crossing and set up a warning system to enable the flagmen to deny vehicle and equipment crossings as aircraft approach the crossing.

The Contractor will be required to establish a training program to be approved by DOA Operations and the FAA to train all escort vehicle drivers and flagmen. "The escort vehicle drivers shall have had a minimum of three (3) years experience working on the Atlanta Hartsfield Airport within the AOA and communicating on both the City radio frequency and the FAA tower frequencies in a capacity of an airline pilot, an FAA controller, an operations supervisor or a similar position acceptable to the City of Atlanta Department of Aviation." Lack of sufficient approved trained personnel shall be cause to deny access to the AOA work sites. The escort vehicle shall be painted a high visibility yellow and the flagmen shall be dressed in high visibility clothing with reflective stripes.

- (d) The Contractor shall furnish a hand-held radio for each crew, each taxiway crossing flagman, and one for the City's use, during the contract to monitor Ground Control. The Contractor shall maintain the radios in operating condition during the contract.

The Ground Radios furnished shall be:

ICOM Incorporated, or approved equal  
IC-A3 VHF Air Band Transceiver with included standard accessories  
BC-119 AC BATTERY CHARGER with an additional CM-166 BATTERY  
HM-112 SPEAKER-MICROPHONE

The transceiver shall also be supplied with an external antenna and a power amplifier, such as Communication Specialists CS-31 antenna and CS-10 power amplifier.

(g) amount bid for the contract, in order to be paid on the above basis of payment. Any amount in excess of 7% will be paid on the final estimate. **Radio cost breakdown shall be identified and shown on payment requests separately from all other mobilization.**

(h) Payment will be made under:

Item 1F-1: Mobilization - Per Lump Sum.

END OF SECTION

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## **Memphis International Airport Runway 18R-36L Reconstruction**

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### **General Information**

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Airport: Memphis International Airport

Owner: Memphis-Shelby County Airport Authority

Airport Classification: Medium Hub

Climatic Region: Wet/No Freeze

FAA Region: Southern

Facility: Runway 18R-36L

Description of project: Runway reconstruction; conversion of parallel taxiway to a temporary runway; 9-month primary runway closure

Dates of construction: February 2002 to October 2002

Engineer/Designer: Kimley-Horn & Associates, Inc.

Project Manager/Construction Manager: Allen & Hoshall, Engineers

Prime Contractor: Lane Construction Company

### **Project Overview**

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Runway 18R-36L is one of four runways at Memphis International Airport, and by the late 1990s it was clear that it had reached the end of its design life and was in need of major rehabilitation or reconstruction. Memphis International Airport is the international hub for Federal Express operations, and has the distinction of being the world's busiest air cargo airport. As such, maintaining flight operations around the clock is critical to the economic stability of the airport, and any solution to reconstruct the runway had to minimize downtime and operational delays.

Unlike many other fast-track runway reconstruction projects, the Memphis project differentiates itself by the need for complete reconstruction of all components of the runway and not just the reconstruction of the pavement section. In addition to the reconstruction of the pavement section, this project included 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 order to facilitate the runway reconstruction project, two other projects had to be completed first: Taxiway M was upgraded to serve as a runway capable of handling Boeing 727 aircraft, and Taxiway N was upgraded to handle the increased traffic that it would receive while serving

as the primary taxiway for the temporary runway. The final project, which is the case study project presented herein, included the following three phases:

- Phase I: conversion of Taxiway M to a temporary runway.
- Phase II: complete reconstruction of Runway 18R-36L.
- Phase III: transition back to serving as the active runway.

A diagram outlining the project is presented in figure A-21.

## **Key Project Components**

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To some, this project might not be considered fast-track in that it did not employ specialized materials, equipment, or procedures. What it did do, however, was optimize the available techniques and methods to successfully accomplish the work and re-open the runway 39 days ahead of schedule. And there are many aspects of this project that could be employed on other projects. Components that were key 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.

Each of these aspects is discussed in more detail in this case study.

## **Planning**

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Detailed advance planning was one of the most critical aspects to the success of this project. The planning efforts extended through all phases of the project—from phasing to design to construction—as noted throughout this case study.

The decision to convert the parallel taxiway to a temporary runway was not made until after the initial planning had progressed out of the conceptual stage; much planning and research went into the decision. There was no specific plan in place when the initial discussions to reconstruct the runway commenced, which was purposely done to encourage innovation and creativity while developing a solution. During this process, there were spirited discussions and some disagreements, which in hindsight proved to be quite valuable to the process. The Airport Authority initially visited with personnel responsible for the reconstruction of Runway 9R-27L at



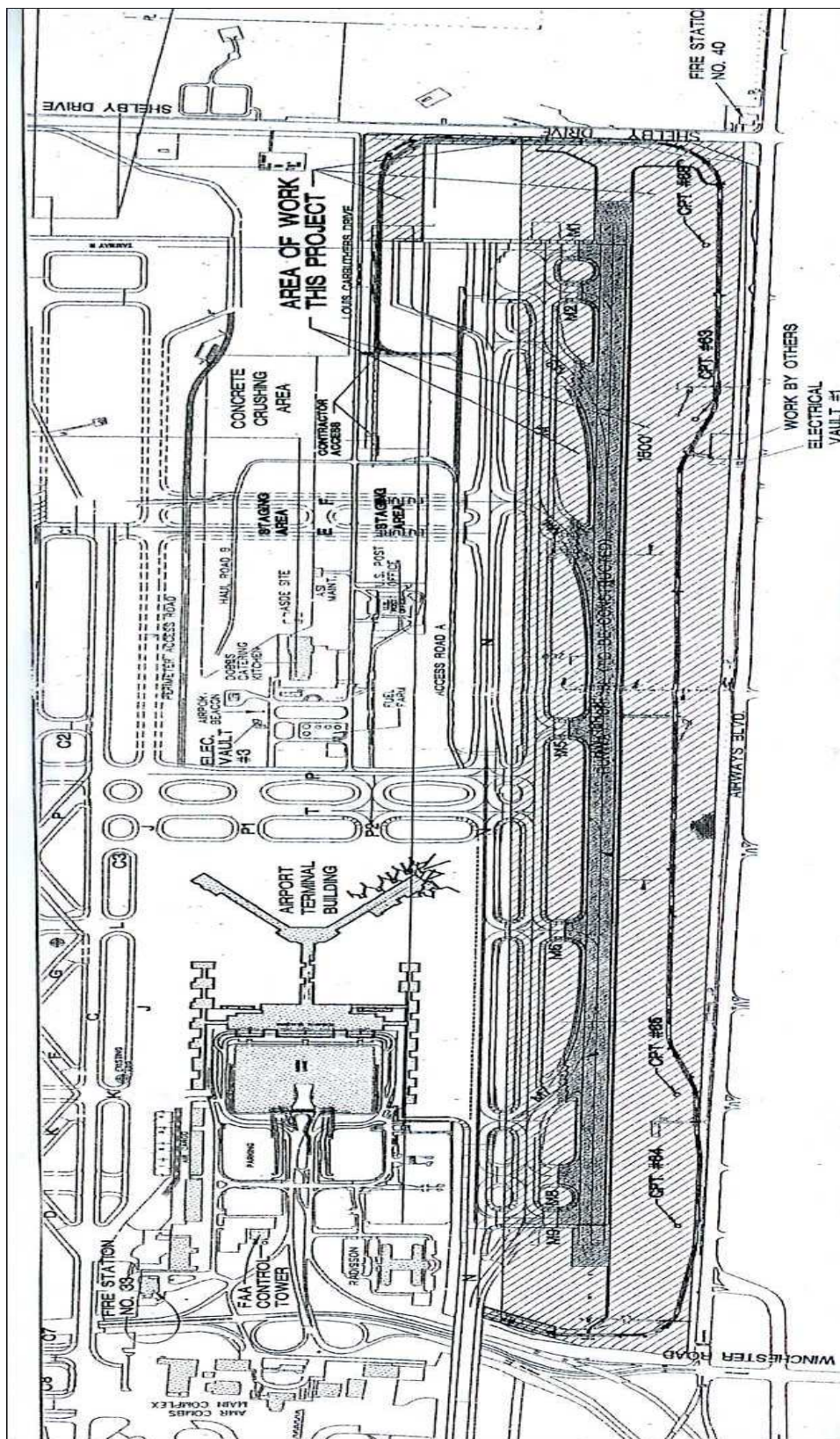


Figure A-21. Project layout plan.

Atlanta Hartsfield International Airport. Although it was determined their situation was quite different from the situation at Memphis, it was still a valuable part of the process.

Once work began, several projects had to be undertaken and completed well in advance of the runway reconstruction, including two major projects on the airside pavement system. First, Taxiway M, the taxiway parallel to Runway 18R-36L, was upgraded to function as a runway capable of handling Boeing 727 aircraft. 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.

Studies were performed to evaluate the roadway system to and from the airport. A traffic signal was added at an intersection where materials and equipment would need access into the airport, which proved valuable in reducing delivery delays. A study was also performed to investigate other major pavement construction projects that would be occurring in the Memphis area during the time of this project to ensure that substantial resources—such as materials or manpower—would not be used elsewhere and contribute to delays on the runway project.

Good communication was one of the key elements to the success of the project. Communication was made a high priority on the project, which promoted creative solutions and a strong team spirit:

- Experts from all trades were invited to three constructability sessions during the design of the runway replacement. The group helped think through the construction steps, identified potential causes of delay, and shared ideas for securing lower bids and faster delivery. These issues were addressed early enough in the design process that modifications could be made without any lost effort.
- Partnering sessions were required and were held twice, pulling together a functioning team more quickly. At the start of the final construction, a formal partnering session was held with policy-setting representatives of all stakeholders, as is often done for large construction projects. However, the partnering was carried one step further when the prime contractor and the airport mutually decided to hold a second partnering session between the foremen, inspectors, testing personnel, and other field personnel to spread the upper-level trust and appreciation for the task at hand. This extra step is credited with maintaining quality and timeliness throughout the project.
- Proactive steps were taken to facilitate interaction between all parties in the field. The owner's chief construction-phase administrator encouraged everyone to interact freely and quickly, setting agreed upon response times, to the point that it became a habit.
- An FAA representative was “hired” by the airport to stay on site full time to continuously perform a myriad of duties. This produced timely responses to questions, more direct understanding of the project, and expedited performance of routine tasks.



- 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). Lack of communication was not an option on this project.
- The designers and construction managers were required to assign their project managers to the trailers so that all questions, decisions, new ideas, and so on could be resolved within 24 hours. The higher fees invested produced the benefit of timely responses, encouraged the elimination of wrong assumptions or interpretations, and led to speedy consideration of innovations informally "run up the flagpole."

The contract was purposely 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. This additional time did come at an additional cost to the Airport Authority. Since timing was essential on this project, the benefits of the extra investment 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.

During the 5-month pre-construction period, the Authority provided several payment provisions to encourage the contractor to be forward looking. Specified mobilization tasks were paid for early to ensure a fast start to the project, which helped reduce the contractor's unpaid overhead, and in turn resulted in a lower bid price. All aggregate and cement were paid for upon delivery to encourage sufficient stockpiling of materials and to avoid shortages in case of flooding of the Mississippi River, which carries much of the bulk construction materials used in the Memphis area. Research was conducted to determine that the high flood stage of the river typically occurs in April, so enough material was stockpiled to last through June 1.

With any large construction project, and especially a fast-track project on a runway at a major commercial airport, there are numerous decisions that need to be made. On the Memphis project, a hierarchy was created such that the layers of decision-making levels were streamlined and compressed. A single person was assigned the responsibility for liaison and primary decision-making on all field issues and was involved in all aspects of the project. In return, everyone had direct access to this person to discuss ideas and to get a quick decision. The job of this individual was to create a focal point for communication between the Senior Airport Management and the field management and construction personnel. This person was knowledgeable and experienced with airport construction projects, was authorized to make quick decisions and, most importantly, was able to accept responsibility for the entire construction project. The Authority felt strongly that multiple levels of decision makers would not work because of the rapid decisions that would be required throughout the project. The Authority also authorized this person to expend additional funds as necessary to keep the project on schedule. The need to use these additional funds never developed.

Portions of the PCC overlay on the existing runway showed signs of deterioration from alkali-silica reactivity (ASR). The aggregate from that project was obtained from a sand pit located along the Mississippi River. The Airport Authority now insists on the use of limestone aggregate and has a process in place to deal with the potential for ASR, both of which were implemented on the Runway 18R-36L project.

The planning process did not always proceed seamlessly. Airport Authority staff indicated that there were meetings in which they continued to discuss the same topics over and over again. In retrospect, they would have tried to narrow the focus of each meeting, and always try to come away from a meeting with a decision and/or a list of action items. There were also some design changes that were made late in the process, such as addressing the 200-foot runway width for the new Airbus A-380 aircraft at the 95 percent stage.

## **Design**

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Throughout the project, cooperation and flexibility on the part of the FAA played a key role in the success of the project. Early in the process, the FAA committed to working with the Airport Authority in a proactive rather than reactive manner. The project team readily acknowledges that the project could not have been completed as quickly or as successfully without the FAA's support. Some of the FAA contributions were as follows:

- Aiding in the process to allow Taxiway N to function as a taxiway serving the temporary runway (despite initial clearance conflicts with taxiing planes), working to set reasonable operating rules instead of unilaterally denying unconventional solutions, and thoroughly evaluating, within FAA guidelines, the allowable aircraft on the temporary runway.
- Modifying the rules for nighttime operations when the airport was under the control of a single ground traffic tower crew and when no commercial aircraft were operating near Taxiway N.
- Developing modified Instrument Flight Rules (IFR) by adding partial NAVAIDs to the temporary runway, allowing greater control capability.
- Assigning to the project, under a Memorandum of Understanding, a full-time representative to work on all FAA matters to maximize operations.

The FAA also allowed construction to occur within 180 feet of the primary runway, instead of the specified 200-foot construction requirement, in rolling increments of 2,300 feet during visual flight rules (VFR) weather (limited to 190 feet toward the temporary runway). This restriction waiver allowed construction of the connecting taxiways without extensive closures of either the primary runway or the temporary runway. FAA's relaxation of the 200-foot construction requirement resulted in a direct, positive impact on airport capacity, and it is certain that, without their cooperation, the project could not have been completed within the 9-month schedule. Although the FAA was at first reluctant to allow work within the 200-foot restricted area, they were convinced when a Northwest pilot put a video camera on board an arriving aircraft to show

the pilot's line of sight during arrival (the airport was planning to use a private aircraft but Northwest took the initiative and did it at their own cost). The orange security fencing at a 200-foot offset could be seen from the aircraft, but it was clear from the video that the 200-foot offset was only in the periphery of the pilot's line of sight and would not be a detrimental factor in safely landing the airplane. The FAA also did their own research regarding runway accidents and the percentage of times that aircraft would penetrate the 180-foot boundary as compared to the 200-foot boundary. Figure A-22 illustrates the runway and taxiway operations protection areas for the various phases.

During the initial phases of the project, results of falling weight deflectometer (FWD) testing performed as part of the airport-wide pavement management system project in the mid 1990s were evaluated to help identify localized areas of questionable support conditions. With that information, a comprehensive boring program was developed, with additional borings located in these questionable areas. Borings were typically performed every 200 feet along the runway and to a depth of 12 to 15 feet, but were concentrated every 100 feet in questionable areas. This process allowed proper planning when dealing with these areas during construction.

In order to limit potential conflicts with utilities during construction, all existing underground utilities on the west side of the airport were located during the design phase and identified using a "soft dig" effort, in which a pneumatic jet and suction process are used to remove loosened material and expose the utility. Once exposed, the type, size, and depth of the utility were marked on the surface with a hub and tack. This extra effort allowed the contractor to accurately bid the project without contingencies and to excavate without fear of disasters. The process is not foolproof—cables can be missed in the sweep, the horizontal and vertical location could change over its length, and fiber optic cable without a trace cable or tape would be missed if not identified by other means—but it did eliminate surprises during construction on this project and proved to be money well invested.

## **Construction**

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As with other phases of the project, the ability to quickly make decisions was a key element during construction. 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 philosophy on the part of the owner and designers was that if they were going to demand performance from the contractor, they had to be willing to live up to those demands as well. In addition, the field trailers were all placed together, so all decision-makers were in close proximity to each other. The entire team made a commitment that all issues would be resolved within 24 hours so the project would always be moving forward. Furthermore, one person assumed responsibility for all decisions, which was key to expediting the decision-making process. By the time many of the issues would have gone through the process for approval or resolution on a typical project, days or even weeks would have been lost.



The contractor and its supervisor were given flexibility in the field to make adjustments to the schedule as needed. Although Primavera was used to schedule tasks at the start of the project in order to identify conflicts or problems, it was not regularly updated during the project. Because many adjustments needed to be made during construction, the construction managers did not want to burden the contractor with the minutia of details; it would have been a constant battle and would have required substantial time and effort by the contractor on such a fast-track project. Because the contractor was part of the team, this approach seemed to work well. The general contractor also stepped up and worked directly with the subcontractors, whereas typically the subcontractors are left to interact directly with the airport.

In terms of materials and processes, there was nothing entirely unique done on this project. In fact, the Airport Authority wanted to use processes and techniques in which the contractors were familiar and which would not present surprises or complications during construction. From a construction standpoint, the difference between this and other projects was in the contingency plans. Extra equipment and work forces were kept on the job at all times, and more frequent maintenance was performed on construction equipment. This is also true of the quality control process: the process was the same, but there were more people to carry out the process in a timely and effective manner. At the start of the project, most experts said that it would take a 24/7 operation to accomplish the work within the 9-month period. Although two crews were used during demolition, the rest of the work was accomplished working 12-hour shifts, 6 days per week.

One unique approach that was used ahead of excavation for utilities was pre-treating wet soil with inexpensive “Code L” lime, which had proven to be effective during previous projects. This process allowed the contractor to begin backfilling immediately, without concern for high moisture contents in the excavated soil. The newly excavated soil was then treated and stockpiled for the next dig.

## **Other Issues**

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From the beginning, those responsible for the project conveyed a positive attitude toward the project and encouraged it in others, to the point where that attitude became contagious. Although everyone understood the difficulties associated with this fast-track project, there were no second thoughts as to whether or not the work could be accomplished. The following catchphrase became the motto for the project: “Don’t tell me why it cannot be done, tell me what needs to be done to make it happen.” Success breeds success: the construction portion of the project got off to a quick start, with pavement removal being completed within 2 weeks, which inspired and motivated others on the project.

The project team also emphasized the importance of advertisement and promotion on political and community acceptance of the project and on the willingness of people involved to carry out the mission. A project-specific logo was created for this project, which highlighted the criticality of opening the runway by October 31. Large display signs were also created and installed around the project site in clear view of both the workmen and the community.

The Authority also noted that 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 the start of Federal Express' 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. The established bonus potential of \$2.5 million was equivalent to 5 percent of the estimated maximum construction budget. On the other hand, liquidated damages, as outlined in table A-3, 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. The runway was cleared for use by the FAA 39 days ahead of the October 31 deadline, and the contractor received the full \$2.5 million bonus. This bonus was completely funded by the Airport Authority and was believed to be money well spent.

Table A-3. Summary of liquidated damage penalties.

<b>Milestone</b>	<b>Completion Date</b>	<b>Liquidated Damages</b>
Runway 17-35 switchover	January 31, 2002	\$25,000 per day or any portion thereof
Runway 17-35 closures	As required	\$1,000 per hour or any portion thereof
Preparation for Runway 18R-36L flight check	October 1, 2002	\$100,000 per day or any portion thereof
Runway 18R-36L and associated taxiways operational	October 31, 2002	\$100,000 per day or any portion thereof
Project completion	December 31, 2002	\$2,000 per day or any portion thereof

Note: no liquidated damages were applied.

Given all of the organizational and procedural changes that were put in place to ensure that this project was completed on time, it might be assumed that this project was delivered with a premium price tag. However, both the designers and the owner believe that the final project actually cost less than it might have. During the design phase, the project was estimated to cost around \$57 million; the total project came in at \$43 million, excluding the bonus payment. In this case, it is believed that the full runway closure helped keep costs down.

## Summary

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By all accounts, this project was a success. 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.

The Airport Authority feels this project was “the most successful airside project ever undertaken at Memphis International Airport” and would consider a similar approach on future projects.

### **Available Sources of Information**

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Interviews with several key individuals involved in this project were held at Memphis International Airport. The project team would like to acknowledge the valuable input and contributions of the following individuals for providing much of the information presented in this case study document:

- Joseph Polk, Construction Administration Manager, Memphis-Shelby County Airport Authority
- Thomas Clarke, Manager of Engineering Administration, Memphis-Shelby County Airport Authority
- Mark Manning, Kimley-Horn & Associates, Inc. (Design Project Manager)
- David Webb, Allen & Hoshall (Construction Project Manager)

The following documents also provided valuable information used in this summary:

- Paper entitled “The Reconstruction of Runway 18R-36L: Lessons Learned (or Relearned),” developed by Kimley-Horn & Associates.
- Paper entitled “Fast Track Reconstruction of Runway 18R-36L at Memphis International Airport, A Case Study,” published in proceedings to the 2003 ASCE Specialty Conference *Airfield Pavements, Challenges and New Technologies* held in Las Vegas, Nevada and authored by Joseph M. Polk, Jr. and Gary Mitchell.
- Engineer’s Design Report for Reconstruction of Runway 18R-36L at Memphis International Airport.
- Project plans and specifications.
- Minutes of Constructability Brainstorming Sessions.
- Special Conditions: SC-60, Sequence of Construction and Liquidated Damages.

## Contacts

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**SPECIAL CONDITIONS****SC-60 - SEQUENCE OF CONSTRUCTION & LIQUIDATED DAMAGES****PART 1 GENERAL****1.01 SUMMARY**

- A. This section describes the sequence of construction of the various phases of the project and sets forth the liquidated damages of each phase.
- B. Related Work:
  - 1. Documents affecting work of this Section include, but are not necessarily limited to the General Provisions and other Sections of these Specifications.

**PART 2 PRODUCTS**

Not used.

**PART 3 EXECUTION****3.01 PHASES AND LIQUIDATED DAMAGES.**

- A. The Contract is required to be completed in phases in order to minimize the impact to aircraft operations, airfield tenants and other construction projects. Each phase shall be completed within the Contract Time as stipulated below. Phase completion includes all work shown on the plans and specifications, including but not limited to excavation and grading, concrete and asphalt paving, grooving, airfield lighting and guidance signs, electrical vault work, pavement and miscellaneous demolition, concrete pavement joint sealing, pavement marking, and turf, seed and mulch. The pavement must be available and accepted for aircraft operations for the Phase to be considered complete. **A separate Notice To Proceed (NTP) will be issued for each phase and sub-phase. New phases for construction cannot begin until preceding Phases are complete (unless another phase is stipulated to run concurrently) as access to active runways and taxiways must be maintained.**
- B. The Runway Safety Area (RSA) is 200 feet wide east of Runway 18R-36L, and west of Runway 17-35. A modified safety area, 210 feet east of 18R-36L and 190 west of 17-35 can be used for work between 200 and 210 feet east of 18R-36L for any continuous distance not to exceed 2300 feet at any given time. See Sheet G-SP-11 for details.
- C. The Contractor will be required to pull men and equipment 250 feet away from an active runway when visibility drops below 800 feet vertically (ceiling) and/or two miles horizontally (commonly referred to as "800 and 2"). During Phase 1 and 3, when runway 18R-36L is active, the Contractor will be required to pull men and equipment at least 400 feet away from the runway when visibility drops below 400 feet vertically and one mile horizontally (400 and 1). Runway 17-35 (Phase 2) will be closed to air operations when visibility drops below 400 and 1.

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D. The phases of work are defined to include but not limited to:

1. **PHASE 1** consists of all work outside of and not affecting the Runway Safety Area (RSA) or approach surfaces for Runway 18R-36L. This work generally consists of, but is not limited to, access road drainage and embankment, staging area preparation and procurement of equipment, materials and permits. Other administrative work includes submittals for equipment, materials and mix designs, procurement of materials and submission of the construction schedule to the engineer. FAA form 7460 must be filed for batch plants, pug mill, crushing operations, and any other structure to be erected on airport property sixty (60) days prior erection.
2. **Phase 1A** work consists of conversion of T/W M to Runway 17-35. Portions of Taxiway M (R/W 17-35) may be closed during this phase. The conversion includes, but is not limited to, removal of the taxiway edge reflectors, addition and modification of runway and taxiway markings such as the runway numbers and hold bars, relocation of the north end centerline of T/W N (centerline marking and reflectors), energizing runway lights and signs (lights and signs installed by others), bagging or removal of some taxiway signs and construction or repair of the safety fence between T/W M and R/W 18R-36L. Intersection closures shall be coordinated with the Owner and Engineer. No more than one intersection may be closed at any one time. Threshold taxiways (M1 and M9) may not be closed more than one and one half hours at a time and must be open between the hours of 1800L and 0700L each day. Phase 1A cannot start earlier than January 12, 2002 and must be complete prior to the start of Phase 2 (February 1, 2002).
3. **Phase 2** begins on February 1, 2002 at 0700 with the closing of Runway 18R-36L. Phase 2 consists of all work within the RSA of 18R-36L (250' west of centerline and 210' east of centerline) and under the approach surfaces of 18R-36L, but outside the approach surfaces and safety area for Runway 17-35. All items of work associated with the runway including, but not limited to, drainage, underground utilities, concrete paving, asphalt paving, grooving, approach lights, electrical, lighting, signage, NAVAID modifications, marking and Runway 18R-36L cleaned and ready to open for operations, must be complete by October 1, 2002.
4. **Phase 2A** begins on October 2, 2002. Work during this phase is limited by the flight check of the NAVAIDs. This test normally takes from two to three weeks to complete, but may require additional time. All items of work associated with making the runway operational have to be completed prior to commencement of FAA flight check. Some work will be permitted on connecting taxiways, such as joint sealing and electrical work, but the contractor will be required to clear areas of work to allow for the flight check activities within a one hours notice. This phase ends October 31, 2002 when the runway is opened, in fully operational condition.
5. **Phase 2B** consists of work (paving, drainage, utilities, electrical conduit, etc.) within 190 feet of the centerline of R/W 17-35 (T/W M). This Phase requires temporary closures of R/W 17-35 and must be coordinated with the Owner and Engineer.

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6. **Phase 2C** consists of work in and under the approach surfaces and within the 1000-foot safety area for Runway 17-35 as shown on Sheet G-SP-09 and G-SP-10. The unrestricted work in this phase is limited to those areas where construction personnel and equipment do not penetrate the affected approach surface, from the beginning of the project to Station 27+00 and from Station 114+00 to the end of the project. In areas where construction personnel and equipment must penetrate the affected approach surface, no work will be allowed except when the affected end of the runway is in departure mode only, or when the runway is closed. Work will not be allowed in or under both approach surfaces at the same time. No work will be allowed in any of these areas between 2230L and 0230L nightly. Additional constraints may include, but are not limited to, denial of work except when the affected end of the runway is in departure mode, restricted entry into the 1000-foot safety area, and denial of work when visibility drops below 800 and 2.
7. **Phase 3** consists of all work associated with the conversion of Runway 17-35 to Taxiway M. This phase cannot begin until Runway 18R-36L is reopened and fully operational. This work generally consists of obliteration or removal of all runway markings, runway centerline lights, runway edge lights, runway signs and the removal and storage of the temporary NAVAIDS. This work also consists of the installation of taxiway centerline lights, taxiway edge lights, taxiway signs, taxiway markings. Runway 18R-36L is open during this phase except during window closures for marking and electrical work within the Runway 18R-36L safety area. Upon completion of all other work in this phase, project safety fences shall be removed and disposed of off site, the area graded smooth and sod placed on all remaining disturbed areas.
8. **Phase 3A** consists of final paving of the Service Road and cleanup of the staging area and haul routes.
9. **Runway Closures**  
For phases which require runway closure or threshold displacement, a NOTAM must be coordinated with the Owner at least 24 hours in advance. When closed, lighted "X's" must be placed at each end of Runway 18R-36L and/or 17-35, on the numbers by the Owner prior to construction and removed by the Owner prior to opening of the runway to aircraft operations. When the runway is closed, generators for use with the "X's", must be started, turned off, fueled, and non-operational lights replaced daily by the Contractor. The Contractor shall have a stand-by generator for use in the event of failure of one of the generators. No direct payment shall be made for the stand-by generator or daily maintenance of the "X's". See Specification S-100 for additional requirements and details for the "X's".

The OWNER and the CONTRACTOR recognize that time is an essential element of this contract and that delay in completing this project will result in damages due to public inconvenience, obstruction to aviation and vehicular traffic, interference with businesses both on and off the airport, and increased costs to the OWNER, associated with engineering services, inspections, and project administration. It is therefore agreed that in view of the difficulty of making a precise determination of such damages, the CONTRACTOR will pay the OWNER, sums of money in the amounts herein stipulated, not as a penalty, but as Liquidated Damages for not meeting the schedule for specific project milestones.

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Critical Project Milestones are established and agreed to as the following:

1. Runway 17-35 Switchover, Phase 1A, - includes all items of work contained within the project scope necessary to convert T/W M to temporary Runway 17-35 to effect the closure for re-construction of Runway 18R-36L, including, but not limited to, installation of temporary signs, re-striping pavements, erection of barricades, etc. This phase of work cannot start prior to January 12, 2002 and must be complete on or before January 31, 2002.
2. Runway 17-35 Closures, Phase 2B, - the CONTRACTOR shall be allowed a total of 720 hours during the contract duration for temporary closures of Runway 17-35 to effect required items of work. These closures will be coordinated with ENGINEER and MSCAA for issuance of all required NOTAMS, etc. Closures of Runway 17-35 may not commence prior to 0700L. All closures shall require that Runway 17-35 is reopened and operational no later than 2200L the day of the closure, unless otherwise approved by the Engineer and MSCAA. Failure to have the runway open and operational and/or exceeding the 720 hours closure allowance shall result in the assessment of liquidated damages.
3. Preparation for Runway 18R-36L Flight Check, completion of Phase 2 - includes all items of work, including but not limited to, all paving, marking, electrical, lighting, signage, NAVAIDS, grading and drainage required for satisfying the Federal Aviation Administration and MSCAA standards for runway operations. This phase of work begins February 1, 2002 and must be complete on or before October 1, 2002.
4. Reopening of Runway 18R-36L and Associated Taxiways in fully operational condition, completion of Phase 2A - includes the completion of all required items of work, including, but not limited to, paving, marking, electrical, lighting, signage, NAVAIDS, completion of FAA flight check (by others), demolition, barricade removal, grading, drainage and complete cleanup of work areas adjacent to the affected runways and taxiways that result in a fully operational runway and taxiway system (excluding Taxiway M). This phase of work begins October 2, 2002 and must be complete on or before October 31, 2002.
5. Project Completion, completion of Phase 3 - includes completion of all work activities required for project completion, including but not limited to, conversion of Runway 17-35 to Taxiway M, completion of the Service Road, and final restoration of all disturbed areas. This phase of work must be completed on or before December 31, 2002.

For these Project Milestones, the OWNER and the CONTRACTOR have, in good faith, agreed to Liquidated Damages as set forth below.

If the CONTRACTOR fails to deliver equipment or materials, or perform any services within the times specified in this Contract to achieve the established Milestones, Dates, or any extensions granted in writing, the CONTRACTOR shall pay to the OWNER as Liquidated Damages, the sum (\$ ) specified in Table 1, below:

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Table 1

<i>Milestone</i>	<i>Completion Date</i>	<i>Liquidated Damages</i>
R/W 17-35 Switchover	January 31, 2002	\$25,000 per Day or any portion thereof
R/W 17-35 Closures	As Required	\$1,000 per Hour or any portion thereof
Preparation for R/W 18R-36L Flight Check	October 1, 2002	\$100,000 per Day or any portion thereof
R/W 18R-36L and Associated Taxiways Operational	October 31, 2002	\$100,000 per Day or any portion thereof
Project Completion	December 31, 2002	\$2,000 per Day or any portion thereof

Application of Liquidated Damages is not a Change to the Contract. The application of any Liquidated Damages to one Milestone shall not effect a change in the subsequent Contract Milestone dates or relieve CONTRACTOR of his responsibility to meet all construction schedules. If multiple Milestone dates are missed, Liquidated Damages for more than one Milestone may be imposed concurrently. If failure to complete any Milestone causes another Milestone to be missed, the separate Liquidated Damages for each Missed Milestone shall be assessed in full, concurrently.

If Liquidated Damages are imposed, the OWNER shall deduct the same from any amounts due the CONTRACTOR at the time Liquidated Damages are imposed. If sufficient amounts are not due to the CONTRACTOR to cover such Liquidated Damages, then the OWNER shall invoice the CONTRACTOR for the amounts due to the OWNER. Such invoices shall become due and payable immediately upon receipt by the CONTRACTOR.

Liquidated Damages are in addition to any other damages, penalties, or retainage, which may be assessed and withheld under other provisions of this contract.

#### COMPLETION BONUS

The OWNER and the CONTRACTOR agree that achieving two critical dates is necessary and that the OWNER shall pay the CONTRACTOR a cash bonus for having Runway 18R-36L ready for flight check on schedule and for reopening Runway 18R-36L and its associated taxiways on schedule. To be eligible for each bonus the CONTRACTOR must have all work completed that relates to each phase of the work on or before the contract date.

**For the purpose of determining bonus eligibility, contract dates are fixed and will not be changed.** Having Runway 18R-36L ready for flight check shall include all items of work including, but not limited to, necessary paving, marking, electrical, lighting, signage, NAVAIDS, grading and drainage required for the runway to meet Federal Aviation Administration and MSCAA standards for operations, including completion of all punch list items within the runway safety area. The contract date for completion of this phase of work is October 1, 2002.

Eligibility for the bonus related to reopening Runway 18R-36L shall include the completion of all items of work including, but not limited to, paving, marking, electrical, lighting, signage, NAVAIDS, grading and drainage and complete cleanups of work areas adjacent to the affected runways and taxiways that result in a fully operational runway and taxiway system (excluding Taxiway M) based on Federal Aviation Administration and MSCAA standards, including completion of all punch list items within the runway and taxiway safety area. The contract date for completion of this phase of work is October 31, 2002. Failure to meet the specified contract date for each phase of work shall result in forfeiture of the related Bonus in its entirety. The Bonus shall be paid as shown in Table 2.

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**Table 2**

<i>For Completion</i>	<i>Bonus Amount</i>
Preparation for Runway 18R-36L Flight Check	\$1,500,000
Reopening of Runway 18R-36L and Associated Taxiways in fully operational condition	\$1,000,000

**NOTES:**

1. All days are calendar days.
2. Daylight hours are defined as starting at 6:00 a.m. local time and ending at 7:00 p.m. local time.
3. Contractor shall be mobilized and on site ready for work on the date stated in the Notice to Proceed. The Owner reserves the right to establish the Notice to Proceed date (Day 1 of the Contract).
4. Bonuses are offered as inducements for the Contractor to overcome all obstacles such as, but not limited to: weather, coordination with other contractors, labor difficulties, material deliveries, inefficiencies, and minor change orders, all in order to complete the phase(s) within the time stated. Completion is as defined in Article 3.01(A) of this Special Condition. Contractor should anticipate weather impacts in his schedule as presented in specification section SC-120.
5. The Owner reserves the right to prohibit the Contractor from working in certain areas of the Aircraft Operations Area (AOA) during periods of inclement and/or Instrument Flight Rules (IFR) weather conditions in Phases 1 and 3, in order to maintain safety for aircraft operations. Runway 17-35 is not an Instrument Runway.
6. "Completion" of a phase shall be defined as work that is 100% complete including all major punch list items. The Engineer shall make the final determination as to the completion of any phase or sub-phase. If the Engineer determines that a phase or sub-phase is not complete by the required completion date, then the Owner intends to withhold all bonuses associated with that phase and assess liquidated damages for the full extent of non-excusable delays in each of the applicable phases, past the Completion Date, until the Engineer determines that a phase or sub-phase is complete. The Owner may deduct liquidated damages accrued during any month from the Contractor's pay request for that month or accrue such liquidated damages until the final pay application.
7. If the Contractor experiences weather related delays, he shall submit a report documenting the weather conditions and delays, if any, experienced during the month. As per SC-120, the report should be submitted by the 15th of each month.

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8. If the Contractor is prevented from working due to any other legitimate reason he shall notify the Engineer in writing as per Specification Sections GP-50 and SC-250 of the delay and request a corresponding increase in the schedule for a phase or sub-phase.

The Engineer shall be the sole judge as to whether or not a request for a phase or sub-phase extension is legitimate.

9. The Owner reserves the right to adjust phase limits to accommodate availability and airfield operations at no additional cost to the Owner.

**END OF SC-60**

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## **Phoenix Sky Harbor International Airport Runway 8-26 Reconstruction**

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### **General Information**

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Airport: Phoenix Sky Harbor International Airport

Owner: City of Phoenix Aviation Department

Airport Classification: Large Hub

Climatic Region: Dry/No Freeze

FAA Region: Western Pacific

Facility: Runway 8-26

Description of project: Reconstruct and extend runway while maintaining daytime operations at all times

Dates of construction: 2002

Engineer/Designer: Michael Baker Corporation

Project Manager/Construction Manager: Parsons Brinckerhoff

Prime Contractor: Ames Construction

Paving Contractor: Kaufman Services, Inc.

### **Project Overview**

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The scope of this project included the reconstruction and extension of Runway 8-26 and the Taxiway B connecting taxiways, as well as the replacement of the drainage, electrical, and NAVAID systems. The existing 11,000-ft runway length was not adequate to accommodate heavy payloads of departing aircraft on long domestic and international flights, especially during the hot summer months. At the time that this project was undertaken, the existing runway was a bituminous pavement, which was on a mill-and-replace cycle of about 7 years, requiring a 2-week runway closure to complete the work.

The biggest constraint on this project was the need to keep the runway operational at all times during the construction process. The challenges of accomplishing this task at Phoenix Sky Harbor International Airport, the world's fourth busiest airport and the world's busiest three-runway airport, cannot be overstated. Innovative construction phasing was necessary to keep 6,000 ft of the runway open at all times during the project, with only night closures permitted. The runway had to be re-opened each morning, be fully operational, and meet all FAA criteria for an active runway. Non-traditional paving materials and paving methods needed to be employed to accomplish this effort.



The original plan was to extend the runway and parallel taxiway 1,000 ft to the west, and to convert the runway surface from asphalt to portland cement concrete. The runway extension was eventually shortened to 900 ft to allow a sufficient safety area for a nearby roadway. The project team decided that 6,000 ft of runway was to remain open at all times, which necessitated the development of an innovative phasing plan for reconstruction. The first phase of reconstruction involved paving the runway extension. After completing the runway extension, 7,000 ft of runway at the east end was kept open while the remaining portion of the runway was reconstructed. The 7,000-ft requirement was necessary to have a 6,000-ft active runway for aircraft operations plus a 1,000-ft safety area. Once the work on the west portion of the runway was completed, the process was repeated on the other end of the runway. The requirement of keeping a 6,000-ft active runway (plus a 1,000-ft safety area) meant that the center 2,000 ft of Runway 8-26 had to be reconstructed completely at night and opened to traffic each morning. The construction sequencing/phasing plan is presented in figure A-23. The reconstruction of the center section required the use of additional fast-track methods, because of the tight scheduling constraints (although the airport did allow some longer weekend closures).

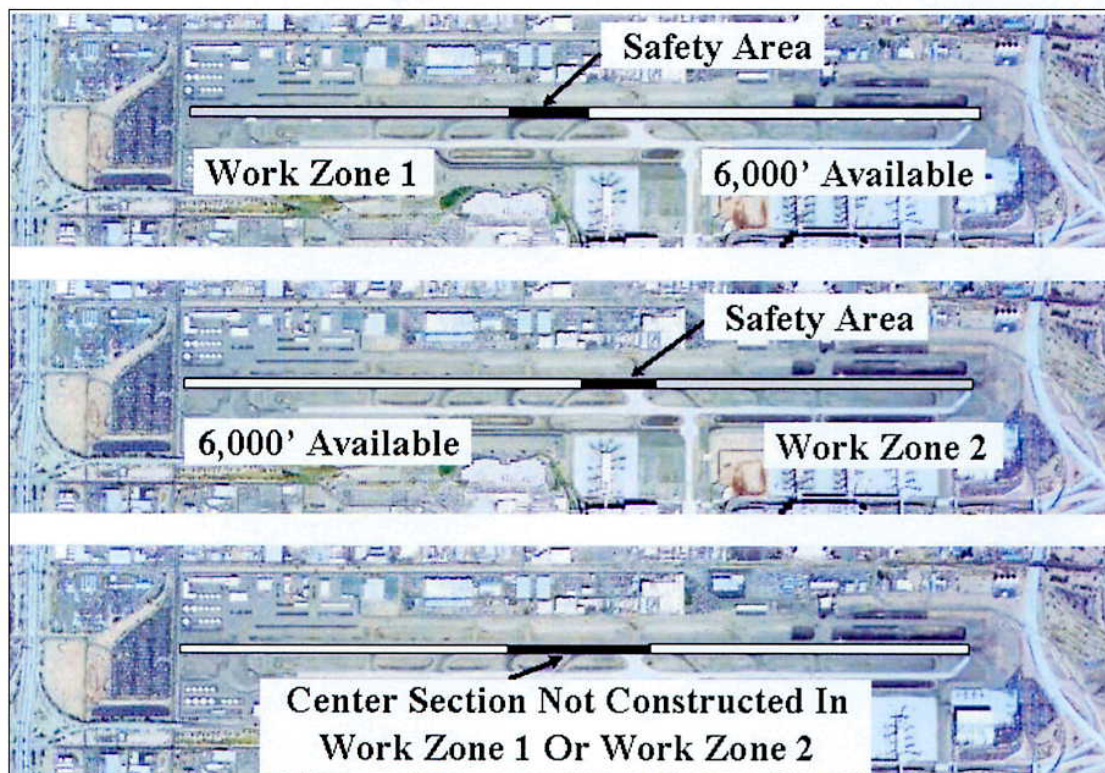


Figure A-23. Construction sequencing plan.

## Key Project Components

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There were many accelerated components throughout the entire project, with additional components required during the reconstruction of the center 2,000 ft that was performed under night closures. There are also many lessons learned from this project that can be applied to other projects. Key components of the success of this project are noted below:

- Use of reduced runway lengths.
- Sound planning and preparation.
- Involvement of all stakeholders.
- Innovative construction phasing.
- Rapid set concrete pavement.
- Non-traditional paving methods.
- Use of stabilized subbase course (not typically used at PHX).
- Stockpiling of materials.
- Process for change orders and Requests for Information (RFIs).
- Bonus/incentive for re-opening runway ahead of schedule.

Each of these aspects is discussed in more detail in this case study.

## Planning

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The planning stage of this project lasted approximately 1 year, so in some sense it was not really accelerated. However, extensive planning is somewhat of a trademark of accelerated projects, and on this particular project there were many ideas and lessons learned during the process. For example, during the project's planning and design, a series of meetings were held with all stakeholders (airlines, operations, planning, security, engineering, maintenance, and so on.) to discuss the project and its impacts. The project team even visited Atlanta to meet with the team involved with Hartsfield's runway reconstruction. The design consultant believes that these meetings were key to the success of the project. As a direct result of the planning meetings, all phasing issues were resolved at the 30-percent submittal, which allowed the planning and design work to move forward.

Three primary options were discussed during the planning phase: a full runway closure, the use of declared distances, and the use of a reduced runway length. The full runway closure was immediately eliminated from further consideration due to the separation distance between the remaining runways, noise mitigation restrictions, and the inability of the remaining two runways to handle the large number of operations. An extended runway closure would have essentially reduced the airport to one arrival runway and one departure runway, resulting in traffic congestion and substantial delays both on the ground and in the air. The FAA then dismissed the use of declared runway distances as a viable option during construction, leaving the use of reduced runway lengths as the best, and only, option.

Because of the high temperatures in Phoenix between May and September, reducing the runway length during this period was not deemed acceptable. Furthermore, the primary air carriers agreed that a minimum runway length of 6,000 ft would be required at all times between October 1 and April 30, and the airport wanted the reduced runway lengths limited to 90 days. The primary air carriers indicated that they would compensate for the reduced runway length by restricting the types of aircraft using the runway and by reducing their takeoff weights. Nightly runway closures were permitted during construction.

The construction sequencing was such that the first 5,000 ft at each end of the runway was reconstructed while keeping 7,000 ft of runway available at the other end. The center 2,000-ft portion of the runway was reconstructed entirely at night and opened to traffic each morning. The airport approached the FAA about reducing the safety area length to 500 feet, but it was not allowed. As a result, rapid set concrete was used on all sections of the runway that would be opened each morning and used as part of the runway safety area. This allowed a lower strength requirement on PCC slabs replaced through the night because the PCC would only have to support an aircraft if it ran into the safety area. In the unlikely event that this happened, the project team agreed that the affected slabs would be removed and replaced.

Although the airport went to great lengths to ensure that a significant portion of the runway remained open during the day for arrivals, pilots often refused to land and did not use the runway as much as they agreed to during the planning stage of the project. A majority of the larger aircraft arriving at the airport refused to use the shortened runway.

## **Design**

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Reconstruction with a new PCC pavement was recommended as part of the pavement management study and, after consideration of other feasible alternatives, the project team also deemed it to be the best alternative. For the center section, which would need to be reconstructed under night closures, alternative materials—such as a full-depth HMA pavement, permanent pre-cast, post-tensioned concrete slabs, and rapid set concrete—were considered. The use of an HMA pavement was quickly rejected based on the decision to use a PCC pavement elsewhere. The use of permanent pre-cast, post-tensioned concrete slabs was also dismissed due to the limited historical data available for this method. There was also some concern about the use of rapid set concrete in an arid climate and its effect on pavement performance and maintenance. Following a field visit and observation of successful experiences using this type of material at Los Angeles International Airport on the Southside Taxiway WG, WF, and T projects, the concerns were eased and the decision was made to use a rapid set concrete.

Several different pavement cross sections were considered by the design team, with reconstruction using PCC selected as the best available alternative. Figure A-24 illustrates the cross section of the reconstructed runway. Another PCC alternative, milling portions of the existing HMA and placing a PCC overlay, was eliminated due to grade restrictions.

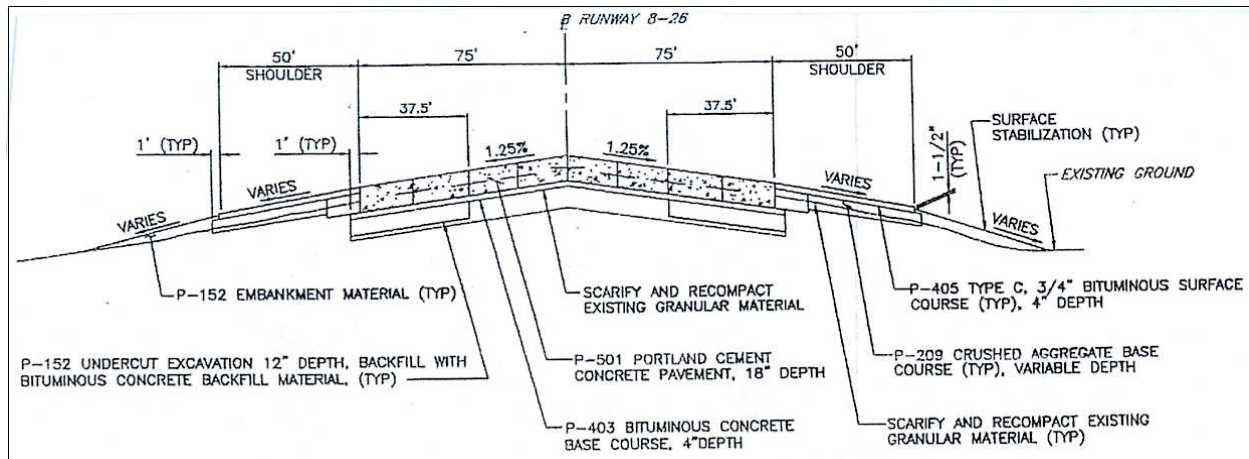


Figure A-24. Pavement cross section for reconstructed runway.

The design team determined that the existing aggregate subbase could be left in place, and that a 4-inch thick asphalt-treated base (ATB) course would be placed on top of it. Leaving the existing aggregate subbase in place helped to expedite the construction process, and the ATB layer helped to satisfy several project requirements, including meeting the FAA's stabilized base requirement for pavements designed to carry aircraft over 100,000 lbs and providing a stable paving platform to reduce weather-related delays. Phoenix International Airport has historically used an aggregate base course because it meets the FAA's minimum CBR requirements, and more importantly, because its use has resulted in longer pavement performance lives. However, after witnessing the benefits of a stabilized base on Atlanta's fast-track runway project, the project team agreed that having a sound paving platform was an important component in achieving a fast-track construction schedule. The option of leaving a portion of the existing HMA course was considered, but determined to be impractical giving the required transitions to adjacent taxiways.

The center portion of the runway was reconstructed with rapid-set concrete that was specified to have 750-psi compressive strength at 4 hours and a flexural strength of 650 psi at 28 days. A compressive strength of 500 psi, based on the average of two tests, was required for opening to traffic. As discussed previously, the lower strength was allowed since this area was serving as an overrun and only needed to support aircraft in an emergency. All PCC placed on the project also had to meet a 750-psi flexural strength requirement at 90 days. The project's P-503 specification is included at the end of this case study.

## Construction

As in the planning phase, regular meetings were also held with all stakeholders during construction. Each Thursday, two meetings were held. The first meeting was to discuss the construction aspects of the project and the second meeting was held to discuss the NAVAIDs (and included a representative from the FAA). These meetings proved to be helpful.

The project team wanted to prevent costly delays on the project due to indecision. Procedures were put into place to ensure that all Requests for Information (RFIs) be resolved within 24 to 48 hours. All RFIs were submitted to the Construction Manager, who either resolved the issue or forwarded the RFI to the Design Manager. The Design Manager would resolve the issue, with the help of one of its subcontractors if needed, and develop a response within the allotted timeframe. This process worked as intended on this project.

The contractor presented a paving plan to the airport that was based on using 1,000-ft paving runs, and convinced the airport that this approach would work to reconstruct the center portion of the runway. Because of the long runs, paving was often performed right up until the time of re-opening the runway to traffic. The project specifications indicated that joints were to be formed before opening to traffic. The intent was to limit the need to saw the joints later, after reopening the runway to traffic. However, for the most part, the paving contractor for this project paved right up until reopening, increasing the amount of accelerant in the PCC mix as the night went on. Because of this, the contractor negotiated for and was given windows of time during the day to perform joint sawing on the center portion of the runway. A 20-minute closure was given for joint sawing, but it usually took more time (generally around 45 minutes), which was a source of displeasure to the Air Traffic Control Tower. Sawcutting was typically performed around noon, or about 6 to 12 hours after paving. The designer stressed the importance of reviewing the contractor's paving plan and being careful about developing ways to limit daily paving production. On future projects, the designer would want to add language to limit paving to 500 feet for a night closure.

Originally, the specifications precluded the use of mechanical means for inserting dowel bars. Following a request by the contractor, and after some debate, the use of dowel bar inserters was allowed for transverse joints, which helped speed up the construction process. The use of inserters for longitudinal joints was not allowed based on problems experienced at other airports. Incidentally, this change went through the accelerated RFI process. Coring was performed, especially early in the project, to verify proper alignment of the dowel bars, and the use of inserters was allowed to continue.

## **Other Issues**

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For final acceptance and payment, each shift's production, regardless of quantity, was considered a single lot. Payments were based on 70 percent of the compressive strength requirement (at the time of opening) and 30 percent of the flexural strength requirement (at 28 days), using the pay factors in tables A-4 and A-5 and the following formula:

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

Table A-4. Opening time factors

<b>Compressive Strength</b>	<b>Factor</b>
> 750 psi	1.00
700 – 749 psi	0.90
650 – 699 psi	0.80
600 – 649 psi	0.70
550 – 599 psi	0.60
500 – 549 psi	0.50
< 500 psi	0.00

Table A-5. 28-day factors.

<b>Percent Within Limits (PWL)</b>	<b>Factor</b>
80 – 100	$0.76 + 0.003 \text{ PWL}$
60 – 79	$0.00017 \text{ PWL}^2 - 0.0105 \text{ PWL} + 0.75$

If the average compressive strength for any lot was below 750 psi, placement was suspended until the deficiency was investigated and corrections were made. If the average compressive strength was less than 500 psi, the contractor would be required to remove and replace the concrete at his own expense. When the percent within limits (PWL) for flexural strength was below 60 percent, the contractor would also be required to remove and replace the concrete at his own expense. However, the Engineer could elect to accept the deficient lot, in which case the lot would be paid at 50 percent of the contract unit price.

Since an average minimum compressive strength value was stipulated, the contractor could have samples that did not meet the minimum opening requirements but still be allowed to open the runway to traffic. One night, the compressive strengths were low on one particular lot because the contractor paved right up until the runway reopening time. The contractor still got paid because the average compressive strength met the specification.

Additionally, closure of the pavement beyond the scheduled opening time, due to concrete strength deficiencies of other concrete deficiencies, was also subject to liquidated damages. Thus, the contractor could be penalized twice due to insufficient strength.

During construction, electrical issues drove the project schedule. Although electrical work was expected to control the project schedule from the onset, additional problems encountered in the field exacerbated the problem. The biggest obstacles encountered were changes to the temporary lighting requirements. For example, the City decided to include temporary PAPIs for the runway, but there were no provisions for any electrical work. More upfront planning and more frequent project meetings to discuss the minimum requirements would have been helpful to reduce these project delays (on the Runway 7L-25R project performed a few years later, the

design engineer was required to provide a lighting expert in the field to quickly address such issues).

The prime contractor was the lone party involved with liquidated damages or bonuses. The contract was written such that early completion was awarded a bonus of \$200,000 per day up to a total of \$4 million. Liquidated damages of \$50,000 per day would have been assessed for late completion. The contractor finished the primary runway work in 80 days, 10 days ahead of schedule, and earned a \$2 million bonus.

Additionally, the “end of project” was defined somewhat differently than on a normal pavement reconstruction project, such that all of the work was not completed. For example, items such as runway grooving were performed later, and all high-speed connecting taxiways were not paved during this timeframe.

## **Summary**

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This project met the overall goals of the airport. Reduced runway lengths were limited to 80 days, 10 fewer days than were planned. Reconstruction of the center portion of the runway, which had to be done under night closures, was accomplished, and performance was not compromised within this area.

During this project, poor coordination was observed between the prime contractor and subcontractors. The paving contractor was not the prime contractor for the project, and as noted above, the paving contractor was not involved in any bonus payments or liquidated damages. Furthermore, the paving contractor and prime contractor had several disagreements. In general, subcontractors dealt directly with the airport rather than with the prime contractor.

After the project, the contractor submitted a claim to be compensated for additional bonus monies that could have been earned. The claim listed 19 separate items and the damages associated with each item. Most of the items had to do with delays experienced due to changes made to the electrical work. The City and the contractor reached a settlement, so the individual issues were never fully resolved.

The importance of developing solid specifications and enforcing those specifications throughout the projects was also emphasized. On several occasions, the contractor did not get the answer they wanted from the Construction Manager, so they then took the issue to the City, who at times reversed the decision of the Construction Manager. All parties must work together to develop and enforce the specifications.

Although the project did go well overall, everyone on the project acknowledge that a full runway closure is the better approach when feasible. The most complex issues with the project phasing are dealing with the temporary taxiways and temporary lighting, as well as the need to constantly issue and change NOTAMs. In fact, when the center runway (Runway 7L-25R) was to be reconstructed a few years later, the airlines agreed to a full closure rather than a phased schedule.



It is anticipated that the 90-day phasing schedule for Runway 8-26 could have been accomplished in about 50 days under a full closure. The cost difference on the projects was about \$10 million, although it is difficult to determine the amount attributable to the phasing differences. In addition, a bonus clause was not used on the center runway.

## **Available Sources of Information**

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Interviews with key members of the design team were held at Baker's office and during telephone conferences. The project team would like to acknowledge the valuable input and contributions of the following individuals for providing much of the information presented in this case study document:

- David Folmar, Design Project Manager, Michael Baker Corporation
- Bruce Loev, Construction Administrator, Michael Baker Corporation

The following documents also provided valuable information used in this summary:

- Paper entitled "Meeting the Demands at Phoenix Sky Harbor International Airport: The Replacement of Runway 8-26 with PCC Pavement," developed by David Folmar and Joseph Grubbs of Michael Baker Corporation and presented at the 27th International Air Transport Conference.
- Paper entitled "Meeting the Demands at Phoenix Sky Harbor International Airport: The Replacement of Runway 8-26 with PCC Pavement," developed by David Folmar and Joseph Grubbs of Michael Baker Corporation and presented at the 2002 FAA Airport Technology Transfer Conference.
- Project plans and specifications, particularly Item P-503, Portland Cement Concrete Pavement-Special, and Item M-003, Airport Safety and Security.

## **Contact**

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## ITEM P-503 PORTLAND CEMENT CONCRETE PAVEMENT-SPECIAL

### DESCRIPTION

**503-1.1** This work shall consist of pavement composed of Portland cement concrete constructed in accordance with these specifications and shall conform to the lines, grades, thickness, and typical cross sections shown on the plans.

### MATERIALS

#### **503-2.1 AGGREGATES.**

- a. **Reactivity:** as specified in Item P-501 Portland Cement Concrete Pavement, Paragraph 501-2.1 a.
- b. **Fine Aggregate:** as specified in Item P-501 Portland Cement Concrete Pavement, Paragraph 501-2.1 b.
- c. **Coarse Aggregate:** as specified in Item P-501 Portland Cement Concrete Pavement, Paragraph 501-2.1 c.

#### **503-2.2 CEMENT.** Cement shall be one of the following:

Portland cement conforming to the requirements of ASTM C 150, Type II or Type III. If Type III cement is used the amount of Tricalcium Aluminate ( $C_3A$ ) shall be limited to 8 percent for moderate sulfate resistance.

All cement of a particular type shall be the product of a single manufacturer. If, for any reason, cement becomes partially set or contains lumps of caked cement, it shall be rejected. Cement salvaged from discarded or used bags shall not be used.

The cement listed above shall be capable of producing concrete with the following properties.

- (1) Development of compressive strength in excess of 750 psi, not later than 4 hours from the time water is added to the mix.
- (2) Development of flexural strength not less than 650 psi in 28 days.
- (3) A mix setting time to accommodate a placing and finishing time of 45 minutes, plus or minus 15 minutes.

#### **503-2.3 CEMENTITIOUS MATERIALS.** As specified in Item P-501 Portland Cement Concrete Pavement, Paragraph 501-2.3.

**503-2.4 PREMOLDED JOINT FILLER.** As specified in Item P-501 Portland Cement Concrete Pavement, Paragraph 501-2.4.

**503-2.5 JOINT SEALER.** As specified in Item P-501 Portland Cement Concrete Pavement, Paragraph 501-2.5.

**503-2.6 STEEL REINFORCEMENT.** As specified in Item P-501 Portland Cement Concrete Pavement, Paragraph 501-2.6.

**503-2.7 DOWEL AND TIE BARS.** As specified in Item P-501 Portland Cement Concrete Pavement, Paragraph 501-2.7.

**503-2.8 WATER.** As specified in Item P-501 Portland Cement Concrete Pavement, Paragraph 501-2.8.

**503-2.9 COVER MATERIAL FOR CURING.** The material used after the initial water curing shall be a liquid membrane-forming compound and shall conform to the requirements of ASTM C 309, Type 2, Class B. Curing materials and methods shall conform to the recommendations of the curing material manufacturer, and shall be approved by the Engineer prior to use.

**503-2.10 ADMIXTURES.** As specified in Item P-501 Portland Cement Concrete Pavement, Paragraph 501-2.10, except that calcium chloride shall not be allowed.

**503-2.11 EPOXY-RESIN.** As specified in Item P-501 Portland Cement Concrete Pavement, Paragraph 501-2.11.

**503-2.12 BOND BREAKING SAND.** A thin layer of washed natural sand shall be used as a bond breaker between the bituminous base and the PCC pavement. One hundred (100) percent of the sand shall pass the #8 sieve and no more than 4 percent shall pass the #200 sieve as tested in accordance with ASTM C 136 and ASTM C 117. This material shall be screened from a natural source and shall not be manufactured or be a byproduct of crushing operations.

**503-2.13 MATERIAL ACCEPTANCE.** Prior to use of materials, the Contractor shall submit certified test reports to the Engineer for those materials proposed for use during construction. The certification shall show the appropriate ASTM test(s) for each material, the test results, and a statement that the material passed or failed.

The Engineer may request samples for testing, prior to and during production, to verify the quality of the materials and to ensure conformance with the applicable specifications.

## **MIX DESIGN AND TEST SECTIONS**

**503-3.1 GENERAL.** The Contractor shall develop a mix design and quality control program to allow adjustment in the procedures so the concrete mix that is used consistently meets the criteria specified at no additional cost to the City.

**503-3.2 PROPORTIONS.** A mix design shall be developed by the Contractor to meet the following properties:

- a. The concrete mix shall achieve a minimum compressive strength of 750 psi within 4 hours of the time water is added to the mix, and shall achieve a minimum flexural strength of 650 psi at 28 days.
- b. The concrete placed during each shift must attain the minimum compressive strength by pavement opening time indicated on the phasing plans. If the Contractor's proposed paving operations require production of concrete at a time later than 4 hours before the schedule pavement opening, the mix shall be designed to attain the required compressive strength by the required opening time.
- c. The concrete mix shall have a set time at a minimum of 30 minutes beyond the time established by the Contractor procedure to batch, transport and place the concrete mix at the work site. The set time shall be defined as the time at which the mix takes a set and no further finishing can be accomplished.
- d. The entrained air content shall be 4.5 percent plus or minus 1 percent.

The Contractor shall note that to ensure that the concrete actually produced will meet or exceed the acceptance criteria for the specified 28 day strength, the mix design average strength at 28 days must be higher than the specified strength. The amount of over design necessary to meet specification requirements depends on the producer's standard deviation of flexural test results and the accuracy with which that value can be estimated from historic data for the same or similar materials.

The minimum cementitious material (cement plus fly ash) shall be 564 pounds per cubic yard. The ratio of water to cementitious material, including free surface moisture on the aggregates but not including moisture absorbed by the aggregates shall not be more than 0.48 by weight.

Prior to the start of paving operations and after approval of all material to be used in the concrete, the Contractor shall submit a mix design showing the proportions, compressive strength at 4 hours and flexural strength obtained from the concrete at 7 and 28 days. The mix design shall include copies of test reports, including test dates, and a complete list of materials including type, brand, source, and amount of, cement, fly ash, coarse aggregate, fine aggregate, water, and admixtures. The fineness modulus of the fine aggregate and the air content shall also be shown. The mix design shall be submitted to the Engineer at least 30 days prior to the start of operations. Production shall not begin until the mix design is approved in writing by the Engineer.

Should a change in sources be made, or admixtures added or deleted from the mix, a new mix design must be submitted to the Engineer for approval a minimum of 10 days prior to its use. Previously approved mix designs older than 90 days shall not be accepted.

Compressive and flexural strength test specimens shall be prepared in accordance with ASTM C 31 and tested in accordance with ASTM C 39 or ASTM C 78 as appropriate. The mix determined shall be workable concrete having a slump for side-form concrete between 1 and 2 inches, and for vibrated slip-form concrete, the slump shall be between ½ inch and 1 ½ inches as determined by ASTM C 143.

#### **503-3.3 CEMENTITIOUS MATERIALS.**

- a. **Fly Ash.** Fly ash may be used in the mix design. When fly ash is used as a partial replacement for cement, the minimum cement content may be met by considering portland cement plus fly ash as the total cementitious material. The replacement rate shall be determined from laboratory trial mixes, but fly ash shall not exceed 20 percent by weight of the total cementitious material.
- b. **Ground Slag.** Ground slag shall not be used.

#### **503-3.4 ADMIXTURES.**

- a. **Air-Entraining.** Air-entraining admixture shall be added in such a manner that will insure uniform distribution of the agent throughout the batch. The air content of freshly mixed air-entrained concrete shall be based upon trial mixes with the materials to be used in the work adjusted to produce concrete of the required plasticity and workability. The percentage of air in the mix shall be 4.5%. Air content shall be determined by testing in accordance with ASTM C 231 for gravel and stone coarse aggregate and ASTM C 173 for slag and other highly porous coarse aggregate.
- b. **Chemical.** Water-reducing, set-controlling, and other approved admixtures shall be added to the mix in the manner recommended by the manufacturer and in the amount necessary to comply with the specification requirements. Calcium chloride shall not be allowed. Tests shall be conducted on trial mixes, with the materials to be used in the work, in accordance with ASTM C 494.

**503-3.5 MIX DESIGN DEVELOPMENT AND SUBMITTAL.** The contractor shall develop a mix design that meets the criteria specified in paragraph 503-3.2. The process shall include the development of a minimum of 3 trial batches with decreasing water/cement ratios. The batches shall use the intended raw materials to be used for the project, including cement, fine and coarse aggregates, as well as chemical and mineral admixtures. The trial batch mixtures shall maintain the same fine aggregate/coarse aggregate ratios as well as the same proportions of intended admixtures, only the water/cement ratio shall be varied. The testing of the trial batches shall, at a minimum, include compressive strength, flexural strength, temperature development, air content and slump. Compressive strength test, flexural beam test and temperature development specimens shall be

prepared in accordance with ASTM C 31, except that specimens shall be surrounded with insulative blankets for a minimum of 5 hours following addition of water to the mix. The mix design to be submitted for use on the project shall be one of the trial batches.

- a. **Compressive Strength Testing.** A minimum of 2 compressive strength tests shall be completed at 3 hours, 4 hours, 5 hours and 8 hours from the addition of mixing water for each of the 3 trial batches. The average value of the 2 tests at each time shall be plotted on a compressive strength versus water/cement ratio graph.
- b. **Flexural Strength Testing.** A minimum of 2 flexural strength tests shall be completed at 4 hours, 8 hours, 24 hours, 7 days and 28 days for each of the trial batches. The average value of the 2 tests at each time shall be plotted on a flexural strength versus water/cement ratio graph.
- c. **Temperature Development.** The trial batches shall be monitored for development of temperature from the time the water is added to the mix until an age of 5 hours at 15 minute intervals. The temperature of the mixing water, other materials and the ambient air temperature at the time of batching shall be recorded. The time at which the mix takes a set shall be recorded along with the corresponding temperature of the mix. The temperatures shall be taken with a thermometer accurate to within 0.5 degrees Fahrenheit. The thermometer shall remain inserted in the curing sample throughout the period of testing. The temperature data shall be plotted for each trial batch, with temperature on the vertical scale and time on the horizontal. The set time of the mix shall be identified for each batch.
- d. **Mix Design Submittal:** The mix design submittal shall include the following minimum information:
  1. Type(s) of cement.
  2. Water /cement ratio.
  3. Slump.
  4. Air entrainment percentage.
  5. Compressive strength test results at 3, 4, 5 and 8 hours.
  6. Flexural strength test results at 4 hours, 8 hours, 24 hours, 7 days and 28 days.
  7. Temperature development graph and set time.
  8. Plant/lab mix certification of proportion of materials including type and quantity of admixtures.
  9. Fine and coarse aggregate supplier, pit location, gradation, fineness modulus, tested wear, specific gravity , absorption capacity and moisture content.
  10. Manufacturers name, catalog information for the cement(s) and admixtures used, including ASTM certification information.
  11. Certification of the testing laboratory designing the mix per Item P-501, Paragraph 501-3.4.
- e. **Tentative Mix Design Approval.** When a mix design meeting all the specified criteria and documentation requirements have been met and approved by the

Engineer, the mix design will be given tentative approval, subject to successful completion of the preliminary test section. Tentative approval may be granted prior to the receipt of the 28 day strength tests, if 650 psi flexural strength has been demonstrated at an earlier test period.

f. **Full Mix Design Approval.** Full approval of the mix design will be granted when the following requirements have been met:

1. Successful completion of the Preliminary and Production Test Sections, including any modifications of the Tentatively Approved Mix Design.
2. Acceptable results from the 4 hour compressive strength and 28 day flexural strength tests.

**503-3.6 PRELIMINARY TEST SECTIONS.** Following tentative approval of the mix design, the Contractor shall construct a Preliminary Test Section, at a location designated by the Engineer. The purpose of the Preliminary Test Section is to demonstrate that the mix design meets all of the requirements in the specifications, in full-scale construction. The Preliminary Test Section may be constructed without the time and operating constraints that will exist for full production paving. However, the equipment and procedures shall be the same as for full production paving.

The test section location will be on a paved or unpaved area at Sky Harbor International Airport. The Contractor shall perform the necessary preparatory work for the test, including excavation of existing base or subgrade materials to a sufficient depth to accommodate the test section, minor grading to level the site, placement and compaction of base course material to establish a suitable work platform, and erection of forms if required. The test section shall be 40 feet long, 18.75 feet wide and 18 inches thick.

The concrete mix shall be tested for compliance with the test/data submitted as part of the mix design submittal. Failure to meet the specified compressive strength, flexural strength, set time or air entrainment percentage shall be cause for rejection of the mix design. The slump and temperature development of the field tested mix shall be compared to the lab tested results to indicate the ability to replicate the mix design under field conditions. The Preliminary Test Section will be inspected by the Engineer for placement procedures, finish, cracking, etc.

If the Preliminary Test Section proves unsatisfactory, the necessary adjustments to the mix design, plant operations and/or placement procedures shall be made. An additional test section shall be completed at the Contractor's expense. Changes in the mix design will require resubmittal of the mix design in accordance with paragraph 503-3.5 prior to completing the additional test section. Removal of the Preliminary Test Section concrete shall be at no cost to the City and shall be incidental to Item P-503.

**503-3.7 PRODUCTION TEST SECTIONS:** Following the Engineer's approval of a Preliminary Test Section, including any necessary adjustments of the mix design, equipment and procedures, the Notice to Proceed on the Production Test Section shall be issued to the Contractor who shall construct a Production Test Section, at a location designated by the Engineer. The purpose of the Production Test Section is to demonstrate that the mix design, equipment, materials and procedures



meet all requirements in the specifications, under the same time constraints, working conditions and operating constraints that will exist for full production paving.

The test section location will be on a planned work area. The test section will consist of at least one full run of paving at least one full slab wide. The length of the run of paving shall be determined by the Engineer. At the completion of the Production Test Section work, the test site must meet all requirements for opening the pavement to aircraft traffic and the concrete must attain a minimum compressive strength of 750 psi by the required pavement opening time and shall attain the minimum flexural strength of 650 psi at 28 days. If the results of the Production Test Section are unsatisfactory in any respect, additional Production Test Sections shall be constructed, at the Contractor's expense, until all requirements of the Specifications have been met. The Engineer may require the removal of the previous test section(s) at the Contractor's expense. Full production paving under this Specification shall not commence until all the requirements of the Specifications have been met to the satisfaction of the Engineer and approval to proceed has been given by the Engineer in writing. Provided that all aspects of the Production Test Section are satisfactory to the Engineer, approval to proceed with full production paving may be given prior to the 28 day flexural test results from the Production Test Section.

**503-3.8 TESTING LABORATORY.** As specified in Item P-501 Portland Cement Concrete Pavement, Paragraph 501-3.4 .

## CONSTRUCTION METHODS

**503-4.1 EQUIPMENT.** As specified in Item P-501 Portland Cement Concrete Pavement, Paragraph 501-4.1, with the following addition:

- a. **Backup Equipment.** The Contractor shall provide backup units for each item of equipment that is essential to the timely completion of each shift's work. The backup equipment shall be itemized in the Contractor's work plan.

**503-4.2 FORM SETTING.** The concrete shall be placed and formed in accordance with one or more of the following, as applicable:

- a. **Against Conventional Forms.** As specified in Item P-501 Portland Cement Concrete Pavement, Paragraph 501-4.2
- b. **Against the sides of Portland cement concrete or asphalt pavement which will be removed in the project.** A sheet of metal or plywood shall be placed vertically against the existing pavement, to serve as a form for the new P-503 concrete, as a bond breaker and as a protective buffer during the removal of the adjacent pavement.
- c. **Against the sides of previously placed concrete slabs, or against other existing slabs or structures which will remain.** Unless the slabs are separated by expansion joint material, the sides of the adjacent concrete shall be sprayed with a debonding agent, approved by the Engineer, that will prevent bonding at the face of the joint.

The prevention of bonding is critical to the prevention of cracking in the newly placed concrete.

Except where placement is against permanent pavement that was previously constructed in the project, the top surface of a new slab may be higher or lower than the adjacent pavement. In this case, the top edge of the forms shall be set as required to match the new pavement elevations as shown on the plans.

#### **503-4.3 CONDITIONING OF UNDERLYING SURFACE, SLIP-FORM CONSTRUCTION.**

The underlying surface on which the pavement will be placed shall be widened approximately 3 feet to extend beyond the paving machine track to support the paver without any noticeable displacement. The grade of the underlying surface shall be controlled by a positive grade control system using lasers, string lines, or guide wires. If damage occurs on a stabilized subbase, it shall be corrected full depth by the Contractor. Prior to paving, the subbase shall be treated as follows to break the bond between the subbase and the PCC pavement:

- a. **Curing Compound.** The subbase shall be treated with 1 application of white pigmented curing compound, as described in Paragraph 503-2.9.
- b. **Bond Breaker Sand.** A thin layer of washed natural sand shall be used as a bond breaker between the treated subbase and the P-503 PCC pavement. Placement of bond breaker sand shall be accomplished with a mechanized unit that will deposit a uniform thin layer of sand on the underlying subbase. The Contractor shall submit his proposed method of placement to the Engineer for review and approval prior to beginning the operation. The Contractor shall be responsible for maintaining the surface condition and thickness of the sand layer prior to concrete placement. Hand labor should be anticipated to maintain the sand layer. The sand layer shall be thick enough to fully cover the treated subbase layer but shall not be more than 1/8 inch thick.
- c. **Moisten Subbase.** The prepared subbase shall be moistened with water, without saturating, ponding or displacing the bond breaker sand layer, immediately ahead of concrete placement to prevent rapid loss of moisture from the concrete. The underlying surface shall be protected so that it will be entirely free of frost when concrete is placed.

#### **503-4.4 CONDITIONING OF UNDERLYING SURFACE, SIDE-FORM AND FILL-IN LANE CONSTRUCTION.**

If damage occurs to a stabilized subbase, it shall be corrected full depth by the Contractor. A template shall be provided and operated on the forms in advance of the placing of all concrete. The template shall be propelled only by hand and not attached to a tractor or other power unit. Templates shall be adjustable so that they may be set and maintained at the correct contour of the underlying surface. The adjustment and operation of the templates shall be such as will provide an accurate retest of the grade before placing the concrete thereon. The template shall be maintained in accurate adjustment, at all times by the Contractor, and shall be checked daily or more often as deemed by the Engineer. High areas in the subbase shall be corrected to the



satisfaction of the Engineer before paving will be allowed to commence. Low areas shall be filled and compacted to a condition similar to that of the surrounding grade or the shortfall may be made up with concrete during paving at the Contractor's option. Prior to paving, the subbase shall be treated as follows to break the bond between the subbase and the P-503 PCC pavement:

- a. **Curing Compound.** The subbase shall be treated with 1 application of white pigmented curing compound, as described in Paragraph 503-2.9.
- b. **Bond Breaker Sand.** A thin layer of washed natural sand shall be used as a bond breaker between the treated subbase and the P-503 PCC pavement. Placement of bond breaker sand shall be accomplished with a mechanized unit that will deposit a uniform thin layer of sand on the underlying subbase. The Contractor shall submit his proposed method of placement to the Engineer for review and approval prior to beginning the operation. The Contractor shall be responsible for maintaining the surface condition and thickness of the sand layer prior to concrete placement. Hand labor should be anticipated to maintain the sand layer. The sand layer shall be thick enough to fully cover the treated subbase layer but shall not be more than 1/8 inch thick.
- c. **Moisten Subbase.** The prepared subbase shall be moistened with water, without saturating, ponding or displacing the bond breaker sand layer, immediately ahead of concrete placement to prevent rapid loss of moisture from the concrete. The underlying surface shall be protected so that it will be entirely free of frost when concrete is placed.

**503-4.5 HANDLING, MEASURING, AND BATCHING MATERIAL.** As specified in Item P-501 Portland Cement Concrete Pavement, Paragraph 501-4.5.

**503-4.6 MIXING CONCRETE.** As specified in Item P-501 Portland Cement Concrete Pavement, Paragraph 501-4.6.

**503-4.7 LIMITATIONS ON MIXING AND PLACING.** As specified in Item P-501 Portland Cement Concrete Pavement, Paragraph 501-4.7 with the following exceptions and additions:

- a. **Lighting.** When paving is to occur at night, portable lighting units sufficient for control and observation of the work shall be in position at the concrete placement site prior to mixing concrete. In addition, adequate lighting shall be provided at the batch plant to facilitate quality control and safe operations.
- b. **Mixing Quantity.** Concrete shall be mixed only in quantities which are required for immediate use and can be placed and finished prior to final setting of the concrete.
- c. **Cold Weather.** Unless authorized in writing by the Engineer, mixing and concreting operations shall be discontinued when a descending air temperature reaches 40 degrees Fahrenheit and shall not be resumed until an ascending air temperature reaches 35 degrees Fahrenheit.

- d. **Material Heating.** To compensate for cool temperatures and/or to enhance early concrete curing and strength gain, the Engineer may require the water and/or aggregates to be heated to not less than 70 degrees Fahrenheit nor more than 150 degrees Fahrenheit. The apparatus used shall heat the mass uniformly to preclude the possible occurrence of overheated areas which might be detrimental to the materials or final product.

**503-4.8 PLACING CONCRETE.** As specified in Item P-501 Portland Cement Concrete Pavement, Paragraph 501-4.8.

**503-4.9 STRIKE-OFF OF CONCRETE AND PLACEMENT OF REINFORCEMENT.** As specified in Item P-501 Portland Cement Concrete Pavement, Paragraph 501-4.9.

**503-4.10 JOINTS.** As specified in Item P-501 Portland Cement Concrete Pavement, Paragraph 501-4.10 with the following additions:

- a. **Bond Breaking.** Prior to placing new concrete, all existing concrete faces shall be sprayed with a bond breaking agent approved by the Engineer to prevent bond of new concrete to the existing surface. Preventing the bond of new concrete at the interface with existing concrete is critical to the prevention of cracking.
- b. **Formation of Joints.** All joints shown in the plans for a shift's work shall be constructed prior to the end of the shift and opening to traffic. To prevent random cracking, it is critical that the initial formation of contraction joints be performed prior the end of the shift in which the concrete was placed. If the Contractor chooses to saw cut the contraction joints, he shall have sufficient sawing equipment, spares and backup equipment present prior to the commencement of a shift's paving to accomplish the necessary work prior to opening time. The Contractor is cautioned that expansion joints must be hand tooled and may not be saw cut per Item P-501, Paragraph 501-4.10c.

**503-4.11 FINAL STRIKE-OFF, CONSOLIDATION, AND FINISHING.** As specified in Item P-501 Portland Cement Concrete Pavement, Paragraph 501-4.11.

**503-4.12 SURFACE TEXTURE.** As specified in Item P-501 Portland Cement Concrete Pavement, Paragraph 501-4.12.

**503-4.13 SKID RESISTANT SURFACES.** As specified in Item P-501 Portland Cement Concrete Pavement, Paragraph 501-4.13.

**503-4.14 CURING.** The initial method of curing, to begin immediately after finishing and set of the pavement surface, shall be water curing. The entire surface shall be kept continuously moist by sprinkling with water for at least 2 hours, or longer if recommended by the cement manufacturer or mix designer. After the minimum water curing period and before opening to traffic, 2 coats of an impervious curing membrane as specified in Item P-501, Paragraph 503-4.14a shall be applied.

**503-4.15 REMOVING FORMS.** Unless otherwise specified, forms shall not be removed from freshly placed concrete until the start of the next shift. After the forms have been removed, the sides of the slab shall be cured with 2 coats of an impervious membrane curing compound as indicated in paragraph 503-4.14. Major honeycombed areas shall be considered as defective work and shall be removed and replaced in accordance with paragraph 503-5.2.

**503-4.16 SEALING JOINTS.** The joints in the pavement shall be sealed in accordance with Item P-605.

**503-4.17 PROTECTION OF PAVEMENT.** As specified in Item P-501 Portland Cement Concrete Pavement, Paragraph 501-4.17.

**503-4.18 OPENING TO TRAFFIC.** The compressive strength of the permanent concrete required for reopening the runway at the end of each shift is 500 psi, based on an average of at least 2 tests. Testing shall be in accordance with ASTM C 39. No traffic, including the Contractors equipment, shall be allowed until the criteria for traffic specified in Paragraph 503-4.8 has been met. If the pavement is subjected to aircraft traffic for emergency purposes prior to meeting the criteria in Paragraph 503-4.8, the pavement will be replaced at the City's expense.

In addition to the above requirements, all equipment, materials and debris shall be removed and the pavement in the work area shall be cleaned by the Contractor to the satisfaction of the Engineer prior to each pavement opening.

**503-4.19 REPAIR, REMOVAL AND REPLACEMENT OF SLABS.** As specified in Item P-501 Portland Cement Concrete Pavement, Paragraph 501-4.19.

## **MATERIAL ACCEPTANCE**

**503-5.1 ACCEPTANCE SAMPLING AND TESTING.** All acceptance sampling and testing, with the exception of coring for thickness determination, necessary to determine conformance with the requirements specified in this section will be performed by the Engineer. Concrete shall be accepted for strength and thickness on a lot basis.

Concrete samples shall be furnished by the Contractor and shall be taken in the field to determine the consistency, air content and strength of the concrete. Compressive test cylinders and flexural test beams shall be made during each shift that the concrete is placed. The specimens shall be made in accordance with ASTM C 31. Each group of test specimens shall be molded from the same batch of concrete and shall consist of a sufficient number of specimens to provide at least two compressive and flexural strength tests at each of the test ages specified below. However, at the start of paving operations and when the aggregate source, aggregate characteristics, or mix design is changed, additional groups of test beams may be required and testing of beams at various hourly ages may be required, until the Engineer is satisfied that the concrete mixture being used complies with the strength requirements of these specifications, for the actual daily placement schedule.

- a. Sample Age.** The time scheduled for opening the pavement to airport traffic each

day is indicated on the phasing plans. For purposes of the following discussion, "batching" means the time that water is added as the final ingredient to the concrete mix. The test reports for all cylinders and beams shall record the age of the concrete, from batching to the time of testing.

**b. Testing Ages.** Test ages for the daily concrete placement shall be the following:

If concrete batching ends later than 4 hours prior to scheduled pavement opening, cylinders made from concrete that is placed in the last slab constructed each day shall be tested at or slightly before the scheduled time for pavement opening, to insure that the required strength has been attained. Tests made at that time shall be the OPENING TIME tests used in the computation of pay factors.

If concrete batching ends earlier than 4 hours prior to scheduled pavement opening, one set of cylinders shall be tested at an age of 4 hours from batching. These tests shall be continued only to the extent determined necessary by the Engineer to evaluate the performance of the specified 4 hour mix design requirement. They shall be used as the OPENING TIME tests only if the 4 hour age coincides with the scheduled opening time.

If concrete batching ends earlier than 4 hours prior to scheduled pavement opening, cylinders made from concrete that is placed in the last slab constructed each day shall be tested at or slightly before the scheduled time for pavement opening, to insure that the required strength has been attained. Tests made at that time shall be the OPENING TIME tests used in the computation of pay factors.

Initially cylinders shall also be tested at ages of 5 hours and 8 hours. When the consistency of the Contractor's paving operations, placement completion time and concrete strength gain has been demonstrated to the satisfaction of the Engineer, some or all of the testing at these ages may be terminated.

Specimens which are obviously defective shall not be considered in the determination of strength. The specimens with the least imperfections shall be used for the earliest tests.

**c. Flexural Strength.** For each shift of placement, the average flexural strength of the specimens tested shall be not less than 650 psi at 28 days. Beams from each shift of work shall be tested at an age of 7 and 28 days, for the duration of the project. The 28 DAY tests will be used in the computation of pay factors.

When a satisfactory relationship between the 7 day and 28 day flexural strengths has been established and approved, the 7 day results may be used as an indication of the 28 day strengths, for purposes of interim acceptance and progress payments. However, final acceptance and payment will be based only on the OPENING TIME and 28 DAY strengths.

- d. **Pay Factors.** For final acceptance and payment, each shift's production, regardless of quantity, shall be considered as one lot. The pay factor for each lot shall be established on the basis of both the OPENING TIME and the 28 DAY-strength test results, according to the following formulas and tables:

$$\text{PAY FACTOR} = (0.3 \times \text{OPENING TIME FACTOR}) + (0.7 \times 28 \text{ DAY FACTOR})$$

**TABLE 1: OPENING TIME FACTORS**

<u>Compressive Strength</u>	<u>Factor</u>
750+ psi	1.00
700 to 749 psi	.90
650 to 699 psi	.80
600 to 649 psi	.70
550 to 599 psi	.60
500 to 549 psi	.50
Below 500 psi	.00

If the average OPENING TIME strength for any lot is below 750 psi, concrete placement shall be suspended until the deficiency is investigated and corrections acceptable to the Engineer are made. The corrections which the Engineer shall have the right to require include additional test strips using the current mix, changes to the mix, and establishing an earlier daily time deadline for final batching and placement of concrete.

Closure of the pavement beyond the scheduled opening time, due to concrete strength deficiencies or other concrete deficiencies, will subject the Contractor to liquidated damages as specified in the general provisions.

If the average OPENING TIME strength for any lot is less than 500 psi, the Contractor shall remove and replace the concrete at his own expense.

**TABLE 2: 28-DAY FACTORS**

<u>Percent Within Limits (PWL)</u>	<u>Factor</u>
80-100	$0.76 + 0.003(\text{PWL})$
60-79	$(0.00017 \times \text{PWL}^2) - (0.0105 \times \text{PWL}) + 0.75$

When the PWL for 28 DAY strength is below 60 percent, the lot shall be removed and replaced at the Contractor's expense. However, the Engineer may decide to accept the deficient lot. In that case, if the Engineer and Contractor agree in writing that the lot shall not be removed, it will be paid for at 50 percent of the contract unit price.

**503-5.2 ACCEPTANCE CRITERIA.** Acceptance will be based on the following characteristics of the completed pavement:

- (1) Compressive Strength
- (2) Flexural strength
- (3) Thickness
- (4) Smoothness
- (5) Grade
- (6) Edge slump
- (7) Dowel bar alignment
- (8) Surface Appearance/Cracking

Acceptance for compressive and flexural strength will be based on the criteria contained in Paragraph 503-5.1. Acceptance for thickness will be based on the criteria contained in Item P-501, Paragraph 501-5.2e(2). Acceptance for smoothness will be based on the criteria contained in Item P-501, Paragraph 501-5.2e(3). Acceptance for grade will be based on the criteria contained in Item P-501, Paragraph 503-5.2e(4). Acceptance for edge slump will be based on the criteria contained in Item P-501, Paragraph 501-5.2e(5). Acceptance for dowel bar alignment will be based on the criteria contained in Item P-501, Paragraph 501-5.2e(6). Acceptance for surface appearance/cracking will be based on the criteria contained in Item P-501, Paragraph 501-5.2e(7).

The Engineer may at any time, notwithstanding previous plant acceptance, reject and require the Contractor to dispose of any batch of concrete mixture which is rendered unfit for use due to contamination, segregation, improper slump or premature set. Such rejection may be based on only visual inspection. In the event of such rejection, the Contractor may take a representative sample of the rejected material in the presence of the Engineer, and if he can demonstrate in the laboratory, in the presence of the Engineer, that such material was erroneously rejected, payment will be made for the material at the contract unit price.

## CONTRACTOR QUALITY CONTROL

**503-6.1 QUALITY CONTROL PROGRAM.** The Contractor shall develop a Quality Control Program in accordance with Section 100 of the General Provisions. The program shall address all elements which effect the quality of the pavement including, but not limited to:

- a. Mix Design
- b. Aggregate Gradation
- c. Quality of Materials
- d. Stockpile Management
- e. Proportioning
- f. Mixing and Transportation
- g. Placing and Consolidation
- h. Joints
- I. Dowel Placement and Alignment
- j. Flexural and Compressive Strength



- k. Finishing and Curing
- l. Surface Smoothness
- m. Set Time

**503-6.2 QUALITY CONTROL TESTING.** As specified in Item P-501 Portland Cement Concrete Pavement, Paragraph 501-6.2, with the following additions.

- a. **Set Time.** The set time of the cement and concrete mix shall be tested for compliance with the set time of the approved concrete mix.
- b. **Temperature Development.** The concrete mix shall be monitored for temperature development of the curing mix from when the water is added to the mix until 5 hours cure. During a shift's work, 2 cylindrical specimens shall be made in accordance to ASTM C 31 from each of a minimum of 2 random batches of production concrete and cured surrounded by insulating blankets. Temperature readings of the concrete in each specimen shall be recorded at 15 minute intervals in accordance with requirements of Paragraph 503-3.5c.

**503-6.3 CONTROL CHARTS.** As specified in Item P-501 Portland Cement Concrete Pavement, Paragraph 501-6.3, with the following additions:

- a. **Set Time.** The contractor shall maintain linear control charts for set time of the concrete mix. The Action Limit shall be defined as  $\pm 15$  minutes from the set time of the approved mix. The Suspension Limit shall be defined as  $\pm 30$  minutes.
- b. **Temperature Development.** The Contractor shall maintain a linear control chart of the temperature development of the concrete mix. The Action Limit and Suspension Limit shall be defined as  $\pm 15$  minutes and  $\pm 30$  minutes respectively from the temperature development versus time curve of the original mix design submittal.

**503-6.4 CORRECTIVE ACTION.** As specified in Item P-501 Portland Cement Concrete Pavement, Paragraph 501-6.4, with the following additions:

For set time and temperature development, the Contractor shall halt production and make appropriate adjustments whenever:

- 1. One point falls outside the Suspension Limit line, or
- 2. Two points in a row fall outside the Action Limit line.

## METHOD OF MEASUREMENT

**503-7.1** "Portland Cement Concrete Pavement-Special" shall be measured by the number of square yards of either plain or reinforced pavement as specified in-place, completed and accepted. Portland Cement Concrete used for transitional slabs to asphalt pavement and test sections shall not be measured separately but shall be considered incidental to the remaining PCC pavement.

**503-7.2** Saw-cut grooving shall be measured by the number of square yards of saw-cut grooving as specified in-place, completed and accepted, including the 10-foot edge not grooved.

**BASIS OF PAYMENT**

**503-8.1 GENERAL.** Payment for an accepted lot of “Portland Cement Concrete Pavement-Special” shall be made at the contract unit price per square yard adjusted in accordance with paragraphs 503-8.1a,b, and c. Payment shall be full compensation for all labor, materials, tools equipment, and incidentals required to complete the work as specified herein and on the drawings, except for saw-cut grooving.

- a. **Basis of Adjusted Payment for Strength.** A pay factor for concrete strength shall be determined as set forth in Paragraph 503-5.1d.
- b. **Basis of Adjusted Payment for Thickness (PFt).** A pay factor for thickness shall be determined in accordance with the following schedule when the percent within specification limits (PWL) equals or exceeds 25 percent.

Percent within Limits (PWL)	Pay Factor for Thickness (PFt)
90-100	1.0
25-89	$0.000034 \times (PWL \times PWL) - (0.00006 \times PWL) + 0.72$

When the PWL is below 25 percent, the lot shall be removed and replaced. However, the Engineer may decide to accept the deficient lot. In that case, if the Engineer and Contractor agree in writing that the lot shall not be removed, it will be paid for at 50 percent of the contract unit price.

- c. **Lot Pay Factor.** The percent payment for an accepted lot shall be arrived at by successively multiplying the contract unit price by both factors determined in paragraphs 503-8.1a and 8.1b.

$$Pfs \times PFt \times \text{Contract unit price} = \text{Adjusted payment for lot}$$

**503-8.2 PAYMENT FORSAW-CUT GROOVING.** Payment for saw-cut grooving shall be made in accordance with Paragraph 501-8.2..

Payment shall be made under:

Item P-503-8.1	Plain Portland Cement Concrete Pavement-Special, 18" depth — per square yard
Item P-503-8.2	Reinforced Portland Cement Concrete Pavement-Special, 18" depth — per square yard



## TESTING REQUIREMENTS

ASTM C 31	Making and Curing Concrete Test Specimens in the Field
ASTM C 39	Compressive Strength of Cylindrical Concrete Specimens
ASTM C 70	Surface Moisture in Fine Aggregate
ASTM C 78	Test for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
ASTM C 117	Test for Materials Finer than 75- $\mu$ m (No. 200) Sieve in Mineral Aggregates by Washing
ASTM C 131	Test for Resistance to Abrasion of Small Size Coarse Aggregate by Use of the Los Angeles Machine
ASTM C 136	Sieve Analysis of Fine and Coarse Aggregates
ASTM C 138	Test for Unit Weight, Yield, and Air Content (Gravimetric) of Concrete
ASTM C 143	Test for Slump of Portland Cement Concrete
ASTM C 172	Sampling Freshly Mixed Concrete
ASTM C 173	Test for Air Content of Freshly Mixed Concrete by the Volumetric Method
ASTM C 174	Measuring Length of Drilled Concrete Cores
ASTM C 227	Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)
ASTM C 231	Test for Air Content of Freshly Mixed Concrete by the Pressure Method
ASTM C 289	Potential Reactivity of Aggregates (Chemical Method)
ASTM C 295	Petrographic Examination of Aggregates for Concrete
ASTM C 311	Sampling and Testing Fly Ash for Use as an Admixture in Portland Cement Concrete
ASTM C 535	Test for Resistance to Abrasion of Large Size Coarse Aggregate by Use of the Los Angeles Machine
ASTM C 566	Total Moisture Content of Aggregates by Drying

ASTM C 1077	Standard Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation
ASTM D 3665	Random Sampling of Construction Materials
ASTM D 4791	Test Method for Flat or Elongated Particles in Coarse Aggregate
AASHTO T 26	Quality of Water to be Used in Concrete

### MATERIAL REQUIREMENTS

ASTM A 184	Specification for Fabricated Deformed Steel Bar Mats for Concrete Reinforcement
ASTM A 615	Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement
ASTM C 33	Specification for Concrete Aggregates
ASTM C 94	Specification for Ready-Mixed Concrete
ASTM C 150	Specification for Portland Cement
ASTM C 260	Specification for Air-Entraining Admixtures for Concrete
ASTM C 309	Specification for Liquid Membrane-Forming Compounds
ASTM C 494	Specification for Chemical Admixtures for Concrete
ASTM C 618	Specification for Fly Ash and Raw or Calcined Natural Pozzolon for Use as a Mineral Admixture in Portland Cement Concrete
ASTM C 881	Specification for Epoxy-Resin Base Bonding System for Concrete
ASTM C 989	Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars
ASTM D 1752	Specification for Preformed Sponge Rubber and Cork Expansion Joint Fillers for Concrete Paving and Structural Construction
AASHTO M 254	Specification for Coated Dowel Bars
ACI 305R	Hot Weather Concreting
ACI 306R	Cold Weather Concreting

TT-P-644 (Rev. D) Federal Specification for Primer Coating, Alkyd, Corrosion-Inhibiting, Lead  
and Chromate Free, VOC-Compliant

**END ITEM P-503**

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## **Norman Y. Mineta San Jose International Airport Runway 12R-30L Extension**

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### **General Information**

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Airport: Norman Y. Mineta San Jose International Airport

Owner: City of San Jose

Airport Classification: Medium Hub

Climatic Region: Dry/No Freeze

FAA Region: Western Pacific

Facility: Runway 12R-30L

Description of project: Extension of Runway 12R-30L with 18-in PCC over 8-in econocrete base

Dates of construction: 1993

Engineer/Designer: HNTB

Project Manager/Construction Manager: City of San Jose

Prime Contractor: Granite Construction Company

### **Project Overview**

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The development of Norman Y. Mineta San Jose International Airport (SJC) dates back to the 1940's. The first comprehensive master plan for SJC was prepared in the late 1970s and adopted by the City in 1980. In 1988, the City of San Jose initiated an update to the 1980 Master Plan. Given the growth occurring in Silicon Valley, the update identified the need for further improvements, including airfield, terminal building, parking, cargo, and other facilities. Due to local community concerns about airport impacts, extensive environmental, technical, and economic analyses were conducted.

By the early 1990's, over 7 million passengers per year passed through the airport. At that time, the airfield included three runways, but only one was long enough for commercial jet service. In 1991, American Airlines informed the airport that the main runway needed to be extended by 1,300 feet to accommodate its daily flight to Japan. For an MD-11 aircraft to operate at this airport during high ambient temperatures, the existing 8,900-ft Runway 12R-30L required reductions in passenger, freight, or fuel loads. The proposed runway lengthening presented a significant challenge, because the airport had 600 operations per day, navigational aids at each end, and almost no room to expand in a very constrained 1,100-acre site. The current airport diagram is shown in figure A-25. At the time of construction, runway 12L-30R parallel to the project was only 4,400 feet long.

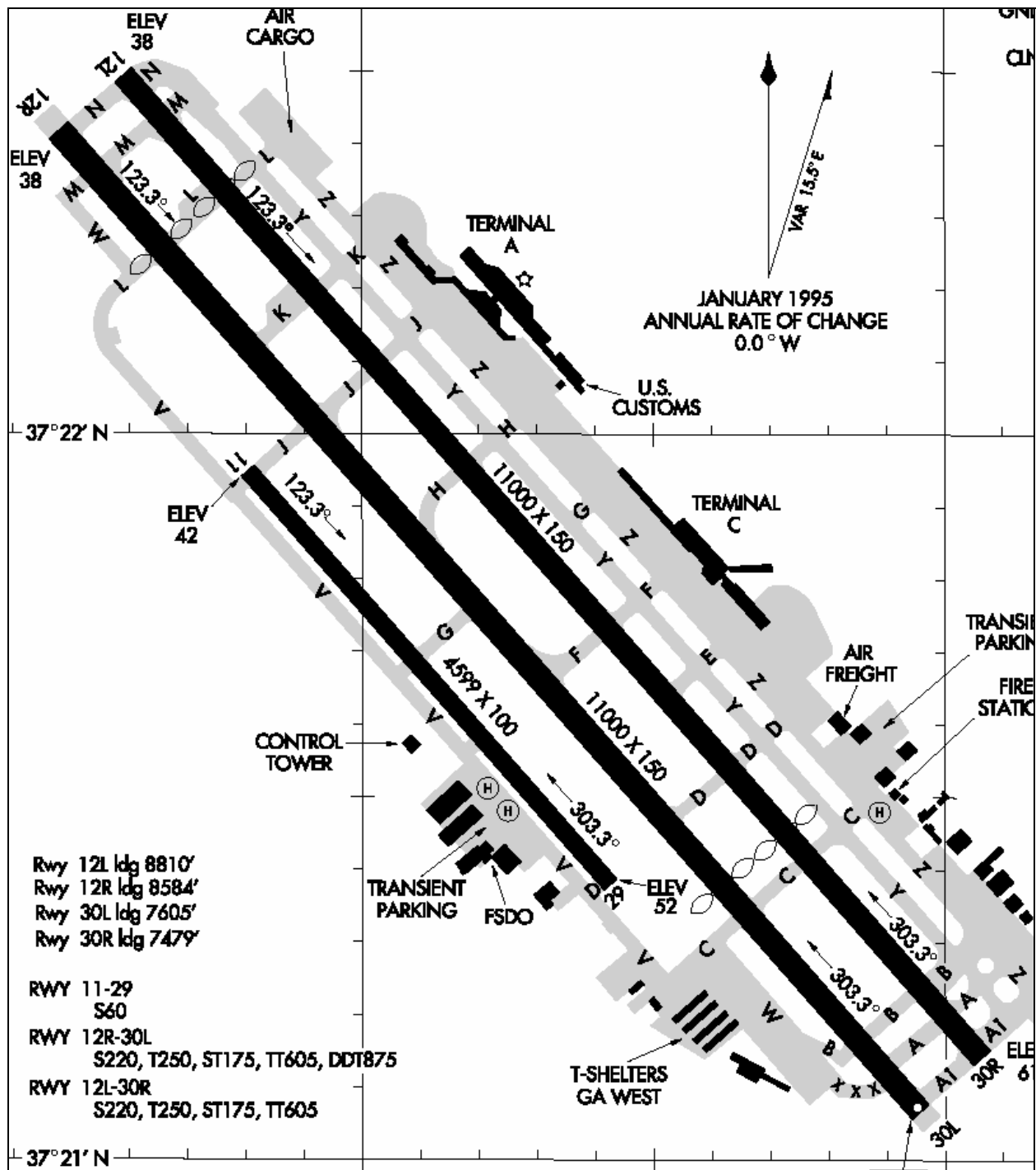


Figure A-25. San Jose International Airport Diagram (from [http://www.naco.faa.gov/ap\\_diagrams.asp](http://www.naco.faa.gov/ap_diagrams.asp))

## **Key Project Components**

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The key fast track components of this project included the following:

- Planning – unusual procurement and contracting procedures, phasing and scheduling of the project, coordination with stakeholders, coordination on safety and protection of NAVAIDs.
- Design – transition between new and existing runway.
- Construction – requirements for onsite batch plant; provision to pay contractor for rapid relocation of equipment.
- Excavation and subgrade – use of reinforced concrete covers to protect utilities in place.
- Interim milestones with liquidated damages and bonus clauses.

## **Planning**

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The airport developed a number of project requirements:

- The runway had to continue to operate for all scheduled jet traffic.
- FAA navigational aids had to be relocated.
- California environmental requirements had to be met.
- Underground utility lines had to be protected.
- The public had to be protected from jet blast effects.

Furthermore, the extensions needed to be usable as soon as possible, and funding was limited. To successfully complete a project such as this one, careful coordination would be required between all parties.

The project to extend Runway 12R-30L by 1,300 ft consisted of adding 400 ft to one end and 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. Coordination with the FAA resulted in establishing operational guidelines to accommodate construction as well as considerable coordination of navigational aids installation, which are discussed in the Other Issues section of this case study.

Detailed schedules were prepared to identify critical activities during construction to help ensure the extended runway was open as soon as possible, with all work scheduled to be completed in just 17 months. Interim milestones were set, each with associated liquidated damages as well as a bonus clause. The City's construction management staff coordinated activities carefully with the contractor, other City staff, consultants, FAA, Air Traffic Control personnel, and airlines.

The City of San Jose identified their critical staff members to manage the construction process early in the 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.

## **Design**

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The FAA pavement design methodology was used to select a runway pavement section consisting of 18 inches of PCC, a wax-based bond breaker, 8 inches of P-306 Econocrete stabilized base, 12 inches of P-209 aggregate subbase, and 9 inches of prepared subgrade. However, the estimated pavement service life for this design was 30 to 40 years. The airport historically had difficulties associated with California's environmental approval process and community resistance due to noise issues with getting approval for construction and maintenance projects. Thus, the airport consciously selected an extended design life to maximize the time before maintenance was likely to be needed on the runway extensions. Joint spacing was 25 feet, with 1-1/2-inch by 20-inch dowels spaced 18 inches on center used for load transfer.

The adjacent existing asphalt pavement dated back to the 1940's and was a combination of various structural sections varying from 24 to 36 inches of asphalt concrete (P-401) on top of 12 to 18 inches of aggregate base. The section varied due to the fact that this runway had evolved over time, and had been extended and widened over its 50-plus year history.

The transition between the new section and the existing section consisted of the following: a 5-foot wide, 21-inch thick section of the existing structural section was removed. The new structural section consisting of 8 inches of econocrete and 14 inches of PCC pavement was placed in this 5-foot area. This was capped with a 4-inch thick section of asphalt concrete (P-401). The asphalt cap varied in thickness and width. On the south end, the cap was 57 feet wide and tapered from 4 to 2 inches. On the north end, the cap was 200 feet wide and also tapered from 4 to 2 inches.

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 delays in concrete delivery due to traffic jams, which were a common occurrence with the airport's inner-city location. Monitoring included inspection of plant operations and materials as well as material testing.

## **Construction**

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During construction the airport imposed a work restriction due to jet blast concerns which required the contractor to vacate the project area for one flight a day. That flight was American Airlines San Jose to Tokyo flight on an MD-11. For all other flights jet blast was a concern but was not problematic. No other special procedures were required.

The total project duration for the runway construction was 220 working days, and the effective day of the Notice to Proceed was July 17, 1992. There were four partial Notices to Proceed issued for various items of work as the airport waited for FAA grant funding. All work was performed during the daytime, with the exception of work within the taxiway safety areas for the last taxiway on either end. Work in this area was restricted to a 12:00 am to 6:00 am closure.

## Other Issues

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Other issues associated with this project include:

- Provisions for relocation of navigational aids.
- Protection of utility structures.
- Protection of pedestrians and vehicles from jet blast.

Relocation of the navigational aids included the runway localizers to allow proper clearance from the relocated runway thresholds. FAA representatives expressed concerns about the localizer electronic signal, since construction activities took place in the electronic path. With close coordination with the FAA, it was agreed that the airport could operate without the localizers when it was necessary to perform construction in front of them. The contract required the contractor to move the equipment quickly if visibility deteriorated, and a method of payment for this rapid response was established.

Extending the runway placed aircraft at maximum take-off thrust only 650 to 1,000 ft from roadways. Thus, blast deflector walls were required at runway ends and adjacent taxiways. However, there was concern that the deflector walls would interfere with the runway ILS equipment. Several options for relocating or protecting the NAVAIDS were explored, including everything from relocating the localizer behind the blast fence to building a non-metallic protective shield that would be installed around the localizer antenna. The airport even explored the option of an aircraft carrier style blast fence that could be raised and lowered depending on whether the operation was a take-off or a landing. Some options were not cost effective and most were ruled out by the FAA. It was determined (by the FAA Airway Facilities staff) that if 600 feet of separation was maintained between the localizer antenna and the aircraft there would be negligible impact from the blast.

An additional challenge to the relocation of the NAVAIDS is that the FAA had not budgeted for work. The design team included personnel with experience in NAVAID design to perform the work and a Reimbursable Agreement was made between the airport and the FAA so that review could be performed. Addressing the budget issue and designing custom flush-mounted fixtures for the new threshold areas—replacing the elevated lights that are standard to FAA installations—allowed the instrumentation to be functional by the time the runway was ready for certification.

The runway extension also impacted large sanitary sewer lines and manholes serving the neighboring city of Santa Clara, which could not be taken out of service. In the end, these were protected by reinforced concrete caps designed to carry aircraft wheel loads.



## Summary

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The project was completed on schedule in just 17 months, including the work prior to the official Notice to Proceed. The City considered the project a success and attributed the success to several factors:

- Recognizing project complexities and demands.
- Commitment by personnel.
- Detailed analysis of issues.
- Follow-through in construction.
- Careful coordination with all parties involved.

Experience in the use of the runway since 1993 indicates that it has been a good investment, with satisfied airline tenants. The airport's positive experience with the 1993 concrete pavement runway extension project influenced pavement type selection for subsequent runway construction. The main change to the pavement section was the use of asphalt base with a sand bond breaker instead of the P-306 Econocrete base.

In subsequent projects, the City of San José has extended parallel Runway 12L-30R from 4,400 feet to 11,050. The existing portion of the runway was also reconstructed from asphalt to concrete. This project was carried out between January 2000 and August 2001. The extension of Runway 12L-30R gave the airport two commercial runways and made the subsequent upgrades to Runway 12R-30L possible.

Once the 12L-30R project was completed, the airport reconstructed the original 8,900-foot asphalt portion of Runway 12R-30L with concrete to enhance its safety and longevity. This project started in April and ended in October 2002. A subsequent project extended the runway by 800 feet to 11,000 feet. The extension also allowed the runway to connect to Taxiways A1 and N, and Taxiway A was widened. The runway extension project started in March and ended in November 2004.

## Available Sources of Information

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Interviews with a key individual involved in this project were held by telephone and email. The project team would like to acknowledge the valuable input and contributions of the following individual for providing much of the information presented in this case study document:

- Michael J. Zimmermann, Airfield Project Captain, Master Plan Team, San Jose International Airport

The following document also provided valuable information used in this summary:

- Warren, Loy, "Extending the Limits San Jose Runway," *Meeting the Challenge: Rebuilding Inner City Airports*, Proceedings of the 24<sup>th</sup> International Air Transportation Conference held in Louisville, Kentucky, June 5 – 7, 1996, ASCE, 1996.

## **Contacts**

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## **Savannah/Hilton Head International Airport Reconstruction of the Intersection of Runways 9-27 and 18-36**

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### **General Information**

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Airport: Savannah/Hilton Head International Airport

Owner: Savannah Airport Commission

Airport Classification: Small Hub

Climatic Region: Wet/No Freeze

FAA Region: Southern

Facility: Intersection of Runways 9-27 and 18-36

Description of project: Reconstruction of intersection of Runways 9-27 and 18-36 using overnight closures, very high-early strength concrete, and temporary pre-cast panels

Dates of construction: 1996

Engineer/Designer: HNTB

Project Manager/Construction Manager: N/A

Prime Contractor: APAC-Georgia, Inc., Ballenger Paving Division

### **Project Overview**

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The Savannah Municipal Airport opened on September 20, 1929 with inaugural air service to New York City and Miami. Following World War II it moved to its present location at Travis Field. In 1953, Runway 9-27 was extended to 8,000 feet to accommodate jet traffic. By 2003, annual emplanements and deplanements reached approximately 850,000, with over 100,000 aircraft operations and 8,000 tons of air cargo.

The airport layout is shown in figure A-26. The existing pavement at the intersection of Runways 9-27 and 18-36 was 12 to 20 inches thick, consisting of 6-inch-thick concrete pavement with multiple asphalt overlays. Because the overlays had deteriorated, and were exhibiting significant rutting, the Savannah Airport Commission decided to rebuild the intersection with concrete.

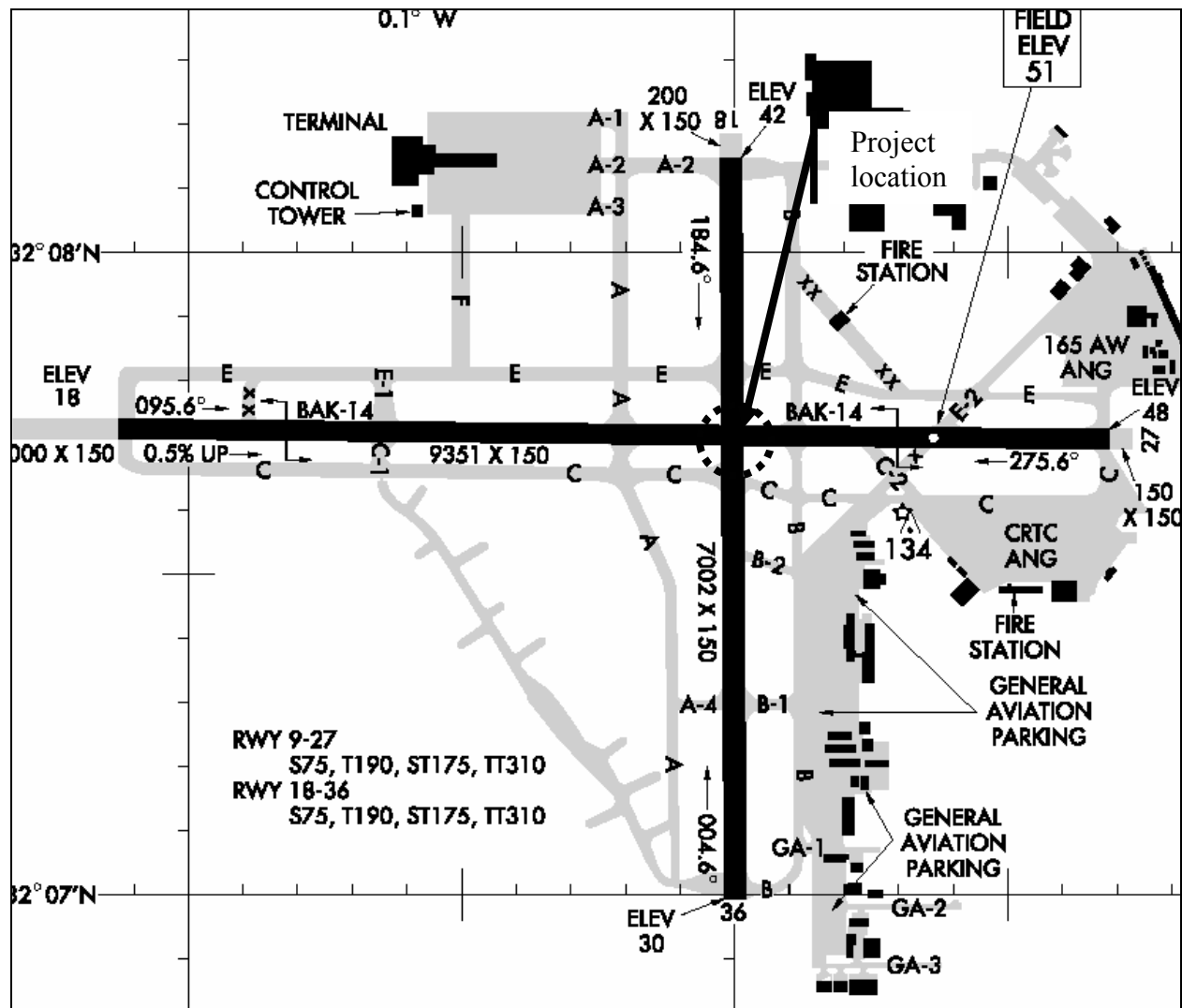


Figure A-26: Savannah International Airport Diagram (from [http://www.naco.faa.gov/ap\\_diagrams.asp](http://www.naco.faa.gov/ap_diagrams.asp))

## Key Project Components

Fast track components of the project included:

- Planning – phasing and scheduling planned and coordinated with the airport, coordination with stakeholders.
- Design – use of a thicker section to eliminate the requirement for a separate base course and dowels.
- Materials – use of precast panels and proprietary rapid setting cement.
- Construction – use of rapid set cement to cast precast panels to validate mix designs and construction methods, use of a sacrificial asphalt overlay, surface grinding to produce a smooth profile.

- Other – preparations for adverse weather.
- Use of a rock saw to demolish existing concrete pavement.
- A backup concrete plant and other equipment to speed production.
- Use of a sacrificial asphalt overlay to establish the new grade.
- Innovative construction staging within 8-hour window.

These are described in greater detail below.

## **Planning**

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The original plan for the intersection replacement for Runways 9-27 and 18-36 would have required a 2-month halt to jet air carrier service. This alternative was rejected outright, and instead the Savannah Airport Commission insisted that one runway remain open between 6:00 am and 10:45 pm every day. The engineer, who had completed a similar project at the nearby Charleston International Airport, developed a plan to complete the construction within the required closure windows.

Construction was performed at night and the pavement was opened to traffic by the following morning. The work was broken down into three phases. In Phase I, Runway 18-36 was closed day and night and Runway 9-27 was only closed from 10:45 pm to 6:00 am. During Phases II and III, Runway 9-27 was closed day and night and Runway 18-36 was only closed only from 10:45 pm to 6:00 am. Project phases are shown in figure A-27.

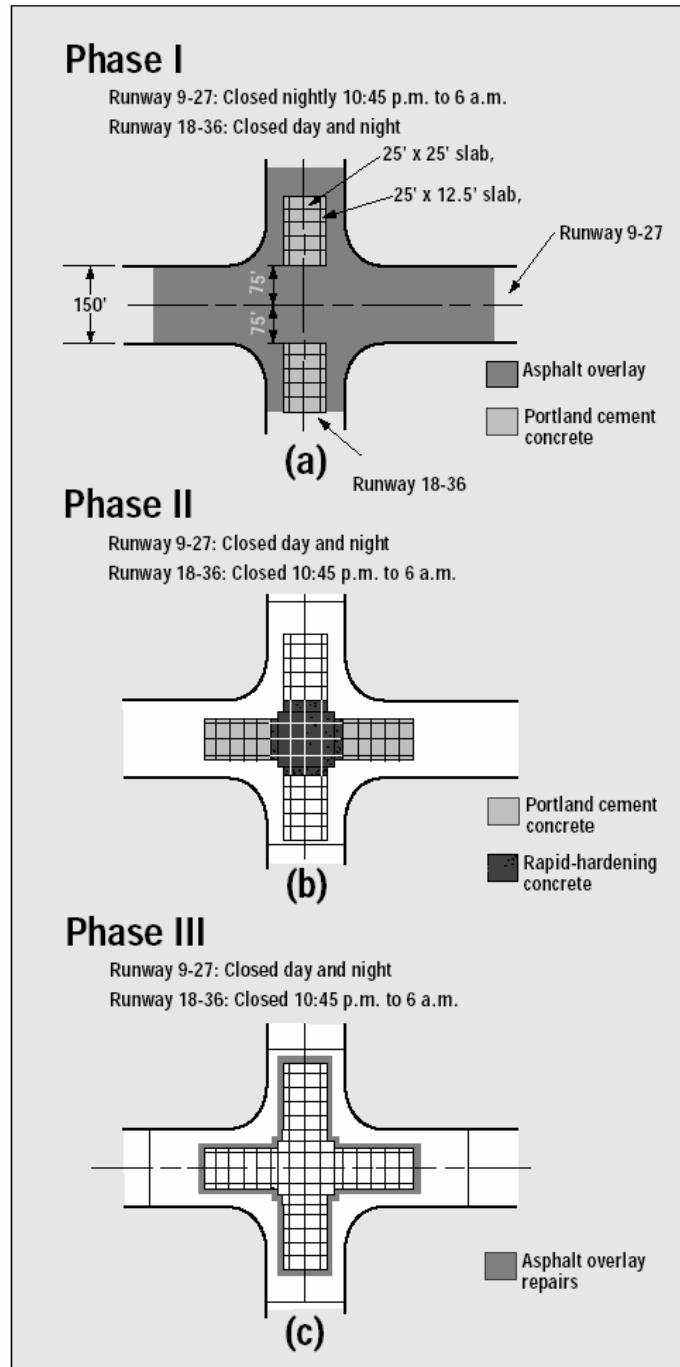


Figure A-27. Portland cement concrete could be placed along closed runway areas that did not overlap the open intersecting runway. However, rapid-hardening concrete was required in the intersection because the open runway had to support traffic by 6 a.m. (Figure courtesy *Concrete Repair Magazine*).

## Design

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The design procedure is outlined with the phasing schedule in figure 2. Prior to the start of the slab replacement, the top 2 inches of the existing pavement were removed and a sacrificial HMA overlay was placed. This sacrificial overlay was intended to establish final grades, improve drainage, and provide a smooth working platform for paving. Then the PCC slabs could be placed, followed by any repairs to the HMA overlay along the outside edge of the PCC pavement.

The design allowed rapid replacement of the intersection with minimal disruption of air traffic. Key features included:

- A 24-inch-thick pavement to eliminate using a separate stabilized base (considered a “monolithic” base) and the need for dowel installation.
- Approximately a third of the concrete contained a rapid-hardening cement producing a flexural strength of 500 psi in 4 hours. Portions of the PCC specification are provided at the end of this case study.
- Pre-cast paving units to provide temporary replacement slabs when the existing pavement had been removed but there was not yet enough time to place and cure the new pavement.

The intersection was designed for a service life of 25 years. Most panels were 25 by 25 feet, with some PCC along the edges of the intersection placed in 12.5 ft by 25 ft panels. These irregular panels were reinforced.

Minimum strength requirements were established using an incentive-based pay scale that is further described in the Other Issues section of this case study.

## Construction

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The total concrete placed was approximately 6,200 square yards. The contractor originally planned to replace 139 square yards per night closure, but achieved a final production rate of 382 square yards.

In Phase I following the placement of the HMA overlay, two 75 ft by 125 ft sections of Runway 18-36 were replaced with PCC. The existing pavement was cut into 8 by 8 foot panels, then removed with a front end loader equipped with forks. This runway was closed to traffic so loose material could be placed back into the trench. The 75-ft wide lane was divided into two 25-ft wide strips with 12.5-ft wide strips at the edges, divided into 25-ft long slabs. The narrow slabs were reinforced to minimize transverse cracking. This paving used conventional PCC, and all of the work was outside of the center 125 ft of Runway 9-27. The construction is shown in figure A-27. Figure A-28 provides an aerial photograph of the intersection.

During Phase II, two 75 ft by 125 ft sections were paved on Runway 9-27, also with conventional PCC. This provided four arms of the runway intersection, but left a 125-ft by 125-

ft square in the middle of the intersection to be paved. The intersection was replaced in sections, using rapid-hardening cement concrete.



Figure A-28. Intersection of Runways 9-27 and 18-35 during construction.

The keys to the success of Phase II were the use of the rapid-hardening cement and the temporary pre-cast concrete insert panels. The rapid-hardening concrete reached 500 psi in 4 hours; thus, all batching had to be completed by 2:00 am to re-open by 6:00am. If an area could not be filled with concrete that night, the excavated areas were filled with temporary pre-cast slabs to allow re-opening of the runway. A typical Phase II nighttime closure used the following sequence of operations:

- 10:45 pm – close runways.
- 10:45 pm to 11:00 pm – remove pre-cast units from area 1.
- 11:00 pm to 12:00 am – place concrete in area 1, and remove existing pavement in area 2.
- 12:00 am to 1:00 am – place concrete in area 2, remove existing pavement in area 3.
- 1:00 am to 6:00 am – set temporary pre-cast units in area 3, cure concrete in areas 1 and 2, clean up.
- 6:00 am – open runway.



The contractor was able to observe an earlier, similar project at the nearby Charleston International Airport. Based on these observations, the contractor made a number of improvements to the process:

- Temporary pre-cast units – the Charleston project used 12.5-ft square panels, which proved to be hard to move. The rubber-tired crane used on the project could lift the panels without difficulty, but could not transport them and had to set the panels down when the crane needed to be repositioned. At Savannah, the contractor made the pre-cast units smaller (12.5 ft by 8 ft). These weighed 15 tons rather than 23 tons, and a very large, container-type forklift with much greater mobility was used. The precast units and the lifting equipment are shown in figure A-28.
- The contractor used more temporary pre-cast units – there were only enough for two 25-ft by 25-ft closures in Charleston. The contractor had twice that many in Savannah, so more work was possible in a night. Eventually, production was doubled.



Formwork and reinforcement for precast slabs



Fork lift moving precast section



Fork lift moving precast section



Precast slabs in place

Figure A-28. Precast unit details and lifting equipment

- Both contracts required backup concrete batch plants and duplicate equipment. However, the contractor at Savannah used the backup plant to increase concrete production.

- The Savannah contractor used a rock saw to demolish the existing pavement – this was a giant wheel with rock teeth, about 8 ft in diameter, which was used to make interior cuts in the existing slabs. The rock saw is shown in figure A-29. Once the primary cut was made, additional cuts were made with conventional saws, and the contractor used a large forklift to lift sections out. Each 25-ft by 25-ft existing panel was cut into eight sections. The Charleston contractor had used a crane to lift sections onto a lowboy. The contractor observed significant wear and tear on the rock saw and later brought in a duplicate.



Figure A-29. Rock saw used to make interior slab cuts.

In Phase III, any damage to the asphalt that had been placed around the perimeter of the concrete intersection was repaired.

### Other Issues

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A sliding pay factor was established for strength, based on strength at opening and strength at 28 days. The pay factor formula was:

$$\text{PAY FACTOR} = (0.3 \times \text{OPENING TIME FACTOR}) + (0.7 \times \text{28 DAY FACTOR})$$

The opening time factor was 1.0 for 500 psi minimum strength, with 0 for strength below 400 psi. The 28-day factor was 1.0 for 750 psi minimum strength, with 0 for strength below 650 psi. However, the specification also had a provision that if the opening strength was 650 psi, then the pay factor would be 1.0 regardless of the 28-day strength. Therefore, in order to ensure full pay, the contractor attempted to achieve the 28-day strength of 650 psi at four hours. This removed any uncertainty as to whether the full pay factor would be achieved.

## **Summary**

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The total project cost was just over \$2 million. All parties involved in the project considered it a success. On November 2, 2004, the Director of Engineering for the airport reported that the intersection had performed quite well since construction eight years before.

## **Available Sources of Information**

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Interviews with several key individuals involved in this project were held by telephone and email. The project team would like to acknowledge the valuable input and contributions of the following individuals for providing much of the information presented in this case study document:

- Gary Skoog, HNTB
- Robert McCord and Kevin Crusa, APAC-Southeast, Inc., Ballenger Division
- George Fidler, Director of Engineering, Savannah Airport Commission

The following documents also provided valuable information used in this summary:

- McGovern, M.S., "Smooth landing for runway intersection replacement," Publication #R980124, *Publication Three*, The Aberdeen Group, April 1998.
- Savannah Project Specifications, Item 502, Rapid-Set® Portland Cement Concrete, with Addendum No. 1, July 26, 1995
- <http://www.savannahairport.com/history.php>
- <http://www.savannahairport.com/webstats.php>
- Additional photographs provided by Gary Skoog, HNTB.

## Contacts

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## ITEM 502

### RAPID-SET® PORTLAND CEMENT CONCRETE

#### 1. DESCRIPTION

This work shall consist of pavement composed of a quick setting high early strength concrete, with or without reinforcement, constructed on recompacted base course, after removal of the existing pavement. The work shall comply with applicable sections of the P-501 Specifications referenced herein, and shall conform to the lines, grades, thicknesses and typical cross sections shown on the drawings.

#### 2. QUALITY ASSURANCE

Quality assurance shall be as specified in General Provisions Section 100 and in Section P-501 - Portland Cement Concrete Pavement, with the addition of the following:

If the concrete is produced at the paving site with a mobile batching-mixing plant, the equipment shall be capable of producing the specified concrete mix to the standards of quality and uniformity that would be required for production by a permanent or portable batch plant. Specifically, the equipment shall be capable of consistent production to the concrete uniformity requirements of Table A1.1 in ASTM C685 - Standard Specification for Concrete Made By Volumetric Batching and Continuous Mixing. Compliance with these requirements shall be demonstrated by quality control testing of the mix produced by each equipment unit proposed for use on the project. The testing shall be performed by a qualified independent laboratory, at the Contractor's expense. The test results and a certification by the laboratory that the equipment meets the above stated requirements shall be submitted and approved by the Engineer before the start of full pavement production will be authorized. If the equipment compliance documentation is not previously submitted and approved, the required testing shall be accomplished during the Mix Design Development and Test Section process.

#### 3. MATERIALS

##### 3.1 Fine Aggregate

Fine Aggregate for concrete shall conform to the requirements of ASTM C33 and shall meet the requirements of Table 1, as specified in Section P-501 - Portland Cement Concrete Pavement, Paragraph 2.1.

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<sup>1</sup>Addendum No. 1, July 26, 1995

### **3.2 Coarse Aggregate**

As specified in Section P-501 - Portland Cement Concrete Pavement, Paragraph 2.2.

### **3.3 Cement**

Cement shall be one of the following:

Portland cement conforming to the requirements of ASTM C150, Type I, Type II, or Type III.

"RAPID-SET® C-150 Cement" as manufactured by the CTS Cement Manufacturing Company, or an approved equal.

A combination of the above.

All cement of a particular type shall be the product of one manufacturer. If, for any reason, cement becomes partially set or contains lumps of caked cement, it shall be rejected. cement salvaged from discarded or used bags shall not be used.

The cement listed above shall be capable of producing a quick setting high early strength concrete with the following properties:

Development of flexural strength in excess of 550 psi, not later than 4 hours from the time water is added to the mix.

The mix setting time shall accommodate a placing and finishing time of 45 minutes, plus or minus 15 minutes.

### **3.4 Admixtures**

As specified in Section P-501 - Portland Cement Concrete Pavement, Paragraph 2.10.

### **3.5 Water**

As specified in Section P-501 - Portland Cement Concrete Pavement, Paragraph 2.8.

### **3.6 Steel Reinforcement and Tie Bars**

Steel reinforcement shall meet the requirements of Section P-501 - Portland Cement Concrete Pavement, Paragraph 2.6.

### **3.7 Premolded Joint Filler**

As specified in section P-501-4 - Portland Cement Concrete Pavement, Paragraph 2.4.

### **3.8 Joint Sealer**

The sealer for joints in the concrete pavement shall meet the requirements of Section P-605 - Joint Sealing Filler.

### **3.9 Cover Material for Curing**

Curing materials and methods shall conform to the recommendations of the curing material manufacturer and the cement manufacturer, and Section P-501 - Portland Cement Concrete Pavement, Paragraph 2.9

## **4. MIX DESIGN AND TEST SECTIONS**

### **4.1 General**

As specified in Section P-501 - Portland Cement Concrete Pavement, Paragraph 3.6 with the exception of the following:

- (a) A mix design shall be developed to allow for the construction of a minimum of two 25 foot square slabs per nightly workshift specified in the phasing plans. The mix design shall meet the criteria specified in 4.2.
- (b) Three quick setting high early strength concrete mix designs, utilizing RAPID-SET Cement as manufactured by CTS Cement Company, were developed, that met the above criteria, and were used on airfield pavement projects at Sea-Tac International Airport in 1994 and 1995. Information on, the concrete mix designs used and a summary of the field test results are attached as Appendix B to these specifications.
- (c) The previous project experience with quick setting concrete mix designs in 1994 at Sea-Tac showed a variability in the set time of the concrete mix and the cement material used. The Contractor shall develop a mix design and quality control program to allow adjustment in the procedures so the concrete mix that is used consistently meets the criteria specified at no cost to the Owner.

## 4.2 Strength and Proportions

As specified in Section P-501 - Portland Cement Concrete Pavement, Paragraph 3.6 with the exception of the following:

(a) A mix design shall be developed by the Contractor to meet the following properties:

1. The concrete mix shall achieve a minimum flexural strength of 500<sup>1</sup> psi within 4 hours of the time water is added to the mix, and shall achieve a minimum flexural of 750 psi in 28 days.
2. The concrete placed each night must attain the 500<sup>1</sup> psi flexural strength by 6:00 a.m. each morning when the pavement is opened to traffic.
3. The concrete mix shall have a set time of a minimum of 30 minutes beyond the time established by the Contractor's procedure to batch, transport, and place the concrete mix at the work site. The set time shall be defined as the time at which the mix takes a set and no further surface finishing can be accomplished.

The proportions of the concrete mix shall be as developed by the Contractor to meet the specified criteria. There is no specified minimum cement content, slump, water/cement ratio or restriction on admixtures. The entrained air content shall be 4.5% plus or minus 1.0 percent.

4. The mix shall have a minimum durability factor of 95 when tested in accordance with ASTM C666.

## 4.3 Cementitious Materials

Fly ash and silica fume may be used in the mix. Ground blast-furnace slag shall not be used.

## 4.4 Admixtures

As specified in Section P-501 - Portland Cement Concrete Pavement, Paragraph 2.10 with the exception of the following:

Air Entraining: The average air content shall be 4.5 percent, plus or minus 1.0 percent, and the mix shall have a durability factor of 95 or more when tested in accordance with ASTM C-666. The durability factor shall be determined by a test of the actual concrete mix to be used on the project.

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<sup>1</sup> Addendum No. 1, July 26, 1995



#### **4.5 Mix Design Development and Submittal**

The Contractor shall develop a mix design that meets the criteria specified in Paragraph 4.2. The process shall include the development of a minimum of three trial batches with decreasing water/cement ratios.

The batches shall use the intended raw materials to be used for the project, including cement, fine and coarse aggregates, as well as chemical and mineral admixtures. The trial batch mixtures shall maintain the same fine aggregate/coarse aggregate ratios as well as the same proportions of intended admixtures, only the water/cement ratio shall be varied. The testing of the trial batches shall, at a minimum, include flexural strength, temperature development, air content and slump. Flexural beam tests and temperature development specimens shall be prepared in accordance with ASTM C31, except that specimens shall be surrounded with insulative blankets for a minimum of 5 hours following addition of water to the mix. The mix design to be submitted for use on the project shall be one of the trial batches. Freeze-thaw durability testing shall be required only on the specific mix design intended for use on the project.

##### **(a) Flexural Strength Testing**

The average of a minimum of two flexural strength test results shall be completed at 4 hours, 5 hours, 6 hours, 8 hours, 24 hours, 7 days and 28 days for each of the three trial batches. The results shall be plotted on a flexural strength versus water/cement ratio.

##### **(b) Temperature Development**

The trial batches shall be monitored for development of temperature from the time the water is added to the mix until an age of 5 hours at 15 minute intervals. The temperature of the water and other materials and the ambient temperature at the time of batching shall be recorded. The time at which the mix takes a set shall be recorded along with the corresponding temperature of the mix. The temperatures shall be taken with a thermometer accurate to within 0.5°F. The thermometer shall remain inserted in the curing sample throughout the period of testing. The temperature data shall be plotted for each trial batch, with temperature on the vertical scale and time on the horizontal. The set time of the mix shall be identified for each batch.

##### **(c) Freeze-Thaw Durability**

The mix intended for use on the project shall be tested for durability in accordance with ASTM C666.

**(d) Mix Design Submittal**

The mix design submittal shall include the following minimum information:

1. Type(s) of cement.
2. Water/cement ratio.
3. Slump.
4. Air Entrainment percentage.
5. Flexural strength test results at 4, 5, 6, 8, and 24 hours, 7 days and 28 days.
6. Results of durability test in accordance with ASTM C666.
7. Temperature development of mix and set time.
8. Plant/lab mix certification of proportion of materials.
9. Fine and coarse aggregate supplier, pit location, gradation, fineness modulus, tested wear, specific gravity, absorption capacity and moisture content.
10. Manufacturer's name, catalog information for the cement(s) and admixtures used, including ASTM certification information.
11. Certification of Testing Laboratory designing the mix.

**(e) Tentative Mix Design Approval**

When a mix design meeting all the specified criteria and documentation requirements have been met and approved by the Engineer, the mix design will be given tentative approval, subject to successful completion of the preliminary test section. Tentative approval may be granted prior to the receipt of the 28 day strength tests, if 750 psi flexural strength has been demonstrated at an earlier test period.

**(f) Full Mix Design Approval**

Full approval of the mix design will be granted when the following requirements have been met:

1. Successful completion of the Test Sections, including any modification of the tentatively approved mix design.
2. Acceptable results from the 28-day strength.

**4.6 Preliminary Test Sections**

Following tentative approval of the mix design, the Contractor shall construct a Preliminary Test Section which will be composed of the pre-cast slab units detailed on the Contract Drawings. The purpose of the Preliminary Test Section is to demonstrate that the mix design meets all the requirements in the specifications in full-scale construction. The Preliminary Test Section may be constructed in

daytime conditions, without the time and operating constraints that will exist for full production paving. However, the equipment and procedures shall be the same as for full production paving.

The test section location will be on a paved or unpaved area at Savannah Airport but not within the pavement replacement area of the project. The Contractor shall perform the necessary preparatory work for the test, including excavation of existing base or subgrade materials to a sufficient depth to accommodate the test slab, minor grading to level the site, placement and compaction of base course material to establish a suitable work platform, and removal and setting of precast temporary slab units. The test slabs shall consist of eight units *12'-4 1/2" long, 12'-4 1/2" wide and 24 inches thick.*<sup>1</sup>

The concrete mix shall be tested for compliance with the test/data submitted as part of the mix design submittal. Failure to meet the specified flexural strength, set time or air entrainment percentage shall be cause for rejection of the mix design. The slump and temperature development of the field tested mix shall be compared to lab tested results to indicate the ability to replicate the mix design under field conditions. The Preliminary Test Section will be inspected by the Engineer for placement procedures, finish, cracking, set time, and strength gain.

If the Preliminary Test Section proves unsatisfactory, the necessary adjustments to the mix design, plant operations and/or placement procedures shall be made. An additional test section shall be completed at the Contractor's expense. Changes in the mix design will require resubmittal of the mix design in accordance with Paragraph 4.5 prior to completing the additional test section.

#### **4.7 Production Test Sections**

Following the Engineer's approval of a Preliminary Test Section, including any necessary adjustments of the mix design, equipment and procedures, the Contractor shall construct Production Test Sections, at a location chosen by the owner. The purpose of the Production Test Sections is to demonstrate that the mix design, equipment, materials and procedures meet all requirements in the specifications, under the same time constraints, night working conditions and operating constraints that will exist for full production paving. The Production Test Section work shall include the removal of existing pavement, excavation and recompaction of existing base course, placement and removal of temporary precast slabs.

The test section locations will be on an existing paved area comparable to the actual pavement replacement area in the project. The test section will consist of at least two full-sized slabs (25 ft. x 25 ft. x 24 in.). At the completion of the Production Test Section work at 6:00 a.m., the test site(s) must meet all requirements for opening the pavement to aircraft traffic and the concrete must

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<sup>1</sup> Addendum No. 1, July 26, 1995

## **5.9 Joints**

As specified in Section P-501 - Portland Cement Concrete Pavement, Paragraph 3.12, excluding provisions for slip-form construction, which is not applicable. Prior to placing the new concrete, the existing concrete faces shall be sprayed with an approved debonding agent to prevent bond of new concrete to the existing concrete.

## **5.10 Final Strike-Off, Consolidating and Finishing**

As specified in Section P-501 - Portland Cement Concrete Pavement, Paragraph 3.13.

## **5.11 Surface Texture**

As specified in Section P-501 - Portland Cement Concrete Pavement, Paragraph 3.14.

## **5.12 Curing**

The initial method of curing, to begin immediately after the finishing and set of the pavement surface, shall be water curing. The entire surface shall be kept continuously moist by sprinkling for at least 2 hours, or longer if recommended by the cement manufacturer or mix designer.

After the minimum water curing period and before opening the pavement to traffic, apply an impervious curing membrane shall be applied as specified in Section P-501 - Portland Cement Concrete Pavement, Paragraph 2.9 and 3.18.

## **5.13 Sealing Joints**

As specified in Section P-605 - Joint Sealing Filler.

## **5.14 Protection of Pavement**

As specified in Section P-605 - Portland Cement Concrete Pavement, Paragraph 3.12.

## **5.15 Opening to Traffic**

The Engineer shall decide when the pavement will be opened to traffic. The flexural strength of the permanent concrete required for opening the pavement to normal airport traffic (vehicles and aircraft) is 500 psi, based on testing in accordance with ASTM C78.

In addition to the above requirements, all equipment, materials and debris shall be removed and the pavement in the immediate work area shall be cleaned by the Contractor to the satisfaction of the Engineer prior to each pavement opening.

## 6. MATERIAL ACCEPTANCE

### 6.1 Acceptance Sampling and Testing

Concrete samples shall be furnished by the Contractor and shall be taken in the field to determine the consistency, air content and strength of the concrete. Flexural test beams shall be made each night that the concrete is placed. The specimens shall be made in accordance with ASTM C31. Each group of test beams shall be molded from the same batch of concrete and shall consist of a sufficient number of specimens to provide at least two flexural strength tests at each of the test ages specified below. However, at the start of paving operations and when the aggregate source, aggregate characteristics, or mix design is changed, additional groups of test beams may be required and testing of beams at various hourly ages may be required, until the Engineer is satisfied that the concrete mixture being used complies with the strength requirements of these specifications, for the actual nightly placement schedule.

- (a) The time scheduled for opening the pavement to normal airport traffic (aircraft and vehicles) each morning is 6:00 a.m. For purposes of the following discussion, "batching" means the time that water is added as the final ingredient to the concrete mix. The test reports for all beams shall record the age of the concrete, from the batching to the time of testing.
- (b) Test ages for the nightly concrete placement shall be the following:
  - 1. If concrete batching ends later than 4 hours prior to scheduled pavement opening, beams made from concrete that is placed in the last slab constructed each night shall be tested at or slightly before the scheduled time for pavement opening, to insure that the required strength has been attained. Tests made at that time shall be the OPENING TIME tests used in the computation of pay factors.
  - 2. If concrete batching ends earlier than 4 hours prior to scheduled pavement opening, one set of beams shall be tested at an age of 4 hours from batching. These tests shall be continued only to the extent determined necessary by the Engineer to evaluate the performance of the specified 4 hour mix design requirement. They shall be used as the OPENING TIME tests only if the 4 hour age coincides with the scheduled opening time.

3. If concrete batching ends earlier than 4 hours prior to scheduled pavement opening, beams made from concrete that is placed in the last slab constructed each night shall be tested at or slightly before the scheduled time for pavement opening, to insure that the required strength has been attained. Tests made at that time shall be the OPENING TIME tests used in the computation of pay factors.
  4. Initially beams shall also be tested at ages of 5 hours, 8 hours and 24 hours. When the consistency of the Contractor's paving operations, placement completion time and concrete strength gain has been demonstrated to the satisfaction of the Engineer, some or all of the testing at these ages may be terminated.
  5. Beams from each night of work shall be tested at an age of 28 days, for the duration of the project. These tests shall be the 28 DAY tests used in the computation of pay factors.
- (c) The flexural strength of the concrete shall meet the following requirements:
1. For each night of placement, the average strength of the concrete tested shall not be less than 500 psi at the time the pavement is scheduled for opening to normal airport traffic.
  2. For each night of placement, the average strength of the concrete tested at an age of 28 days shall not be less than 750 psi.
- (d) Specimens which are obviously defective shall not be considered in the determination of strength. The specimens with the least imperfections shall be used for the earlier tests.
- (e) When a satisfactory relationship between the 24 hour and 28 day strengths has been established and approved, the 24 hour results may be used as an indication of the 28 day strengths, for purposes of interim acceptance and progress payments. However, final acceptance and payment will be based only on the OPENING TIME and 28 DAY strengths, with the following exception: If the OPENING TIME strength of any lot of concrete is 650 psi or more, the pay factor from that lot shall be 1.0, regardless of the 28 DAY strength.
- (f) For final acceptance and payment, each night's production, regardless of quantity, shall be considered as one lot. Except as provided above, the pay factor for each lot shall be established on the basis of both the OPENING TIME and the 28 DAY-strength test results, according to the following formulas and tables:

$$\text{PAY FACTOR} = (0.3 \times \text{OPENING TIME FACTOR}) + (0.7 \times 28 \text{ DAY FACTOR})$$

TABLE 1: OPENING TIME FACTOR

Flexural Strength	Factor
500 psi min.	1.00
450 to 499 psi	.90
440 to 489 psi	.80
430 to 479 psi	.70
420 to 469 psi	.60
410 to 459 psi	.50
below 400 psi	.00

TABLE 2: 28 DAY FACTOR

Flexural Strength	Factor
750 psi min.	1.00
740 to 759 psi	.90
720 to 739 psi	.70
700 to 719 psi	.50
650 to 700 psi	.30
below 650 psi	.00

1. If the average OPENING TIME strength for any lot is below 500 psi, concrete placement shall be suspended until the deficiency is investigated and corrections acceptable to the Engineer are made. The corrections which the Engineer shall have the right to require include additional test strips using the current mix, changes to the mix, and establishing an earlier nightly time deadline for final batching and placement of concrete.
2. Closure of the pavement beyond the scheduled opening time of 6:00 a.m., due to concrete strength deficiencies or other concrete deficiencies, will subject the contractor to liquidated damages as specified in the Contract.
3. If the average OPENING TIME strength for any lot is less than 400 psi, the Contractor shall remove and replace the concrete at his own expense.
4. If the average 28 DAY strength for any lot is less than 650 psi, regardless of the OPENING TIME strength, the Contractor shall remove and replace the concrete at his own expense.

## **6.2 Acceptance Criteria**

### **(a) Flexural Strength**

Acceptance based on flexural strength shall be specified in Paragraph 6.1.

### **(b) Thickness**

The existing base course will be partially excavated, regraded and compacted prior to placement of precast temporary slabs. The depth to the top of the base course from the surface of the existing pavement shall be measured on a grid pattern and recorded. The temporary slab will be equal in thickness to the permanent slabs and will be installed to match the surface elevations of the existing slabs. After removal of the temporary slabs, the base will be rechecked with a template and irregularities will be corrected for each slab prior to placement of permanent concrete. This procedure will insure that the minimum specified thickness of the permanent concrete is achieved throughout each slab.

Therefore, no coring or acceptance criteria for out-of-tolerance pavement thicknesses are necessary.

## **7. METHOD OF MEASUREMENT**

7.1 "Rapid-Set® Portland Cement - Mix Design Development and Test Sections" (Preliminary Test Sections and Production Test Sections) will be measured as a lump sum unit and shall include all labor, materials, testing, and equipment required to complete the work, as specified herein and indicated on the drawings.

7.2 The quantity for "Rapid-Set® Portland Concrete" to be measure for payment shall be the number of square yards of pavement in place, completed and accepted, excluding pavement constructed as part of test sections.

## **8. BASIS OF PAYMENT**

8.1 Rapid-Set® Portland Cement - Mix Design Development and Test Sections" shall be paid for at the lump sum price stated in the schedule of prices, regardless of the number of Preliminary and Production Test Sections required. The lump sum price shall be full compensation for furnishing all labor, materials, tools, equipment and testing to develop an



approved mix design and complete Preliminary and Production Test Sections as required prior to starting full production paving.

Twenty percent (20%) of the lump sum price will be paid upon Tentative Mix Design approval. Ten percent (10%) of the lump sum price will be paid upon Full Mix Design Approval. Thirty percent (30%) of the lump sum price will be paid upon satisfactory completion of a Preliminary Test Section. Forty percent (40%) of the lump sum price will be paid upon satisfactory completion of a Production Test Section and approval to start full production paving.

- 8.2 The accepted quantity of "Rapid-Set® Portland Cement" (excluding test sections) will be paid for at the contract unit price per square yard, which price and payment shall be full compensation for furnishing required lighting and other equipment, excavation, compaction and placing all materials, steel reinforcement, joint sawing, curing and surface texturing, except for saw-cut grooving and grinding, provided, however, that for any pavement found deficient in flexural strength, price adjustment shall be made as specified in Paragraph 8.4. No payment adjustments based on pavement thickness shall be made.

**8.4 Price Adjustment**

The pay factor for each lot shall be determined as specified in Paragraph 6.1. If the pay factor for a lot of concrete is less than 1.0, payment for the material in that lot shall be made at a reduced price, arrived at by multiplying the contract price per square yard by the appropriate pay factor.

**8.5 Payment will be made under:**

Item P-502-1	Rapid-Set® Portland Cement Concrete - Mix Design Development and Test Sections - Lump Sum.
Item P-502-2	Rapid-Set® Portland Cement Concrete, 24" - Per Square Yard.
Item P-502-3	Reinforced Rapid-Set® Portland Cement Concrete, 24" - Per Square Yard.

**TEST REQUIREMENTS**

As specified in Section P-501 - Portland Cement Concrete Pavement.

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## Seattle-Tacoma International Airport Runway 16R-34L Reconstruction

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### General Information

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Airport: Seattle-Tacoma International Airport

Owner: Port of Seattle

Airport Classification: Large Hub

Climatic Region: Wet/No Freeze

FAA Region: Northwest Mountain

Facility: Runway 16R-34L

Description of project: Runway slab replacement

Dates of construction: 2003 (slab replacement work actually began in 1994)

Engineer/Designer: Port of Seattle

Project Manager/Construction Manager: Port of Seattle

Prime Contractor: Gary Merlino Construction

### Project Overview

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Runway 16R-34L at Seattle-Tacoma International Airport (Sea-Tac) was constructed in 1970 and by the 1990's had received more loadings than it had been designed to carry. Additionally, this pavement was constructed in the early years of airport slip-form paving and there were marginal quality issues associated with the original construction. As a result, the runway pavement began having distresses that required repair. The challenge at Sea-Tac, with its limited runway capacity, was to do complete repairs without interrupting air traffic.

In 1994, the Port of Seattle (POS), which owns and operates Sea-Tac, started a fast-track program to replace deteriorated slabs. Operational constraints dictated that the rehabilitation work be performed during nighttime closures and that the runway be reopened to traffic each morning. Reopening each morning was achieved by the use of a rapid-set, high-early strength concrete and temporary pre-cast filler panels.

The 1994 project began with approximately 30 slabs and has continued during most years since then. Over the years the process has been refined and approximately 50 to 60 slabs are replaced in a construction year (the work is now performed every other year on average), with over 400 runway slabs being replaced through 2003. The typical slab dimensions are 18.75 ft by 20 ft; the existing slabs are 14 inches thick and the replacement slabs are 18 inches thick. Numerous slabs also included replacement of runway or taxiway lead-in lighting. An overview of the runway is provided in figure A-30.

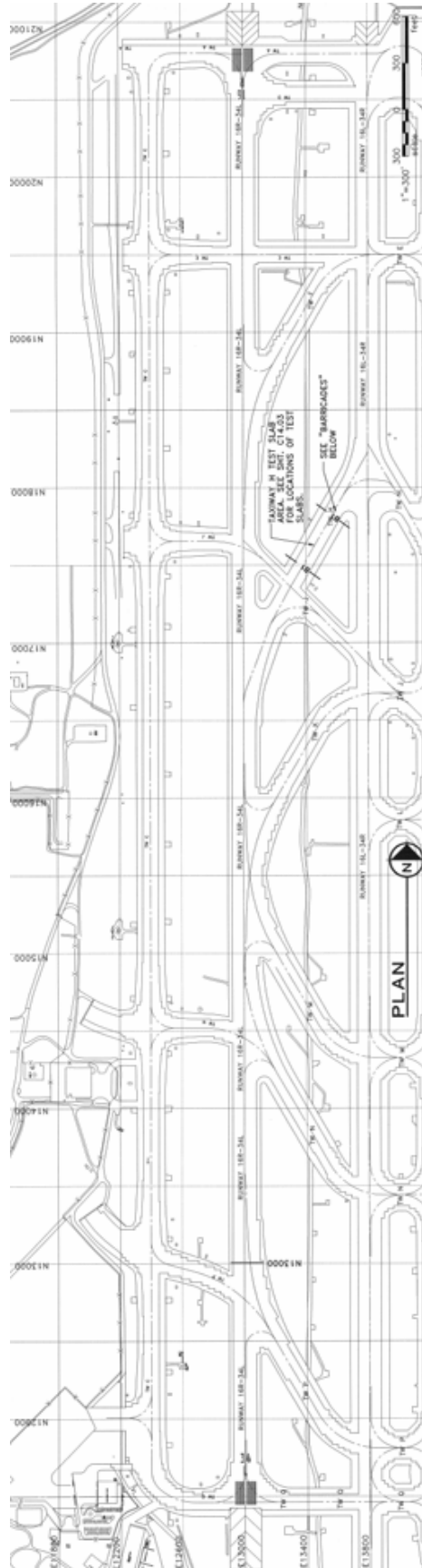


Figure A-30. Runway 16R-34L layout at Seattle-Tacoma International Airport.

## **Key Project Components**

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The key components in the success of this project are noted below:

- Cohesive team effort from owner/engineer, contractor, material supplier, airlines and airport operations to plan closures and develop contingency plans.
- Experience of team with methods and materials, which includes extensive research and development with the PCC mixtures.
- Demonstration of mix and construction methods prior to beginning runway construction.
- Innovations in removal methods and the use of temporary pre-cast panels to provide a temporary pavement surface.

Each of these aspects is discussed in more detail in this case study.

## **Planning**

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Having only two runways, Runway 16R-34L is critical to operations at Sea-Tac, particularly during poor weather. Thus, the runway has to remain operational during any rehabilitation work. Coordination of the slab replacement work with operations and the airlines was an essential element because it would require the temporary closure of the runway. It was decided that with reduced operations the available closure established for Runway 16R-34L would begin at 11:00 pm and could last until 6:30am the following morning.

Another consideration in scheduling the rehabilitation work was maintenance work on other facilities. So that work could be performed elsewhere on the airport, the contractor was allowed to replace slabs on the runway only 6 nights per week.

## **Design**

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The original pavement section consists of 14-inch thick PCC with 18-inch thickened edges at alternate longitudinal joints. The existing base is crushed aggregate with a nominal thickness of 10 inches. The rehabilitation design called for an 18-inch thick slab, which required the removal of 4 inches of the base aggregate. The typical joint spacings are 18.75 ft for longitudinal joints and 20 ft for transverse joints. All joints for replaced slabs are dowelled with 1.5-inch diameter dowels placed 15 inches on center. Several detail sheets for the slab replacements are included at the end of this case study.

The slabs selected for replacement are based on visual condition surveys. The POS surveys the runway to identify slabs that are unlikely to continue performing satisfactorily until the next year and then the year's project is developed based on these surveys.

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 from failed repairs due to the use of rapid setting materials was a risk the owner was willing to take.

The project plans and specifications defined the required quality, strengths, time constraints, and general methods of repair. For example, the specifications for the concrete mix required a 550 psi flexural strength in 5 hours and a 650 psi flexural strength at 28 days. However, much of the final mix design and construction methods were left to the contractor to determine; there was no specified slump, water/cement ratio, or minimum cement content. Project specifications for the P-503 material are included at the end of this case study.

Plans and specifications have evolved over the years as experience has been gained both by the POS and the contractor. The POS once specified the cement mix (Type I and Type III) in the specification, but it is now left to the contractor to provide a workable mix. Other items tried and changed are requiring relief cuts for slab removal and placing angle iron along the edges of existing slabs to remain in place to protect them from spalling during slab removal.

Although the plans and specifications do allow the contractor to determine a workable mix design and have control over construction methods, the POS requires an approved mix design and demonstration of the construction methods prior to beginning work on the runway. To develop a workable mix, the contractor performs a significant amount of materials research. Every year the rehabilitation work is performed the materials are evaluated to make sure the mix will work as expected. Cement is sole-sourced to ensure uniform quality; aggregates are crushed, double washed, and kept wet; and extensive mix testing is conducted to obtain temperature gain and time of set information. The contractor has found that the cement has changed over the years and this has required alterations to the mix design and placement times. The admixtures used have also changed, with earlier contracts using citric acid as a set retarder and commercially available admixtures used more recently. The contractor's goal is produce a 650 psi flexural strength in 4 hours. The current contractor owns and operates the ready-mix company that provides the concrete for the repair work and notes that having control over the mix design and production is a critical element in the success of the work.

To demonstrate construction methods, the POS identified several slabs on an adjacent taxiway that would need to be completed under the same time constraints as the runway. The contractor emphasized the need to be comfortable with the operation, familiar with the materials, and noted that a single test slab is not sufficient to evaluate the mix. By the time the construction was started on the runway, the entire team was well organized and prepared for the runway closure.

Several contingency plans are addressed in this project. Temporary pre-cast panels, discussed in more detail later, provided a quick pavement surface in case of the need for emergency re-opening of the runway or inability to place the new concrete slab within the allowed closure, such as a plant breakdown. The contractor was 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.

## **Construction**

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The experience of the contractor has played a key role in the success of this rehabilitation program. Although the current contractor was not involved with the rehabilitation program in the earliest years (over the years, three different contractors have done this work, each using their own techniques), the current contractor's experience and innovation with the materials and methods has resulted in the successful implementation of the slab rehabilitation program.

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. The existing slabs were typically sawcut into nine pieces during this step; a full-depth sawcut was made around the slab perimeter as well as the interior cuts. A key element to the sawcutting operations to ease panel removal was to slightly angle the interior sawcuts toward the center of the slab. Angling the sawcuts made it easier to lift out the center piece by helping to break the suction often encountered with slab removals. The pieces were then lifted out using mining anchors. The use of these anchors has proven to be instrumental in the pavement removal operations.

Once the existing pavement was removed, an additional 4 inches of the base material was excavated to make room for the 18-inch pavement. If unsuitable material was exposed during excavation, undercutting was performed. Once the base material was compacted, two alternatives existed: place temporary panels for reopening the runway or continue the preparation work for placing the concrete.

Temporary pre-cast panels had been constructed to act as temporary pavement to allow work to be performed over multiple nights. The pre-cast panels were 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. For non-standard slab sizes, temporary filler material (currently wood is being used) was placed to provide a uniform riding surface with no gaps. A unique feature of the pre-cast panels was the use of cast-in adjustable screw jacks to adjust the elevation of the panels and to provide a smooth riding surface. The drawing sheet for pre-cast panels is included at the end of this case study.

The pre-cast panels also provided a contingency should there be any problems (such as a plant breakdown, additional base preparation, or equipment failure) during construction. The contractor was required to have on hand sufficient pre-cast panels to replace all of the runway slabs that were being removed.

Holes were drilled and dowel bars were epoxied into the adjacent slabs. However, if the adjacent slab was sufficiently deteriorated, dowel bars were not installed. A POS representative was onsite to assist with determining whether or not to install dowel bars.

Placement of the concrete was time sensitive. Based on the materials research performed by the contractor prior to construction, temperature and set curves were established. Once the material reached an established temperature it had to be placed or it would set and become unworkable. Additionally, all of the material for each slab had to be onsite before placement began. If all of the material was not ready to be placed, a cold joint would form and the concrete would need to be removed. Although an onsite batch plant had been used at one time, the materials are now brought to the site from a nearby ready-mix plant. The key to transporting the concrete is to limit the batch size so that excessive heat does not cause early setting and to rotate the drum as slowly as possible during transit. To minimize delays in delivery, all vehicles are permitted for access to the AOA and all employees on the site are badged.

Placement of the material is by conventional methods, except that all tasks must be performed as quickly as possible. After the concrete is placed and the surface has set sufficiently, curing is performed using sprinklers. Water curing has proven to be the best method to minimize the potential for cracking due to the amount of heat generated. The repairs are typically sprayed with water for approximately 90 minutes after placement.

Slab replacement locations were planned such that the areas were far enough apart that the water from curing the slab in one location would not saturate the base material in an adjacent repair location. The contractor has also learned from experience that only one slab should be replaced at any location; two adjacent slabs require too much material to be placed at one time without having set, heat, and cracking problems.

Temporary pavement markings were painted on a weekly basis. At the end of the year's rehabilitation work, the new pavement was grooved, joint sealant installed, and permanent markings painted.

Concrete testing included air content, slump, and temperature (however, the applicability of the slump test with the rapid-set material is questionable). The concrete had a very high initial slump, but 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. Beam specimens were prepared (six beams per slab were required for acceptance) and broken at numerous times prior to opening to ensure that the required strength was achieved. Beams were also broken to determine the 28-day strength.

## **Other Issues**

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In-pavement lights were located in many of the slabs that were replaced. Additionally, the electrical conduit for many of the lights was located within the pavement joints. The POS allowed the temporary removal of light cans so that two runway lights and one light per taxiway lead-in could be out of service at any given time. However, the runway lights could not be adjacent lights and temporary connections had to be made by the time of reopening to keep the remaining lights operational.

During construction, the replacement work for slabs with lights followed the following general steps:

- Disconnect electrical wiring at adjacent locations.
- Remove slab with light can.
- Replace conduit, wiring, and light can.
- Place concrete for light can base at beginning of closure.
- Finish placing slab later in the closure.

If the replacement slab was not finished during the same closure then the wiring was temporarily reconnected after the base layer preparation and the pre-cast panels were placed until the following evening. After the temporary panels were removed the next evening the replacement work continued. The use of rapid set material allowed the light can bases to set sufficiently to allow the slab to be placed later the same night. Runway lighting details are included at the end of this case study.

Final acceptance and payment for the slab replacement work was made on a per slab basis. Payment factors were based on 70 percent for the flexural strength at the time of opening and 30 percent for the flexural strength requirement at 28 days, using the factors in tables A-6 and A-7 and the following formula:

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

Table A-6. *Opening Time Factor* for Pay Factor determination.

<b>Flexural Strength</b>	<b>Factor</b>
550 psi min.	1.00
540 – 549 psi	0.90
530 – 539 psi	0.80
520 – 529 psi	0.70
510 – 519 psi	0.60
500 – 509 psi	0.50
Below 500 psi	0.00

Table A-7. *28-Day Factor* for Pay Factor determination.

<b>Flexural Strength</b>	<b>Factor</b>
650 psi min.	1.00
640 – 649 psi	0.90
630 – 639 psi	0.80
620 – 629 psi	0.70
610 – 619 psi	0.60
600 – 609 psi	0.50
Below 600 psi	0.00



If the average flexural strength for opening was below 550 psi, placement was suspended until the deficiency was investigated and corrections were made. If the average flexural strength was less than 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 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, the slab replacement work was to be completed within 50 days. A penalty of \$3,000 per day was established for not completing the work within the 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.

## **Summary**

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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. A POS official's statement that "A project like this requires a lot of teamwork" highlights the efforts required to replace multiple slabs during a relatively short closure with using a material that provides little margin for error.

The project team does, however, caution the use of quick-setting materials. The POS stresses that the material is problematic and hard to use, and recommends that only an experienced contractor should be hired for this work. They point out that only the current contractor (one out of three) has had what they consider success. The contractor, even with the years of experience, also says that working with the material is nerve-wracking: "it looks like PCC but it isn't."

There have also been problems with the materials. Some of the earliest placed slabs have been replaced due to cracking. Some slabs have had 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.

Although there have been some durability issues with some of the replaced slabs, the repair work was always approached only as a temporary repair measure and 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.

## **Available Sources of Information**

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Interviews with several key individuals involved in this project were held at Seattle-Tacoma International Airport. The project team would like to acknowledge the valuable input and contributions of the following individuals for providing much of the information presented in this case study:

- Ray Rawe, Chief Engineer, Port of Seattle, Seattle-Tacoma International Airport
- John Rothnie, Airfield Program Manager, Port of Seattle, Seattle-Tacoma International Airport
- Brian Kittleson, Vice President, Gary Merlino Construction Co., Inc.

The following documents also provided valuable information used in this summary:

- Project plans and specifications.

**DIVISION 2 - SITE WORK**

**Section 02755 - Quick Setting High Early Strength Cement Concrete Pavement (FAA)**

**PART 1 - GENERAL**

Portland Cement Concrete (PCC) pavement, constructed on a prepared subgrade or subbase course, shall be provided in accordance with the provisions of FAA Item P-503, Quick Setting High Early Strength Cement Concrete Pavement, attached hereto.

**END OF SECTION**

ITEM P-503 QUICK SETTING HIGH EARLY STRENGTH CEMENT CONCRETE  
PAVEMENT

DESCRIPTION

- 503-1.1 This work shall consist of pavement composed of a quick setting high early strength concrete, with or without reinforcement, constructed on the new base course, after removal of the existing pavement. The work shall comply with applicable sections of the P-501 Specifications referenced herein, and shall conform to the lines, grades, thickness and typical cross sections shown on the drawings.
- 503-1.2 The provisions and intent of this contract, including the General Conditions, Supplementary Conditions and General Requirements, apply to the work as if specified in this section. Work related to this section is described in:
- A. Section 02220 - Demolition
  - B. Section 02330 - Excavation and Embankment (FAA)
  - C. Section 02724 - Crushed Aggregate Base Course (FAA)
  - D. Section 02754 - Portland Cement Concrete Pavement (FAA)
  - E. Section 02763 - Joint Sealing Filler (FAA)
  - F. Section 02766 - Airfield Marking (FAA)
  - G. Section 03200 - Concrete Reinforcement
  - H. Division 16 - Electrical

QUALITY ASSURANCE

- 503-1.3 **QUALITY ASSURANCE.**
- A. Sampling and testing for compliance with the Contract provisions shall be in accordance with Section 01451 – Quality Control: Testing Laboratory Services and as outlined in this section. The Contractor shall provide copies of the results of tests to the Resident Engineer. Tests conducted for the sole benefit of the Contractor shall be at the Contractor's expense.
  - B. **Qualification of the Testing Laboratory:** The Contractor's testing laboratory used to develop the concrete mix design and perform required tests, inspections and certifications as specified shall meet the requirements of ASTM C 1077, including accreditation. The laboratory accreditation will include ASTM C78. A certification that it meets these

requirements shall be submitted to the Engineer prior to the start of mix design and shall contain as a minimum:

1. Qualifications of personnel; laboratory manager, supervising technician and testing technicians.
2. A statement that the equipment used in developing the mix design is in calibration.
3. A statement that each test specified in developing the mix design is offered in the scope of the laboratory's services.
4. A copy of the laboratory's quality control system.

- C. **Qualification of Manufacturer:** Ready-mixed concrete plants shall be approved and certified by the NRMCA. Ready-mix concrete shall be batched in accordance with the applicable portions of ASTM C 94.

Portable batch plants shall meet the requirements of ASTM C 94, if utilized, shall be inspected and certified by a recognized independent testing laboratory selected and paid for by the Contractor. Copies of the inspection test report and certification shall be submitted to the Engineer prior to production of concrete for this project.

D. **Qualifications of Workmen:**

1. Provide at least one person, thoroughly trained and experienced in placing the types of concrete specified, who shall be present at all times during execution of this portion of the work and shall direct all work performed under this section.
2. Thoroughly trained and experienced journeyman concrete finishers shall be responsible for finishing of exposed surfaces.

**SUBMITTALS**

- 503-1.4 Submittals shall be as specified in Section 02754 Portland Cement Concrete Pavement, except as modified in Paragraph 503-3.5 of these specifications.

**MATERIALS**

503-2.1 **AGGREGATES:**

- A. **Reactivity:** as specified in Section 02754 - Portland Cement Concrete Pavement.
- B. **Fine Aggregate:** Fine aggregate for concrete shall conform to the requirements of ASTM C 33 and shall meet the requirements of Table 1, as specified in Section 02754 - Portland Cement Concrete Pavement, Paragraph 501-2.1B, with the exception of the following:

The Fineness Modulus of the Fine Aggregate shall be minimum of 2.95.

- C. **Coarse Aggregate:** As specified in Section 02754 - Portland Cement Concrete Pavement, Paragraph 501-2.1C.

503-2.2 **CEMENT:** Cement shall be one of the following:

Portland cement conforming to the requirements of ASTM C150, Type I, Type II or Type III.

“Rapid Set C-150 Cement” as manufactured by the CTS Cement Manufacturing Company, or an approved equal.

A combination of the above.

All cement of a particular type shall be the product of one manufacturer. If, for any reason, cement becomes partially set or contains lumps of caked cement, it shall be rejected. Cement salvaged from discarded or used bags shall not be used.

The cement listed above shall be capable of producing a quick setting, high early strength concrete with the following properties:

Development of flexural strength in excess of 550 psi, not later than 5 hours from the time water is added to the mix.

The mix setting time shall accommodate a placing and finishing time of 45 minutes, plus or minus 15 minutes.

503-2.3 **CEMENTITIOUS MATERIALS:** As specified in Section 02754 - Portland Cement Concrete Pavement, paragraph 501-2.3.

503-2.4 **ADMIXTURES:** As specified in Section 02754 - Portland Cement Concrete Pavement, Paragraph 501-2.4.

503-2.5 **WATER:** As specified in Section 02754 - Portland Cement Concrete Pavement, Paragraph 501-2.5.

- 503-2.6      **STEEL REINFORCEMENT:** Steel reinforcement, if required, shall meet the requirements of Section 03200.
- 503-2.7      **DOWEL BARS:** As specified in Section 02754 - Portland Cement Concrete Pavement, Paragraph 501-2.7.
- 503-2.8      **EPOXY MATERIAL FOR INSTALLING DOWELS:** As specified in Section 02754 - Portland Cement Concrete Pavement, Paragraph 501-2.8, with the following additional requirements:
- The curing time of the material used to install dowels is critical to the timeliness of the nightly construction operations. The material must have sufficient pot life to allow proper dowel installation, but must cure rapidly in each hole, to allow rapid placement of concrete without moving the dowels or disrupting the bond between the dowels, the epoxy material and the surrounding concrete. The epoxy gel material for the night work shall have a curing time of not more than one hour, at a temperature of not more than 80°F, unless the Contractor provides a means of holding the protruding dowels rigidly in place during concrete placement, or otherwise demonstrates construction procedures and timing for the dowel and concrete placement that are acceptable to the Engineer. The estimated curing time for the epoxy material at the lower temperatures anticipated within the existing concrete during the night work shall be provided by the manufacturer, and shall be considered in establishing the construction procedures and timing.
- 503-2.9      **MATERIAL FOR REPAIRING SPALLS:** The Spall patching material shall be P-503 Quick Setting High Early Strength Cement Concrete as specified in this specification.
- 503-2.10     **EPOXY MATERIAL FOR CORE HOLES:** As specified in Section 02754 - Portland Cement Concrete Pavement, Paragraph 501-2.9.
- 503-2.11     **PREMOLDED JOINT FILLER:** As specified in Section 02763 - Joint Sealing Filler.
- 503-2.12     **JOINT SEALER:** The sealer for joints in the concrete pavement shall meet the requirements of Section 02763 - Joint Sealing Filler.
- 503-2.13     **COVER MATERIAL FOR CURING:** The material shall be as specified in Section 02754 – Portland Cement Concrete Pavement paragraph 501-2.13.
- 503-2.14     **MATERIAL ACCEPTANCE:** As specified in Section 02754 - Portland Cement Concrete Pavement, Paragraph 501-2.14

#### MIX DESIGN AND TEST SECTIONS

- 503-3.1      **GENERAL:** As specified in Section 02754 - Portland Cement Concrete Pavement with the following addition:

A mix design shall be developed to allow for the construction of a minimum of two slabs per nightly workshift specified in the phasing plans. The mix design shall meet the criteria specified in paragraph 503-3.2.

This previous project experience with quick setting concrete mix designs at Sea-Tac showed a variability in the set time of the concrete mix and the cement material used. The Contractor shall develop a mix design and quality control program to allow adjustment in the procedures so the concrete mix that is used consistently meets the criteria specified at no cost to the Port.

503-3.2 **STRENGTH AND PROPORTIONS:** A mix design shall be developed by the Contractor to meet the following properties:

- A. The concrete mix shall achieve a minimum flexural strength of 550 psi within 5 hours of the time the water is added to the mix, and shall achieve a minimum flexural strength of 650 psi in 28 days.
- B. The concrete placed each night must attain the 550 psi flexural strength by the pavement opening time indicated on the phasing plans. If the Contractor's proposed paving operations require production of concrete at a time later than 5 hours before scheduled pavement opening, the mix shall be designed to attain the 550 psi by the required opening time.
- C. The concrete mix shall have set time of a minimum 30 minutes beyond the time established by the Contractor procedure to batch, transport and place the concrete mix at the work site. The set time shall be defined as the time at which the mix takes a set and no further surface finishing can be accomplished.

The proportions of the concrete mix shall be as developed by the Contractor to meet the specified criteria. There is no specified minimum cement content, slump, water/cement ratio or restriction on admixtures.

- D. The mix shall have a minimum durability factor of 95 when tested in accordance with ASTM C 666.

503-3.3 **CEMENTITIOUS MATERIALS:** Fly ash and silica fume may be used in the mix. Ground blast-furnace slag shall not be used.

503-3.4 **ADMIXTURES:** As specified in Section 02754 - Portland Cement Concrete Pavement, Paragraph 501-3.4 with the exception of the following:

Air Entraining: The average air content shall be 4.5 percent, plus or minus 1.0 percent, and the mix shall have a durability factor of 95 or more when tested in accordance with ASTM C 666. The durability factor shall be determined by a test of the actual concrete mix to be used on the project.



503-3.5 **MIX DESIGN DEVELOPMENT AND SUBMITTAL:** The Contractor shall develop a mix design that meets the criteria specified in paragraph 503-3.2. The process shall include the development of a minimum of three trial batches with decreasing water/cement ratios. The batches shall use the intended raw materials to be used for the project, including cement, fine and coarse aggregates, as well as chemical and mineral admixtures. The trial batch mixtures shall maintain the same fine aggregate/coarse aggregate ratios as well as the same proportions of intended admixtures; only the water/cement ratio shall be varied. The testing of the trial batches shall, at a minimum, include flexural strength, temperature development, air content and slump. Flexural beam tests and temperature development specimens shall be prepared in accordance with ASTM C 31, except that specimens shall be surrounded with insulative blankets for a minimum of 5 hours following addition of water to the mix. The mix design to be submitted for use on the project shall be one of the trial batches. Freeze-Thaw durability testing shall be required only on the specific mix design intended for use on the project.

- A. **Flexural Strength Testing:** The average of a minimum of two flexural strength test results shall be completed at 3 hours, 4 hours, 5 hours, 24 hours, and 28 days for each of the three trial batches. The results shall be plotted on a flexural strength versus water/cement ratio.
- B. **Temperature Development:** The trial batches shall be monitored for development of temperature from the time the water is added to the mix until an age of 5 hours at 15 minute intervals. The temperature of the water and other materials and the ambient temperature at the time of batching shall be recorded. The time at which the mix takes a set shall be recorded along with the corresponding temperature of the mix. The temperatures shall be taken with a thermometer accurate to within 0.5°F. The thermometer shall remain inserted in the curing sample throughout the period of testing. The temperature data shall be plotted for each trial batch, with temperature on the vertical scale and time on the horizontal. The set time of the mix shall be identified for each batch.
- C. **Freeze-Thaw Durability:** The mix intended for use on the project shall be tested for durability in accordance with ASTM C 666.
- D. **Mix Design Submittal:** The mix design submittal shall include the following minimum information:
  - 1. Type(s) of cement.
  - 2. Water/cement ratio
  - 3. Slump.
  - 4. Air Entrainment percentage.
  - 5. Flexural strength test results at 3, 4, 5, and 24 hours, and 28 days.
  - 6. Results of durability test in accordance with ASTM C 666.
  - 7. Temperature development of mixes and set time.

8. Plant/lab mix certification of proportion of materials.
9. Fine aggregate - Supplier, pit location, current gradation, fineness modulus, reactivity, absorption capacity and moisture content.
10. Coarse aggregate - Supplier, pit location, current gradation, LA wear, flat and elongation, fineness modulus, reactivity, specific gravity, absorption capacity, moisture content, and D-cracking.
11. Manufacturer's name, catalog information for the Cement(s), and admixtures used including ASTM certification Information.
12. Certification of Testing Laboratory designing the mix.

E. **Tentative Mix Design Approval:** When a mix design meeting all the specified criteria and documentation requirements have been met and approved by the Engineer, the mix design will be given tentative approval, subject to successful completion of the preliminary test section. Tentative approval may be granted prior to the receipt of the 28-day strength tests, if 650 psi flexural strength has been demonstrated at an earlier test period and prior to the freeze-thaw test.

F. **Full Mix Design Approval:** Full approval of the mix design will be granted when the following requirements have been met:

1. Successful completion of the Preliminary and Production Test Sections, including any modifications of the Tentatively Approved Mix Design,
2. Acceptable results from the 28-day strength tests,
3. Acceptable results from the freeze-thaw durability test.

503-3.6 **PRELIMINARY TEST SECTIONS:** Following tentative approval of the mix design, the Contractor shall construct a Preliminary Test Section, at a location designated by the Engineer. The purpose of the Preliminary Test Section is to demonstrate that the mix design meets all of the requirements in the specifications, in full-scale construction. The Preliminary Test Section may be constructed in daytime conditions, without the time and operating constraints that will exist for full production paving. However, the equipment and procedures shall be the same as for full production paving.

The test section location will be on a paved or unpaved area at Sea-Tac Airport, but not within the pavement replacement area of the project. The test slab shall be 20.00 feet long, 18.75 feet wide and 18 inches thick.

The concrete mix shall be tested for compliance with the test/data submitted as part of the mix design submittal. Failure to meet the specified flexural strength, set time or air entrainment percentage shall be cause for rejection of the mix design. The slump and temperature development of the field-tested mix shall be compared to the lab tested results to indicate the ability to replicate the mix design under field conditions. The Engineer for placement procedures, finish, cracking, etc will inspect the Preliminary Test Section.

If the Preliminary Test Section proves unsatisfactory, the necessary adjustments to the mix design, plant operations and/or placement procedures shall be made. An additional test section shall be completed at the Contractor's expense. Changes in the mix design will require resubmitted of the mix design in accordance with paragraph 503-3.5 prior to completing the additional test section. The Engineer may require the removal of the previous test section concrete prior to the proceeding with additional preliminary test sections.

503-3.7 **PRODUCTION TEST SECTIONS:** Following the Engineer's approval of a Preliminary Test Section, including any necessary adjustments of the mix design, equipment and procedures, the Contractor shall construct a Production Test Section, in the area designated on the drawings. The purpose of the Production Test Section is to demonstrate that the mix design, equipment, materials and procedures meet all requirements in the specifications, under the same time constraints, night working conditions and operating constraints that will exist for full production paving. The Production Test Section work shall include the removal of existing pavement, excavation, compaction of base course, placement and removal of temporary pavement panels, and the installation of dowels in adjacent slabs.

The test section location will be on an existing paved area, comparable to the actual pavement replacement area in the project. The test section will consist of at least one full-sized slab (20.00 ft. x 18.75 ft. x 18 in.). At the completion of the Production Test Section work, the test site must meet all requirements for opening the pavement to aircraft traffic and the concrete must attain a minimum flexural strength of 550 psi by the required pavement opening time. If the results of the Production Test Section are unsatisfactory in any respect, additional Production Test Sections shall be constructed, at the Contractor's expense, until all requirements of the Specifications have been met. The Engineer may require the removal of the previous test section(s) at the Contractor's expense.

#### CONSTRUCTION METHODS

503-4.1 **EQUIPMENT:** As specified in Section 02754 - Portland Cement Concrete Pavement, Paragraph 501-4.1, with the following additions:

- A. **Backup Equipment:** For pavement removal and replacement under night working conditions, the Contractor shall provide backup units for each item of equipment that is essential to the timely completion of each nights work. The backup equipment shall be itemized in the Contractor's work plan.
- B. **Grooving Equipment.** Equipment used in the performance of work shall be subject to the approval of the Engineer. Sufficient equipment shall be provided so as to complete the work as expeditiously as possible.

Self-propelled sawing or grinding equipment using either abrasive or diamond blades, which are suitable for the intended use, will be approved for groove cutting on proven performance. Equipment shall be capable of grooving the pavement surface according to the specified pattern and depth without damaging the pavement to remain.

At the beginning of each work shift, all grooving machines shall be equipped with a full complement of grooving blades that are capable of cutting grooves of the specified width, depth and spacing.

503-4.2 **FORM SETTING:** The concrete shall be placed and formed in accordance with one or more of the following, as applicable:

- A. Placement against Conventional Forms: As specified in Section 02754 - Portland Cement Concrete Pavement, Paragraph 501-4.2.
- B. Placement against the sides of precast temporary pavement panels, Portland cement concrete or asphalt pavement which will be removed in the project: A sheet of metal or plywood shall be placed vertically against the existing pavement, to serve as a form for the new P-503 concrete, as a bond breaker and as a protective buffer during the removal of the adjacent pavement.
- C. Placement against previously placed P-503 concrete slabs, or against other existing slabs which will remain: Unless the slabs are separated by expansion joint material, the sides of the adjacent concrete shall be sprayed with a debonding agent, approved by the Engineer, that will prevent bonding at the face of the joint. The prevention of bonding is critical to the prevention of cracking in the newly placed P-503 concrete.

503-4.3 **CONDITIONING OF UNDERLYING SURFACE, FOR SLIP-FORM CONSTRUCTION:** (Not applicable)

503-4.4 **CONDITIONING OF UNDERLYING SURFACE, FOR SIDE-FORM AND FILL-IN SLAB CONSTRUCTION:** The base shall be well moistened with water, without saturating, immediately ahead of concrete placement to prevent loss of moisture from the concrete. Depressions in the base or dislodged base material resulting from placement and removal of precast temporary panels, or from other causes, shall be smoothed out and recompact to provide a uniform, stable surface for placing the permanent concrete. The grade of the base course shall be rechecked with an approved template to insure that the minimum specified thickness of permanent concrete can be achieved throughout each newly placed slab. The elevations of the finished base course shall be properly recorded at sufficient locations (grid pattern not exceeding five foot spacing) in each slab in order to establish the depth of the new concrete slab. All excess material shall be removed. Low areas may be filled and compacted to a condition similar to that of the surrounding grade, or filled in with concrete integral with the pavement.

- 503-4.5      **HANDLING, MEASURING AND BATCHING MATERIAL:** As specified in Section 02754 - Portland Cement Concrete Pavement, Paragraph 501-4.5.
- 503-4.6      **MIXING CONCRETE:** As specified in Section 02754 - Portland Cement Concrete Pavement, Paragraphs 501-4.6.
- 503-4.7      **LIMITATIONS OF MIXING:** As specified in Section 02754 - Portland Cement Concrete Pavement, Paragraph 501-4.7 with the following exceptions and additions:
- A.      Portable Lighting Units sufficient for control and observation of the work shall be in position at the concrete placement site prior to mixing concrete each night. In addition, adequate lighting shall be provided at the batch plant to facilitate quality control and safe operations.
  - B.      Concrete shall be mixed only in quantities which are required for immediate use and can be placed and finished prior to final setting of the concrete.
  - C.      Unless authorized in writing by the Engineer, mixing and concreting operations shall be discontinued when a descending air temperature reaches 40°F and shall not be resumed until an ascending air temperature reaches 35°F.
  - D.      To compensate for cool temperatures and to enhance early concrete curing and strength gain, the Engineer may require the water and/or aggregates to be heated to not less than 70° F.
- 503-4.8      **PLACING CONCRETE:** As specified in Section 02754 - Portland Cement Concrete Pavement, Paragraph 501-4.8, with the following exceptions and additions:
- A.      Slip-forming is not an acceptable method for placement of the concrete covered by these specifications.
  - B.      The Contractor shall use all means necessary to protect concrete materials before, during and after installation and to protect the installed work and materials of all other trades such that final conditions will be as specified. In the event of damage, immediately make all repairs and replacements necessary, to the satisfaction and approval of the Engineer and at no additional cost to the Port.

- C. The concrete shall be deposited on the moistened base in a manner, which requires as little rehandling as possible. Unless truck mixers, truck agitators, or non-agitating hauling equipment is equipped with means for discharge of concrete without segregation of the materials, the concrete shall be unloaded into an approved spreading device and mechanically spread to prevent segregation of the materials. Necessary hand spreading shall be done with shovels--not rakes. Workmen shall not be allowed to walk in the freshly mixed concrete with boots coated with foreign substances.
- D. Concrete shall be thoroughly consolidated against and along the faces of all adjacent slabs and along the full length and on both sides of all joint assemblies by means of vibrators inserted in the concrete. Vibrators shall not be permitted to come in contact with a joint assembly, the base or adjacent slabs. In no case shall a vibrator be operated longer than 15 seconds in any one location, nor shall they be used to move concrete. The Contractor shall demonstrate that the method of vibration he chooses to use will properly consolidate the concrete and shall not build up excessive slurry on the surface.
- E. Concrete shall be deposited on or as near to joint assemblies as possible, without disturbing them.

- 503-4.9 **STRIKE-OFF OF CONCRETE AND PLACEMENT OF REINFORCEMENT:** As specified in Section 02754 - Portland Cement Concrete Pavement, Paragraph 501-4.9.
- 503-4.10 **JOINTS:** As specified in Section 02754 - Portland Cement Concrete Pavement, Paragraph 501-4.10, excluding provisions for slip-form construction, which are not applicable. Prior to placing the new concrete, the existing concrete faces shall be sprayed with an approved debonding agent to prevent bond of new concrete to the existing concrete.
- 503-4.11 **FINAL STRIKE-OFF, CONSOLIDATION AND FINISHING:** As specified in Section 02754 - Portland Cement Concrete Pavement, Paragraph 501-4.11.
- 503-4.12 **SURFACE TEXTURE:** As specified in Section 02754 - Portland Cement Concrete Pavement, Paragraph 501-4.12.
- 503-4.13 **SKID RESISTANT SURFACES:** A skid resistant surface shall be provided by saw-cut grooving of the hardened runway replacement slabs, as shown on the drawings.

The grooves shall be transverse saw-cut in the pavement forming a 1/4 inch by 1/4 inch by 1-1/4 inches configuration. The grooves shall be continuous for the entire area. The grooves shall be saw-cut as indicated on the drawings. The tolerances for the saw-cut grooves shall meet the following:



Alignment tolerance:

Plus or minus 1-1/2 inches in alignment for 75 feet.

Groove tolerance:

Minimum depth 3/16 inch.  
Maximum depth 5/16 inch.  
Minimum width 1/4 inch.  
Maximum width 5/16 inch.

Center-to-center spacing:

Minimum spacing 1-3/8 inches.  
Maximum spacing 1-5/8 inches.

Saw-cut grooves shall not be closer than 3 inches to transverse paving joints or exceed 6 inches. Grooves may be continued through longitudinal construction joints. Grooves shall be stopped 24 inches from in-pavement fixtures.

- A. Test Section: The Contractor shall complete a test section of pavement grooving as and where directed by the Engineer, to demonstrate that the equipment proposed to be used shall provide the specified configuration within the prescribed tolerances before approval is given to commence the pavement grooving.
- B. Curing: Prior to grooving, the cement concrete pavement must have cured a minimum of 14 days, or as directed by the Engineer, to permit the construction of a clean, neat grooving pattern and cross-section, free of raveling and tearing.
- C. Clean-up: Debris and residue from the grooving operation shall be removed promptly. Waste material from cutting and grooving shall not be permitted to accumulate or build-up along the edges of the pavement surfaces. Before the close of each workshift, the surface shall be free of all loose material. Cleanup operations shall commence within one hour after the grooving operation and at no time shall large areas requiring cleanup exist. At the scheduled time to end each workshift, all cleanup shall have been completed and the surface shall be in an acceptable condition for aircraft operations.

The waste material generated during the grooving operation shall be collected by either sweeping or vacuuming. No waste material shall be allowed to enter the non-paved area or storm drain system. Waste material collected during the grooving operation shall be properly disposed of off Port property.

- 503-4.14 **CURING:** The initial method of curing, to begin immediately after the finishing and set of the pavement surface, shall be water curing. The entire surface shall be kept continuously moist by sprinkling for at least 2 hours, or longer if recommended by the cement manufacturer or mix designer.
- 503-4.15 **REMOVING FORMS:** As specified in Section 02754 - Portland Cement Concrete Pavement, Paragraph 501-4.15, with the following addition:
- No forms shall be removed from P-503 concrete until the night after concrete placement.
- 503-4.16 **SEALING JOINTS:** As specified in Section 02754 - Portland Cement Concrete Pavement, Paragraph 501-4.16.
- 503-4.17 **PROTECTION OF PAVEMENT:** As specified in Section 02754 - Portland Cement Concrete Pavement, Paragraph 501-4.17.
- 503-4.18 **OPENING TO TRAFFIC:** The Engineer shall decide when the pavement will be opened to traffic. The flexural strength of the permanent concrete required for opening the pavement to normal airport traffic (vehicles and aircraft) is 550 psi, based on testing in accordance with ASTM C78.
- In addition to the above requirements, all equipment, materials and debris shall be removed and the pavement in the immediate work area shall be cleaned by the Contractor to the satisfaction of the Engineer prior to each pavement opening.
- 503-4.19 **REPAIR, REMOVAL, REPLACEMENT OF SLABS:** As specified in Section 02754 - Portland Cement Concrete Pavement, Paragraph 501-4.19.
- 503-4.20 **EXISTING CONCRETE PAVEMENT REMOVAL AND REPAIR:** As specified in Section 02754 - Portland Cement Concrete Pavement, Paragraph 501-4.20.

#### MATERIAL ACCEPTANCE

- 503-5.1 **ACCEPTANCE SAMPLING AND TESTING:** Concrete samples shall be furnished by the Contractor and shall be taken in the field by the Engineer to determine the consistency, air content and strength of the concrete. Six flexural test beams shall be made for each concrete slab placed two beams will be tested at 5 hour age, two beams will be tested at the time of opening to represent the opening strength of the slab and two beams will be tested at 28 days. The specimens shall be made in accordance with ASTM C 31. Each group of two test beams shall be molded from the same batch of concrete.
- A. The flexural strength of the concrete shall meet the following requirements:



For each concrete slab placed, the average strength of the concrete tested shall be not less than 550 psi at the time the pavement is scheduled for opening to normal airport traffic.

For each concrete slab placed, the average strength of the concrete tested at an age of 28 days shall be not less than 650 psi.

- B. Specimens which are obviously defective shall not be considered in the determination of strength. The specimens with the least imperfections shall be used for the earliest tests.
- C. Final acceptance and payment will be based only on the OPENING TIME and 28 DAY strengths, with the following exception: If the OPENING TIME strength of any lot of concrete is 650 psi or more, the pay factor for that lot shall be 1.0, regardless of the 28 DAY strength.
- D. The pay factor for each slab placed shall be established on the basis of both the OPENING TIME and the 28 DAY-strength test results, according to the following formulas and tables:

$$\text{PAY FACTOR} = (0.7 \times \text{OPENING TIME FACTOR}) + (0.3 \times \text{28 DAY FACTOR})$$

**TABLE 1: OPENING TIME FACTOR**

<u>Flexural Strength</u>	<u>Factor</u>
550 psi min.	1.00
540 to 549 psi	.90
530 to 539 psi	.80
520 to 529 psi	.70
510 to 519 psi	.60
500 to 509 psi	.50
Below 500 psi	.00

**TABLE 2: 28-DAY FACTOR**

<u>Flexural Strength</u>	<u>Factor</u>
650 psi min.	1.00
640 to 649 psi	.90
630 to 639 psi	.80
620 to 629 psi	.70
610 to 619 psi	.60
600 to 609 psi	.50
Below 600 psi	.00

If the average OPENING TIME strength for any lot is below 550 psi, concrete placement shall be suspended until the deficiency is investigated and corrections acceptable to the Engineer are made. The corrections which the Engineer shall

have the right to require include additional test strips using the current mix, changes to the mix, and establishing an earlier nightly time deadline for final batching and placement of concrete.

Closure of the pavement beyond the scheduled opening time, due to concrete strength deficiencies or other concrete deficiencies, will subject the Contractor to liquidated damages as specified in Document 00800 - Supplementary Conditions.

If the average OPENING TIME strength for any lot is less than 500 psi, the Contractor shall remove and replace the concrete at his own expense.

If the average 28 DAY strength for any lot is less than 600 psi, regardless of the OPENING TIME strength, the Contractor shall remove and replace the concrete at his own expense.

503-5.2 ACCEPTANCE CRITERIA:

- A. **Flexural Strength:** Acceptance based on flexural strength shall be as specified in Paragraph 503-5.1.
- B. **Thickness:** The existing base course will be partially excavated, regraded and compacted prior to placement of precast temporary panels. The depth to the top of the base course from the surface of the existing pavement shall be measured on a grid pattern and recorded. The temporary panels will be equal in thickness to the permanent slabs and will be installed to match the surface elevations of the new pavement. After removal of the temporary slabs, the base will be rechecked with a template and irregularities will be corrected for each slab prior to placement of permanent concrete. This procedure will insure that the minimum specified thickness of the permanent concrete is achieved throughout each slab. Therefore, no coring or acceptance criteria for out-of-tolerance pavement thicknesses are necessary.
- C. **Smoothness:** Acceptance for smoothness shall be as specified in Section 02754 - Portland Cement Concrete Pavement, Paragraph 501-5.2E(3).
- D. **Grade.** Acceptance for grade shall be as specified in Section 02754 - Portland Cement Concrete Pavement, Paragraph 501-5.2E(4).
- E. **Dowel Bar Alignment.** Acceptance for grade shall be as specified in Section 02754 - Portland Cement Concrete Pavement, Paragraph 501-5.2E(6).

CONTRACTOR QUALITY CONTROL

503-6.1 **QUALITY CONTROL PROGRAM:** As specified in Section 02754 - Portland Cement Concrete Pavement, Paragraph 501-6.1.

503-6.2 **QUALITY CONTROL TESTING:** As specified in Section 02754 - Portland Cement Concrete Pavement, Paragraph 501-6.2, with the following additions:

**Set Time:** The set time of the cement and concrete mix shall be tested nightly for compliance with the set time of the approved concrete mix.

**Temperature Development:** The concrete mix shall be monitored for temperature development of the curing mix from when the water is added to the mix until 5 hours cure. Specimens shall be taken in accordance with ASTM C 31 and cured surrounded with insulative blankets. The temperature shall be recorded at 15 minute intervals in accordance with requirements of 503-3.5B.

503-6.3 **CONTROL CHARTS:** As specified in as specified in Section 02754 - Portland Cement Concrete Pavement, Paragraph 501-6.3, with the following additions:

**Additional Control Charts:** In addition to the control charts for fine and coarse aggregate gradation, slump, air content, the Contractor shall maintain linear charts for concrete set time and temperature development.

**Set Time:** The Contractor shall maintain linear control charts for set time of the concrete mix. The Action Limit shall be defined as  $\pm 15$  minutes from the set time of the approved mix. The Suspension Limit shall be as defined as  $\pm 30$  minutes.

**Temperature Development:** The Contractor shall maintain a linear control chart of the temperature development of the concrete mix. The Action Limit and Suspension Limit shall be defined as a  $\pm 15$  minutes and  $\pm 30$  minutes, respectively from the temperature development versus time curve of the original mix design submittal.

503-6.4 **CORRECTIVE ACTION:** As specified in as specified in Section 02754 - Portland Cement Concrete Pavement, Paragraph 501-6.4, with the following additions:

**Set Time and Temperature Development:** The Contractor shall halt production and make appropriate adjustments whenever:

1. One point falls outside the Suspension Limit line, or
2. Two points in a row fall outside the Action Limit line.

#### METHOD OF MEASUREMENT

- 503.7.1 “Quick Setting High Early Strength Cement Concrete - Mix Design Development and Test Sections” will be measured as a lump sum unit.
- 503-7.2 The quantity of “Quick Setting High Early Strength Cement Concrete Pavement” shall be measured by the number of square yards of pavement in place, completed and accepted, per the criteria specified in Paragraph 503-5.2, excluding pavement constructed as part of test sections.
- 503.7.3 “Pavement Grooving” shall be measured by the number of square yards.

**BASIS OF PAYMENT**

- 503.8.1 Payment for “Quick Setting, High Early Strength Cement Concrete Mix Design Development and Test Sections” will be made at the contract lump sum price stated in the Schedule of Unit Prices-C, regardless of the number of preliminary and production test sections required. The lump sum price shall be full compensation for furnishing all labor, materials, tools, equipment and testing to develop an approved mix design and complete preliminary and production test sections as required prior to starting full production paving. Required safety provisions, demolition of existing pavement, common excavation, required electrical work, including installation of new light bases, and all incidentals shall be part of the lump sum bid item price.
- 503-8.2 Payment for “Quick Setting, High Early Strength Cement Concrete Pavement” will be made at the contract unit price per square yard as stated in the Schedule of Unit Prices-C, and shall be full compensation to provide all materials, equipment, labor and tools to complete the work as described herein and shown on the drawings. The unit price shall include dowels, joint sawing, and sealing, curing, daily lifting, transporting, placement and relocating of the precast temporary panels.
- 503-8.3 **PRICE ADJUSTMENT:** The pay factor for each lot shall be determined as specified in Paragraph 503-5.1. If the pay factor for a lot of concrete is less than 1.0, payment for the material in that lot shall be made at a reduced price, arrived at by multiplying the contract price per square yard by the appropriate pay factor.
- 503-8.4 “Pavement Grooving” shall be paid for at the contract unit price per square yard as stated in the Schedule of Unit Prices-C and shall be full compensation for furnishing all labor, material, tools, equipment to complete the saw-cut grooves as shown on the drawings and described herein, including clean-up, disposal and all incidentals.

**ITEM P-503 QUICK SETTING HIGH EARLY STRENGTH CEMENT  
CONCRETE PAVEMENT (CONTINUED)**

**FAA**

503-8.5 Payment will be made under:

**RW 16R-34L SLAB REPLACEMENT  
SCHEDULE OF UNIT PRICES - C**

Quick Setting High Early Strength Cement Concrete – Mix Design Development and Test Sections -	lump sum
Quick Setting High Early Strength Cement Concrete Pavement -	per square yard
Pavement Grooving –	per square yard.

**TESTING REQUIREMENTS**

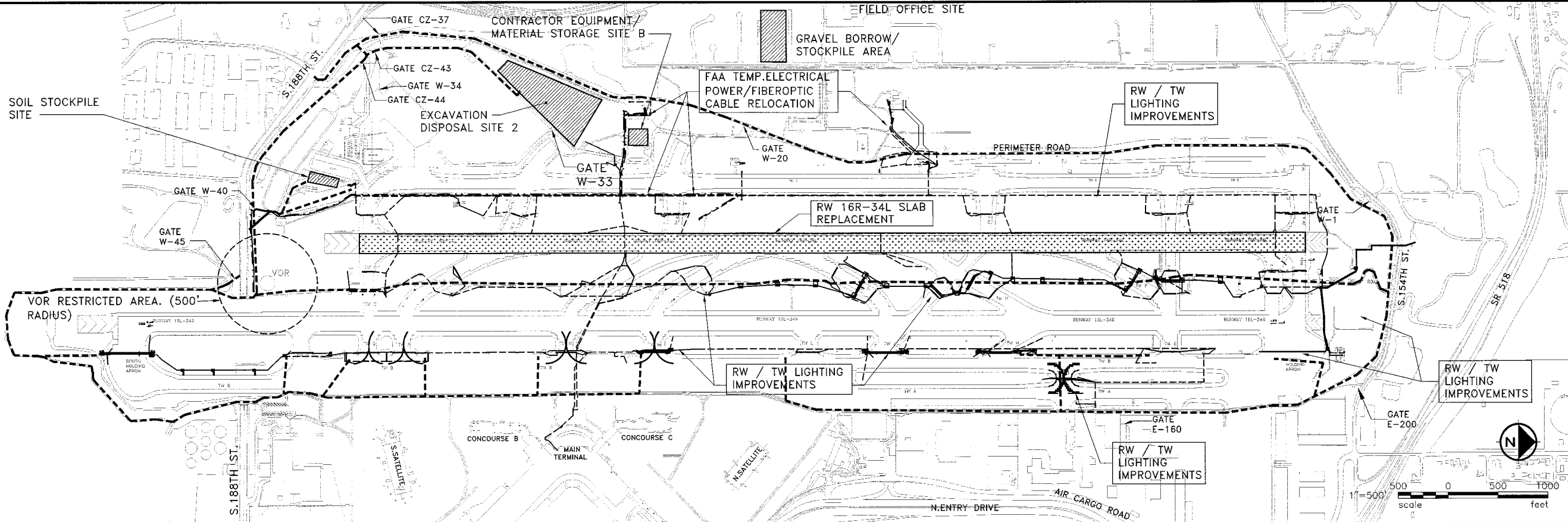
As specified in as specified in Section 02754 - Portland Cement Concrete Pavement.

**MATERIAL REQUIREMENTS**

As specified in as specified in Section 02754 - Portland Cement Concrete Pavement.

<b>END OF ITEM P-503</b>
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dwg : 04-17-2003 Title : 11:15  
Date : 04-17-2003  
Dwg : 04-17-2003 CONTRACTOR: LWS GENERAL (0002.DWG) Xref : AOA-BKG0, dcor-dcor



#### GENERAL PHASING REQUIREMENTS

ALL WORK SHALL BE COMPLETED WITHIN THE CONTRACT TIME OUTLINED IN THE SPECIFICATIONS. A GENERAL DESCRIPTION OF THE WORK INCLUDED IN THE CONTRACT INCLUDES BUT IS NOT LIMITED TO:

- \* EROSION AND SEDIMENTATION CONTROL
- \* DEMOLITION OF EXISTING AND CONSTRUCTION OF NEW PORTLAND CEMENT CONCRETE PAVEMENT
- \* DEMOLITION OF EXISTING AND CONSTRUCTION OF NEW ASPHALT CONCRETE PAVEMENT
- \* EXISTING UTILITY DEMOLITION, MODIFICATIONS AND CONSTRUCTION.
- \* JOINT SEALING AND PAVEMENT MARKING
- \* NEW AND MODIFICATION TO EXISTING ELECTRICAL, AIRFIELD LIGHTING AND COMMUNICATION SYSTEMS, DUCTBANKS AND STRUCTURES

FOLLOWING ARE THE GENERAL REQUIREMENTS FOR ALL WORK ON THIS PROJECT. THE PHASING PLANS SPECIFICALLY OUTLINE CONSTRUCTION TIME PERIODS AND ADDITIONAL PHASING REQUIREMENTS.

#### WORKING HOURS:

**TAXILANE OBJECT FREE AREA:** ANY WORK THAT IS WITHIN 138 FEET OF THE CENTERLINE OF A TAXILANE REQUIRES CLOSURE OF THAT TAXILANE. UNLESS OTHERWISE INDICATED, ANY WORK REQUIRING CLOSURE OF A TAXILANE SHALL BE PERFORMED DURING OFF-PEAK AIRCRAFT TRAFFIC PERIODS (OFF-PEAK HOURS), BETWEEN THE HOURS OF 2300-0630. SEE "OPERATING CONDITIONS AND SAFETY" FOR TAXILANE CLOSURE RESTRICTIONS.

**TAXIWAY OBJECT FREE AREA:** ANY WORK THAT IS WITHIN 160 FEET OF THE CENTERLINE OF A TAXIWAY REQUIRES CLOSURE OF THAT TAXIWAY. UNLESS OTHERWISE INDICATED, ANY WORK REQUIRING CLOSURE OF A TAXIWAY SHALL BE PERFORMED DURING OFF-PEAK AIRCRAFT TRAFFIC PERIODS (OFF-PEAK HOURS), BETWEEN THE HOURS OF 2300-0630. SEE "OPERATING CONDITIONS AND SAFETY" FOR TAXIWAY CLOSURE RESTRICTIONS.

**TAXIWAY / TAXILANE CONSTRUCTION SAFETY AREA (TCSA):** ANY WORK THAT IS WITHIN 136 FEET OF THE CENTERLINE OF A TAXIWAY OR TAXILANE REQUIRES CLOSURE OF THAT TAXIWAY OR TAXILANE. UNLESS OTHERWISE INDICATED, ANY WORK REQUIRING CLOSURE OF A TAXIWAY OR TAXILANE SHALL BE PERFORMED DURING OFF-PEAK AIRCRAFT TRAFFIC PERIODS (OFF-PEAK HOURS), BETWEEN THE HOURS OF 2300-0630. SEE "OPERATING CONDITIONS AND SAFETY" FOR RUNWAY, TAXIWAY AND TAXILANE CLOSURE RESTRICTIONS.

**RUNWAY SAFETY AREA (RSA) AND RUNWAY CONSTRUCTION SAFETY AREA (RCSA):** UNLESS OTHERWISE INDICATED, ANY WORK THAT IS WITHIN 250 FEET OF THE CENTERLINE OF A RUNWAY (THE RSA) REQUIRES CLOSURE OF THAT RUNWAY. ANY WORK REQUIRING CLOSURE OF A RUNWAY SHALL BE PERFORMED DURING OFF-PEAK AIRCRAFT TRAFFIC PERIODS (OFF-PEAK HOURS), BETWEEN THE HOURS OF 2300-0630. SEE "OPERATING CONDITIONS AND SAFETY" FOR ADDITIONAL RUNWAY CLOSURE RESTRICTIONS. AT NO TIME SHALL BOTH RUNWAYS BE CLOSED SIMULTANEOUSLY. ONLY ONE RUNWAY MAY BE SCHEDULED CLOSED PER NIGHT. NO RUNWAY SHALL BE SCHEDULED CLOSED FOR MORE THAN 6 NIGHTS PER WEEK. UNLESS SPECIFICALLY REQUIRED, RW 16L-34R SHALL NOT BE SCHEDULED CLOSED ON SATURDAY PM THROUGH SUNDAY AM.

WHEN ALLOWED AS PART OF THE CONTRACT, AND AS MAY BE INCLUDED ON THE INDIVIDUAL PHASING PLANS, THE CONTRACTOR MAY WORK UP TO 200 FEET OF THE RUNWAY CENTERLINE (THE RCSA) WITHOUT REQUIRING CLOSURE OF THE RUNWAY. WORK HOURS AND ALL OTHER RESTRICTIONS ARE AS OUTLINED ABOVE OR AS INDICATED ON THE INDIVIDUAL PHASING PLANS.

**WORK OUTSIDE OF SAFETY AREAS:** UNLESS OTHERWISE INDICATED, WORK OUTSIDE OF BUT

ADJACENT TO A RUNWAY SAFETY AREA, RUNWAY CONSTRUCTION SAFETY AREA, AND/OR A TAXIWAY/TAXILANE CONSTRUCTION SAFETY AREA IS NOT RESTRICTED TO OFF-PEAK HOURS. ACCESS TO OR FROM THE WORKSITES ACROSS ANY ACTIVE SURFACE WILL BE SUBJECT TO RECEIVING CLEARANCE TO CROSS THAT SURFACE. NO CONTRACTOR CROSSINGS OF ACTIVE RUNWAYS WILL BE ALLOWED.

**SCHEDULING AND DAILY OPERATIONS:** SEA-TAC HAS OVER 1400 OPERATIONS PER DAY. BETWEEN THE HOURS OF 0600 TO 2200, THERE ARE 30 TO 75 OPERATIONS PER HOUR. EACH OPERATION REQUIRES ACCESS ALONG EXISTING APRONS, TAXILANES AND TAXIWAYS TO GET TO AND FROM THE PASSENGER GATES, CARGO FACILITIES, OR HANGARS. IF THE CONTRACTOR MUST ACCESS AND CROSS THESE AREAS, LONG WAITING PERIODS MAY RESULT DUE TO THE DAY TO DAY OPERATIONS OF THE AIRPORT. THE CONTRACTOR SHOULD CONSIDER THIS A PART OF WORKING AT AN ACTIVE AIRPORT AND INCLUDE IT IN THE BID PRICE. AIRCRAFT OPERATIONS AND SAFETY HAVE PRIORITY AND THE CONTRACTOR IS MADE AWARE THAT THIS WILL AFFECT HIS NEED FOR TIMELY CROSSINGS OF THE APRONS, TAXILANES AND TAXIWAYS. THE CONTRACTOR SHALL SCHEDULE WITH AIRPORT OPERATIONS, BY WAY OF THE ENGINEER, POSSIBLE WINDOWS OF TIME WHERE AIRCRAFT OPERATIONS WILL MINIMALLY AFFECT CROSSINGS. THIS IS PARTICULARLY IMPORTANT FOR DELIVERY OF MATERIALS THAT ARE TIME SENSITIVE, I.E. PCPC, ACP.

FOR WORK ON THE AOA, THE CONTRACTOR SHALL NOT SCHEDULE ANY HAULING OF DEMOLISHED PAVEMENTS, CRUSHED AGGREGATE BASE COURSE, ASPHALT PAVEMENT OR PORTLAND CEMENT CONCRETE PAVEMENT BETWEEN THE HOURS OF 0530-0900.

**CONDITIONS REQUIRED TO START:** THE CONTRACTOR MUST HAVE THE FOLLOWING PRIOR TO STARTING ANY WORK ON THE AOA:

- \* AN ACCEPTED WORK SCHEDULE.
- \* ON-SITE CABLE LOCATING COMPANY AVAILABLE.
- \* APPROVED CABLE SPLICING EQUIPMENT/MATERIALS AND CERTIFIED CABLE SPLICERS AVAILABLE ON A 24-HOUR/DAY BASIS FOR EMERGENCY REPAIRS.
- \* CONTRACTORS EROSION CONTROL PLAN (CECS) SUBMITTED AND APPROVED.
- \* AIRCRAFT AND VEHICLE MOVEMENTS ON TEMPORARY ROUTES ESTABLISHED (SEE "OPERATING CONDITIONS AND SAFETY").
- \* NOTICE TO AIRMEN (NOTAM) FILED BY THE PORT OF SEATTLE.
- \* 72-HOUR NOTICE PRIOR TO REQUIRING ANY CLOSURE OR REROUTING OF RUNWAYS, TAXIWAYS OR TAXILANES.

IN ADDITION TO THE REQUIREMENTS OUTLINED IN THE SPECIFICATIONS, THE CONTRACTOR MUST HAVE THE FOLLOWING PRIOR TO STARTING ON THE SPECIFIC ITEMS OF WORK LISTED:

- \* APPROVED P501 CONCRETE PAVEMENT MIX DESIGNS BEFORE STARTING ANY P501 PAVEMENT WORK.
- \* APPROVED P503 CONCRETE PAVEMENT MIX DESIGNS BEFORE STARTING ANY P503 PAVEMENT WORK.
- \* APPROVED ASPHALT CONCRETE PAVEMENT (ACP) MIX DESIGNS BEFORE STARTING ANY ACP WORK.
- \* APPROVED PIPE/UTILITY MATERIALS BEFORE INSTALLING ANY PIPE OR UTILITY MATERIALS.
- \* APPROVED LIGHTING/POWER/COMMUNICATION EQUIPMENT/MATERIALS BEFORE ANY LIGHTING/POWER/COMMUNICATION WORK BEGINS.

REFER TO INDIVIDUAL PHASING SHEETS FOR ANY ADDITIONAL REQUIREMENTS.

**CLOSURE RESTRICTIONS:** TO MAINTAIN ACCEPTABLE OPERATIONAL LEVELS AND SAFETY, THE FOLLOWING RESTRICTIONS ARE MANDATORY:

A. DURING LOW-VISIBILITY OPERATIONS (DAY OR NIGHT), THE CONTRACTOR WILL NOT BE ALLOWED ON THE AOA. THE PORT WILL NOTIFY THE CONTRACTOR BY 6:00 P.M. (1800) IF THE OFF-PEAK HOUR CONSTRUCTION SCHEDULED THAT NIGHT WILL BE STOPPED/

SUSPENDED DUE TO UNSUITABLE WEATHER.

B. ANY CLOSURES REQUIRED OF TAXIWAYS, TAXILANES, APRONS OR RUNWAYS SHALL BE SCHEDULED AND COORDINATED WITH CLOSURES REQUIRED BY OTHER CONTRACTORS COMPLETING WORK WITHIN THE AIRFIELD AREA. SEE "WORK BY OTHERS". FOR ADDITIONAL RESTRICTIONS SEE THE SPECIFIC PHASING PLANS.

**NAVAIDS AND FAA FACILITIES:** AS INDICATED ON THE EXISTING CONDITIONS PLAN, THERE ARE FAA EQUIPMENT, MANHOLES, DUCTBANKS, CABLES, ETC. LOCATED WITHIN AND ADJACENT TO THE WORK AREAS. UNDER NO CIRCUMSTANCES SHALL THESE FACILITIES/EQUIPMENT BE DISTURBED OR SERVICE DISRUPTED.

THE CONTRACTOR SHALL LOCATE ALL FAA UTILITIES (OPERATIONAL AND ABANDONED) IN THE AREAS 14 DAYS PRIOR TO STARTING EXCAVATION, DEMOLITION OR EARTHWORK. MAKE ARRANGEMENTS THROUGH THE ENGINEER'S OFFICE TO INFORM THE FAA OF ANY CABLEING/EQUIPMENT THAT WILL BE AFFECTED ON A WEEKLY BASIS. ANY SHUTDOWN OF FAA POWER OR SIGNAL CABLES SHALL BE MADE THROUGH THE ENGINEER'S OFFICE AT LEAST 72 HOURS IN ADVANCE OF THE SHUTDOWN. THE CONTRACTOR SHALL BE AWARE THAT THE FAA WILL WANT TO VERIFY THE LOCATIONS AND TYPE OF CABLE PRIOR TO ANY DEMOLITION OR EXCAVATION WORK AROUND THESE AREAS.

**LIGHTING/UTILITIES:** EXISTING AIRFIELD LIGHTING AND UTILITY LINES IN THE WORK AREAS AND AT THE STORAGE SITES SHALL REMAIN IN OPERATION EXCEPT THOSE DESIGNATED REMOVED, MODIFIED OR REPLACED ON THE PLANS. THE CONTRACTOR SHALL LOCATE ALL EXISTING UTILITIES (OPERATIONAL AND ABANDONED) 14 DAYS PRIOR TO STARTING WORK IN AN AREA.

THE CONTRACTOR SHALL PROTECT THE LIGHTING/UTILITY SYSTEMS FROM DAMAGE AT ALL TIMES WHILE WORKING AT THE WORKSITES. ANY DAMAGE SHALL BE REPAIRED IMMEDIATELY. DAMAGE DUE TO THE CONTRACTOR'S OPERATIONS SHALL BE REPAIRED AT THE CONTRACTOR'S EXPENSE.

BARRICADE LIGHTS CANNOT BE CONNECTED TO EXISTING AIRFIELD LIGHTING REGULATORS. THE CONTRACTOR SHALL PROVIDE A SEPARATE POWER SOURCE FOR CONSTRUCTION RELATED POWER NEEDS.

**OPERATING CONDITIONS AND SAFETY:** REFER TO "CLOSURE RESTRICTIONS" ABOVE. AT THE START OF CONSTRUCTION, ESTABLISH BARRICADE LINES, CONSTRUCTION FENCE LINES, DELINEATOR LINES, ETC. AS INDICATED ON THE INDIVIDUAL PHASING PLANS TO PROVIDE A CLEAR DELINEATION BETWEEN WORK AREA AND OPERATIONAL AREA.

TO ACCESS THE CONSTRUCTION SITES, THE CONTRACTOR WILL REQUIRE ACCESS ALONG EXISTING SERVICE ROADS WHICH ARE ADJACENT TO AND CROSS ACTIVE TAXIWAYS, TAXILANES AND APRON AREAS. THE PORT WILL PROVIDE ESCORTS TO MONITOR AND CONTROL THE CONTRACTORS USE OF THESE AREAS. AIRCRAFT TRAFFIC ALWAYS HAS PRIORITY OVER CONTRACTOR TRAFFIC. NO CONTRACTOR CROSSINGS OF ACTIVE RUNWAYS WILL BE ALLOWED. NO UNCONTROLLED CONTRACTOR CROSSINGS OF ACTIVE TAXIWAYS WILL BE ALLOWED. SEE SECTION 01140 & 01567 OF THE SPECIFICATIONS FOR ESCORT REQUIREMENTS.

THE CONTRACTOR SHALL BE AWARE THAT THE OPERATIONS OF AIRCRAFT IN ADJACENT AREAS WILL RESULT IN JET BLAST OCCURRING IN THE WORK AREA. REFER TO SPECIFICATION SECTION 01140 FOR FURTHER DEFINITION AND INFORMATION ON JET BLAST. THE CONTRACTOR SHALL TAKE ALL STEPS NECESSARY TO PROTECT WORKERS, EQUIPMENT AND MATERIALS. ALL CONTRACTOR VEHICLES, EQUIPMENT AND SUPPLIES MUST REMAIN INSIDE THE WORK AREA ESTABLISHED FOR THE WORK SHIFT UNLESS IN TRANSIT TO OR FROM THE SITE. ALL EXPOSED SOILS OR BASE COURSES SHALL BE COVERED AND SECURED OR TREATED IN A MANNER APPROVED BY THE ENGINEER SUCH THAT IT DOES NOT CREATE FOREIGN OBJECT DEBRIS (FOD), DUST OR POSE ANY TYPE OF DANGER TO

OPERATING AIRCRAFT.

NO HOLES OR OPEN DITCHES MAY BE LEFT OUTSIDE OF THE BARRICADE, REFLECTOR OR CONSTRUCTION FENCE LINES. NO PROTRUDING LIFTING EYES OR HOOKS WILL BE ALLOWED ON ANY TEMPORARY GROUND COVERS OR SLABS THAT THE CONTRACTOR MAY PROPOSE TO USE UNLESS SET BELOW THE SURFACE.

ALL SURPLUS MATERIALS SUCH AS ROCK, CONCRETE AND ACP SHALL BE HAULED OFF THE AOA. TRUCKS DELIVERING ACP OR CONCRETE SHALL NOT WASH OUT CHUTES, BEDS, MIXERS, ETC. ON THE AOA.

SEE THE "SITE PLAN/SAFETY NOTES" DRAWING FOR LOCATION OF EQUIPMENT/MATERIAL STORAGE AREA AND RESTRICTIONS FOR USE. THE PORT WILL CHECK ALL AREAS AT THE END OF EACH WORKSHIFT AND WILL REQUIRE THE CONTRACTOR TO REMOVE EQUIPMENT OR MATERIALS FROM THE SITES THAT DO NOT MEET THE REQUIREMENTS OUTLINED ON THE "SITE PLAN/SAFETY NOTES" DRAWING.

**WORK BY OTHERS:** THE CONTRACTOR SHALL CLOSELY COORDINATE AND SCHEDULE WORK WITH OTHER CONTRACTORS COMPLETING WORK ON THE AIRFIELD. THE CONTRACTOR SHALL CLOSELY COORDINATE ANY ACCESS REQUIREMENTS, SURFACE CLOSURES, EQUIPMENT SHUTDOWNS, ETC. WITH THE CONTRACTORS COMPLETING WORK ON THESE CONTRACTS. PRIOR TO PREPARING THE CONSTRUCTION SCHEDULE AND REGULARLY DURING THE CONSTRUCTION, THE CONTRACTOR SHALL MEET WITH THE ENGINEER AND BE UPDATED ON OTHER WORK OCCURRING ON THE AIRFIELD. THE CONTRACTOR SHALL INCORPORATE IN THE CONSTRUCTION SCHEDULE ANY REQUIRED RESTRICTIONS OR DATES REQUIRED TO MAKE SURE THAT NO CONFLICTS WITH OTHER CONTRACTORS OCCURS.

- A. 2003 AIRFIELD IMPROVEMENT PROJECTS - CONTRACT 1. CONTRACT 1 OF THE 2003 AIRFIELD IMPROVEMENT PROJECTS WILL BE COMPLETED. THE WORK INCLUDES INSTALLATION OF THE NEW AIRCRAFT FUELING SYSTEM, CONSTRUCTION OF THE STEP APRON PAVEMENT, TAXIWAY B SOUTH HARDSTAND AND FEDEX RAMP REPAIRING A
- B. CENTRAL TERMINAL EXPANSION. THE CENTRAL TERMINAL EXPANSION CONSTRUCTION WILL CONTINUE. THIS WORK INCLUDES THE DEMOLITION OF THE EXISTING CENTRAL TERMINAL BUILDING AND CONSTRUCTION OF THE NEW CENTRAL TERMINAL BUILDING.
- C. SOUTH TERMINAL EXPANSION PROJECT (STEP). CONSTRUCTION OF THE NEW SOUTH TERMINAL WILL CONTINUE. THIS WORK IS LOCATED SOUTHEAST OF THE MAIN TERMINAL BUILDING.
- D. 16L ALSF. CONSTRUCTION OF THE NEW RUNWAY 16L ALSF 2 APPROACH LIGHT SYSTEM BY THE FAA AT THE NORTH END OF RW 16L-34R.

**BARRICADES:** BARRICADES ARE REQUIRED TO PROVIDE A CLEAR SEPARATION LINE BETWEEN ACTIVE AIRCRAFT OPERATING AREAS AND THE CONTRACTOR WORK AREA. SEE THE INDIVIDUAL PHASING PLANS FOR SPECIFIC REQUIREMENTS ASSOCIATED WITH BARRICADES IN THOSE AREAS. THE CONTRACTOR MAY BE REQUIRED TO PROVIDE BARRICADES AT OTHER LOCATIONS REQUESTED BY THE ENGINEER.

SOME BARRICADES MAY BE REQUIRED ONLY DURING THE WORKSHIFT. INSTALL BARRICADES AT THE BEGINNING OF THE WORKSHIFT TO PROVIDE A SAFE OPERATING AREA FOR BOTH THE CONTRACTOR AND THE AIRCRAFT. REMOVE AT THE END OF THE WORKSHIFT. AT NO TIME SHALL A BARRICADE BE PLACED WITHIN A RUNWAY SAFETY AREA OR A TAXIWAY OR TAXILANE CONSTRUCTION SAFETY AREA WHILE THAT SURFACE IS OPERATIONAL. FOR BARRICADE DETAILS, SEE SHEET SD1.01.

CALL 48 HOURS  
BEFORE YOU DIG  
1-800-424-5555

DESIGNER:  
DRAWN BY:  
SCALE:  
DATE:  
CHECKED BY:  
APPROVED BY:

REVISIONS									
NO.	DATE	BY	DESCRIPTION	APP'D	NO.	DATE	BY	DESCRIPTION	APP'D



PROJECT MANAGER:  
SCOTT KYLES  
PROJECT ENGINEER:  
DENISE A. ALMOJUELA  
DESIGN ENGINEER:  
DENISE A. ALMOJUELA  
DRAFTER:  
DAA  
SCALE:  
AS NOTED  
DATE:  
04/21/03  
CHECKED/APPROVED BY:  
JOHN R. ROTHIE



Port of Seattle  
SEA-TAC INTERNATIONAL AIRPORT

PROJECT: 2003 AIRFIELD IMPROVEMENT PROJECTS - CONTRACT 2

SHEET TITLE: PHASING PLAN/GENERAL REQUIREMENTS

WORK ORDER NO.

101642

CONSULTANT'S NO.

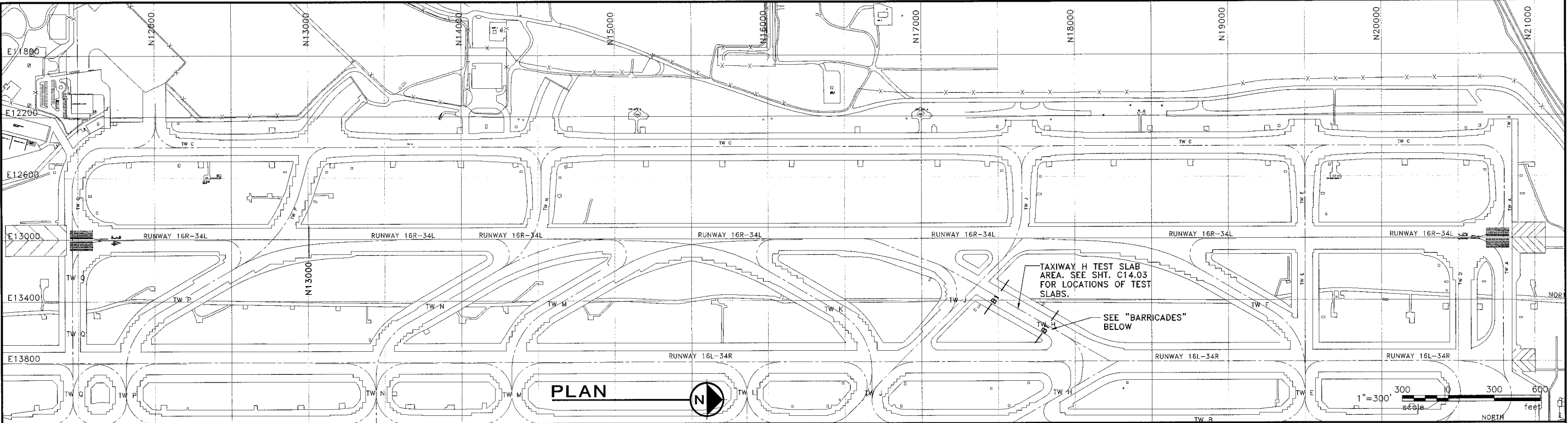
C002

PORT OF SEATTLE NO.

STIA-0302-C0.02



dwg : 04-18-2003, Time : 14:35  
Date : 04-18-2003, Time : 14:35  
Dwg : A-1793-CONTRACTA-DWG-RW-SLAB-C13.01.DWG Xref : A04-BK03



#### LEGEND:

- B1— TIMBER BARRICADE LINE—TYPE B1  
(UNPINNED). SEE DETAIL B1, SHEET SD1.01
- TW D TAXIWAY DESIGNATION

IN ADDITION TO THE REQUIREMENTS OUTLINED ON SHEET C0.02, THE FOLLOWING REQUIREMENTS ARE SPECIFIC FOR RW 16R-34L SLAB REPLACEMENT WORK.

**CALENDAR DAYS:** 60 CONSECUTIVE DAYS.

**SCHEDULING REQUIREMENTS:** RW 16R-34L SLAB REPLACEMENT WORK SHALL NOT BE SCHEDULED TO START BEFORE JULY 14, 2003.

**WORK HOURS:** 2300-0630.

**MUST BE DONE WITH:** WORK IN AREA D - AREA D2 OF THE RW/TW LIGHTING IMPROVEMENTS PORTION OF THE WORK SHALL BE COMPLETED CONCURRENTLY.

**CANNOT BE DONE WITH:**

1. AREA D - AREA D1 OF THE RW/TW LIGHTING IMPROVEMENTS PORTION OF THE WORK.
2. ANY WORK THAT CLOSURES RW 16L-34R.

#### IMPACTS/COORDINATION REQUIREMENTS:

1. CLOSURES RW 16R-34L UP TO SIX NIGHTS PER WEEK.
2. CLOSURES A PORTION OF TAXIWAY H BETWEEN THE RUNWAYS WHILE TEST SECTIONS ARE COMPLETED.

#### CONDITIONS REQUIRED TO START:

1. THE CONTRACTOR SHALL HAVE PROVIDED ALL THE INFORMATION AND COMPLETED ALL THE TESTING REQUIRED AS OUTLINED ON SHEET C0.02.
2. THE CONTRACTOR SHALL HAVE AN APPROVED QUICK SETTING HIGH EARLY STRENGTH CEMENT CONCRETE PAVEMENT MIX (P-503) BEFORE STARTING THE PRELIMINARY TEST SECTION. SEE SPECIFICATION SECTION 02755 FOR PRELIMINARY TEST SECTION REQUIREMENTS.
3. THE CONTRACTOR SHALL SUCCESSFULLY COMPLETE THE PRELIMINARY TEST SECTION BEFORE STARTING ANY PRODUCTION TEST SECTIONS.
4. THE CONTRACTOR SHALL SUCCESSFULLY COMPLETE THE REQUIRED TEST SLABS AT TAXIWAY H BEFORE STARTING SLAB REPLACEMENT ON THE RUNWAY. TEST SLAB WORK SHALL BE COMPLETED BETWEEN THE HOURS OF 2300-0630. LOCATIONS OF TEST SLABS ARE SHOWN ON SHEET C14.03.
5. LIGHT BASE/CONDUIT INSTALLATION EQUIPMENT AND MATERIALS SHALL BE APPROVED AND DELIVERED TO THE SITE BEFORE REPLACEMENT OF SLABS WITH LIGHTING WORK MAY BEGIN.

**PRODUCTION TEST SLABS:** THE CONTRACTOR SHALL HAVE AN APPROVED P-503 CONCRETE MIX DESIGN, TEMPORARY PANEL DESIGN (IF PROPOSED BY THE CONTRACTOR), SLAB REPLACEMENT SCHEDULE AND CONTINGENCY PLANS BEFORE TEST SLAB REPLACEMENT IS STARTED.

1. SEE SPECIFICATIONS FOR CONCRETE MIX DESIGN REQUIREMENTS.
2. THE REPLACEMENT SCHEDULE SHALL INCLUDE A NIGHTLY AND OVERALL SCHEDULE.

THE NIGHTLY SCHEDULE SHALL CONTAIN ALL PORTIONS OF WORK INCLUDING LIGHTING WORK. THE SCHEDULE FOR SLABS WITHOUT LIGHTING WORK WILL BE ADJUSTED ACCORDINGLY. THE SCHEDULE SHALL SPECIFICALLY OUTLINE THE NIGHTLY SEQUENCING OF WORK, BROKEN DOWN INTO 15-MINUTE INTERVALS. THE PORT WILL USE THIS TO VERIFY THAT THE CONTRACTOR'S WORK WILL BE COMPLETED WITHIN THE WORK HOURS ALLOWED. BASED ON RESULTS FROM ANY TEST SLAB WORK, THE CONTRACTOR MAY BE REQUIRED TO REVISE THE SLAB REPLACEMENT SCHEDULE AND COMPLETE REPLACEMENT OF ADDITIONAL SLABS. THE REVISION TO THE SCHEDULE AND TEST SLAB REPLACEMENT WILL CONTINUE UNTIL THE PORT IS CONFIDENT THAT THE CONTRACTOR CAN COMPLETE THE SCHEDULED NIGHTLY WORK AND HAVE THE RUNWAY OPERATIONAL AT 0630.

THE OVERALL SCHEDULE SHALL SPECIFICALLY OUTLINE THE SEQUENCING OF SLAB REPLACEMENTS ON THE RUNWAY.

NOTE: THE CONTRACTOR IS NOT REQUIRED TO REMOVE A SLAB AND PLACE THE FINAL CONCRETE IN ONE NIGHT. THE WORK MAY BE COMPLETED IN CONSECUTIVE NIGHTS, BUT EACH MORNING AT THE RUNWAY OPENING TIME, THE SURFACE SHALL EITHER BE TEMPORARY CONCRETE PANELS OR THE FINAL CONCRETE SLAB. IN EITHER CASE, THE SURFACE SHALL BE CAPABLE OF HANDLING THE WHEEL LOADING OF LANDING AIRCRAFT. IF THE WORK IS TO BE SCHEDULED OVER CONSECUTIVE NIGHTS, A NIGHTLY SCHEDULE FOR EACH NIGHT SHALL BE PROVIDED.

3. THE CONTRACTOR SHALL PROVIDE CONTINGENCY PLANS AND THE TIME REQUIRED TO IMPLEMENT THOSE PLANS FOR THE FOLLOWING:

- \* FAILURE TO MEET CRITICAL PATH ITEMS IN THE NIGHTLY SCHEDULE THAT COULD IMPACT OPENING OF RUNWAY AT 0630.
- \* FAILURE OF CONCRETE MIX TO MEET REQUIRED STRENGTH BY 0630.
- \* EMERGENCY RE-OPENING OF RUNWAY FOR LOW-VISIBILITY OPERATIONS.
- \* BACKUP PROCEDURES AND AVAILABILITY OF BACKUP EQUIPMENT OR MATERIALS FOR CRITICAL PATH ITEMS SUCH AS BREAKDOWN OF BATCH PLANT OR READY MIX PLANT, SLAB REMOVAL EQUIPMENT, TEMPORARY PANEL INSTALLATION/REMOVAL EQUIPMENT, ETC.

**CLOSURE RESTRICTIONS:** SEE SHEET C0.02 FOR ADDITIONAL RUNWAY CLOSURE RESTRICTIONS AND REQUIREMENTS. FOLLOWING THE SUCCESSFUL COMPLETION OF TEST SLABS, THE CONTRACTOR SHALL COMPLETE THE SLAB REPLACEMENT SOUTH OF N13000 FIRST. FOLLOWING COMPLETION OF THESE SLABS, THE CONTRACTOR SHALL COMPLETE SLAB REPLACEMENT WORK MOVING SOUTH TO NORTH.

IF THE CONTRACTOR OPTS TO USE PRECAST TEMPORARY PANELS, THE CONTRACTOR SHALL ALWAYS HAVE A SUFFICIENT NUMBER OF TEMPORARY PANELS TO ACCOMMODATE THE CONSTRUCTION SEQUENCING AND HAVE BACKUP PANELS AVAILABLE FOR EMERGENCY SITUATIONS. AT NO TIME SHALL THERE BE MORE EXISTING SLABS REMOVED THAN THERE ARE TEMPORARY PANELS TO REPLACE THEM, INCLUDING THE SLABS SCHEDULED TO BE POURED THAT NIGHT.

**WORK BY THE CONTRACTOR:** MAINTAIN AIRCRAFT AND VEHICLE ROUTES AROUND WORK AREA. PRIOR TO STARTING ON THE RUNWAY SET UP RUNWAY CLOSURE MARKERS. TEMPORARILY COVER ANY ACTIVE CENTERLINE LIGHTS THAT LEAD INTO WORK AREA. SAWCUT EXISTING CONCRETE SLABS (WITH DOWELS AND/OR TIEBARS) TO BE REPLACED. REMOVE SLABS, EXCAVATE AND COMPACT SUBGRADE. PROVIDE, INSTALL AND REMOVE TEMPORARY PANELS. INSTALL DOWELS. PLACE CONCRETE PAVING. TEMPORARILY CONNECT POWER FOR

ADJACENT CENTERLINE LIGHTS, INSTALL NEW OR RE-INSTALL LIGHTING AFFECTED BY THE SLAB REPLACEMENT. INSTALL NEW JOINT SEALANT. GROOVE SURFACE AND MARK NEW RUNWAY SLAB.

AT THE END OF EACH WORKSHIFT, THE CONTRACTOR SHALL LEAVE A SMOOTH CONCRETE SURFACE CAPABLE OF HANDLING AIRCRAFT TRAFFIC, WITH LIGHTING OPERATIONAL ON A TEMPORARY OR PERMANENT BASIS. ALL TEMPORARY PANELS SHALL BE SET TO MATCH THE EXISTING GRADES, WITH NO LIPS OR PROTRUSIONS BETWEEN THE TEMPORARY PANELS AND EXISTING PAVEMENT SURFACE. ALL EQUIPMENT AND EXCESS MATERIALS MUST BE MOVED TO THE CONTRACTOR'S EQUIPMENT STORAGE SITE B DURING NON-WORKING HOURS.

REMARK THE REPLACED SLABS ON A WEEKLY BASIS AND PROVIDE FINAL MARKING AT THE COMPLETION OF THE SLAB REPLACEMENT AND SURFACE GROOVING.

THE PORT WILL CLOSELY MONITOR THE WORK COMPLETED DURING THE WORKSHIFT AND COMPARE IT TO THE NIGHTLY SCHEDULE. IF THE CONTRACTOR IS NOT MEETING THE NIGHTLY SCHEDULE AND THE PORT FEELS THAT THE CONTRACTOR CANNOT COMPLETE THE SCHEDULED WORK BEFORE THE RUNWAY OPENING TIME, THE CONTRACTOR WILL BE REQUIRED TO IMPLEMENT ONE OF THE CONTINGENCY PLANS OR TAKE WHATEVER MEASURES ARE NECESSARY TO HAVE THE RUNWAY OPEN ON SCHEDULE AND OPERATING IN A SAFE MANNER.

**LIGHTING:** ALL REPLACEMENT OF LIGHTS IN NEW SLABS SHALL BE INSTALLED PER DETAILS SHOWN ON SHEET C14.07. AT REPLACEMENT SLABS, WHICH CONTAIN LIGHTS, THE CONTRACTOR IS NOT REQUIRED TO PROVIDE A TEMPORARY LIGHT AT THAT LOCATION, BUT MUST PROVIDE TEMPORARY CONNECTIONS BETWEEN THE ADJACENT LIGHTS SO THAT THE RUNWAY AND/OR TAXIWAY LIGHTING SYSTEMS ARE OPERATIONAL AT THE END OF THE WORKSHIFT. NO MORE THAN TWO RUNWAY CENTERLINE LIGHTS SHALL BE OUT OF SERVICE AT ANY ONE TIME. NO ADJACENT RUNWAY CENTERLINE LIGHTS SHALL BE OUT OF SERVICE AT ANY ONE TIME. NO MORE THAN ONE TAXIWAY CENTERLINE LIGHT AT EACH TAXIWAY SHALL BE OUT OF SERVICE AT ANY ONE TIME.

**OPERATING CONDITIONS AND SAFETY:** RW 16R-34L WILL BE CLOSED DURING OFF-PEAK HOURS AS SCHEDULED BY THE CONTRACTOR. THE CONTRACTOR SHALL COORDINATE ANY CLOSURES OF CROSS TAXIWAYS WITH THE PORT, AS THESE TAXIWAYS MAY BE REQUIRED TO ACCESS WESTSIDE TAXIWAYS AND PARKING AREAS.

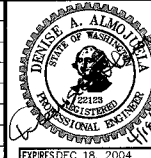
AS OUTLINED ON SHEET C0.01, ACCESS ROUTES SHALL BE KEPT FREE OF DEBRIS AT ALL TIMES. REFER TO THE SPECIFICATIONS FOR NOISE RESTRICTION REQUIREMENTS.

**BARRICADES:** WHEN COMPLETING TEST SLABS AT TAXIWAY H, PROVIDE BARRICADES ACROSS THE TAXIWAY AT THE RUNWAY HOLDLINES.

CALL 48 HOURS  
BEFORE YOU DIG  
1-800-424-5555

PROJECT ENGR./ARCH:  
DESIGNER:  
DRAWN BY:  
SCALE:  
DATE:  
CHECKED BY:  
APPROVED BY:

REVISIONS									
NO.	DATE	BY	DESCRIPTION	APP'D	NO.	DATE	BY	DESCRIPTION	APP'D



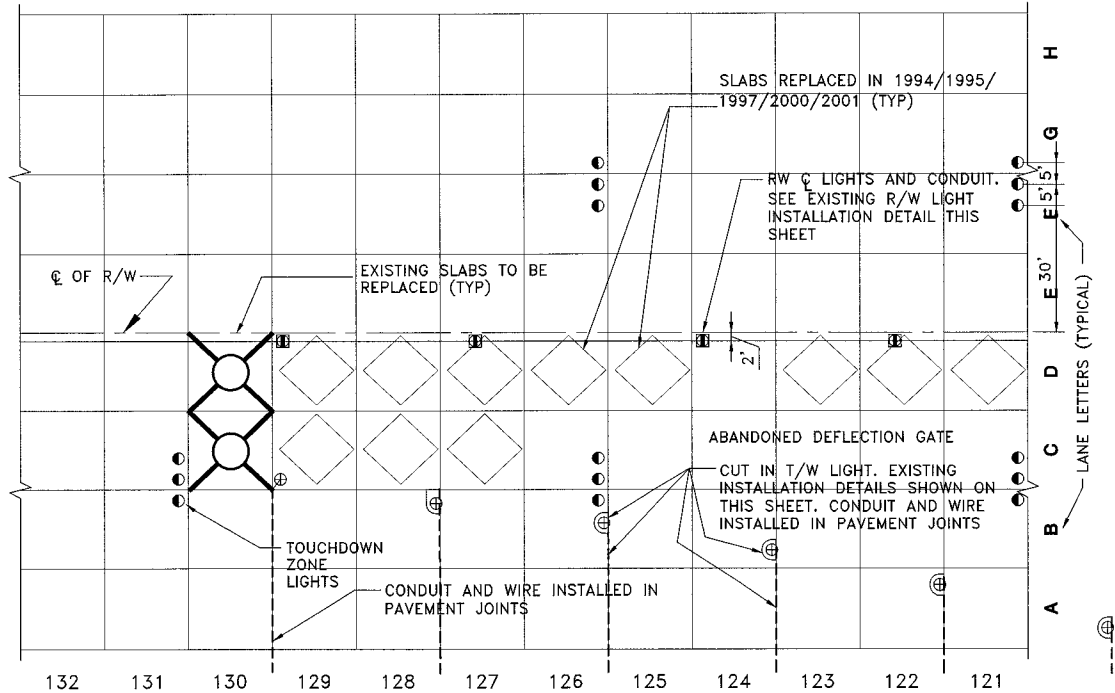
PROJECT MANAGER:  
JOHN R. ROTHNIE  
PROJECT ENGINEER:  
DENISE A. ALMOJUELA  
DESIGN ENGINEER:  
DENISE A. ALMOJUELA  
DRAFTER:  
DAA  
SCALE:  
AS NOTED  
DATE:  
04/21/03  
CHECKED/APPROVED BY:  
JOHN R. ROTHNIE



**Port of Seattle**  
**SEA-TAC INTERNATIONAL AIRPORT**  
PROJECT: **2003 AIRFIELD IMPROVEMENT PROJECTS - CONTRACT 2**  
**RW 16R-34L SLAB REPLACEMENT**  
SHEET TITLE: **CONSTRUCTION PHASING**  
**RW 16R-34L SLAB REPLACEMENT**

WORK ORDER NO.  
101646  
CONSULTANT'S NO.  
C13.01  
PORT OF SEATTLE NO.  
STIA-0302-C13.01

SLAB #	EXISTING RW LIGHT	EXISTING TW LIGHT	NOTES	LIGHTING INSTALLATION DETAIL
30C	-	-		
57E	-	-		
57F	-	-		
58E	-	-		
58F	-	-		
59F	-	-		
60E	-	-		
60F	-	-		
62E	-	-		
66E	-	-		
71E	-	-		
77F	-	-		
80F	-	-		
82E	-	-		
92F	-	-		
93F	-	-		
94F	-	-		
95F	-	-		
103D	-	-		
108E	-	-		
109E	-	-		
110E	-	-		
111E	-	-		
114E	-	-		
115E	-	-		
130C	-	-	TW F CENTERLINE LIGHT IN ADJACENT SLAB 129C. CONDUIT IN JOINT BETWEEN.	SIMILAR TO SECTION 1 / C14.05
130D	-	-		
153D	-	-	TW F CENTERLINE LIGHT IN ADJACENT SLAB 154D. CONDUIT IN JOINT BETWEEN.	SIMILAR TO SECTION 1 / C14.05
170D	-	-		
181D	-	-	SLAB SIZE 15' X 20'	
189E	-	-		
190E	-	-		
211D	-	-		
234D	-	X	EXISTING TW H LIGHT. CONDUIT UNDER SLAB. EXISTING SIMILAR TO SECTION A / C14.05.	TW LT.-SECTION 4 / C14.07
248D	-	X	CUT IN TW M LIGHT. CONDUIT FOR TW M LIGHT IN N.JOINT. EXISTING SIMILAR TO DETAIL 1 / C14.05.	TW LT.-DETAIL 3 / C14.07
249D	-	-	TW M CENTERLINE LIGHT IN ADJACENT SLAB 250D. CONDUIT IN JOINT BETWEEN.	SIMILAR TO SECTION 1 / C14.05
250C	-	-	TW M CENTERLINE LIGHT IN ADJACENT SLAB 250D. CONDUIT IN NORTH JOINT.	SIMILAR TO SECTION 1 / C14.05
273F	-	-		
274F	-	-		
297D	X	-	1. EXISTING RW CENTERLINE LIGHT. EXISTING SIMILAR TO SECTION A / C14.05	RW LT.-SECTION 4 / C14.07
			2. CUT IN TW K CENTERLINE LIGHT IN ADJACENT SLAB 298D. CONDUIT IN JOINT BETWEEN	SIMILAR TO SECTION 1 / C14.05
298D	-	X (2)	1. EXISTING TW N LIGHT. CONDUIT UNDER SLAB. EXISTING SIMILAR TO SECTION A / C14.05.	TW LT.-SECTION 4 / C14.07
			2. CUT IN TW K LIGHT. CONDUIT FOR TW K LIGHT IN N.JOINT. EXISTING SIMILAR TO DETAIL 2 / C14.05	TW LT.-DETAIL 3 / C14.07
300D	X	X	1. EXISTING RW CENTERLINE LIGHT. EXISTING SIMILAR TO SECTION A / C14.05	RW LT.-SECTION 4 / C14.07
			2. CUT IN TW K LIGHT. CONDUIT FOR TW K LIGHT IN N.JOINT. EXISTING SIMILAR TO DETAIL 2 / C14.05	TW LT.-DETAIL 3 / C14.07
301E	-	-		
302D	X	X	1. EXISTING RW CENTERLINE LIGHT. EXISTING SIMILAR TO SECTION A / C14.05	RW LT.-SECTION 4 / C14.07
			2. EXISTING TW K LIGHT. CONDUIT FOR TW K LIGHT UNDER SLAB AND IN N.JOINT. EXISTING SIMILAR TO DETAIL 3 / C14.07	TW LT.-DETAIL 3 / C14.07
304D	-	X	CUT IN TW K LIGHT. CONDUIT FOR TW K LIGHT IN N.JOINT. EXISTING SIMILAR TO DETAIL 2 / C14.05	TW LT.-DETAIL 3 / C14.07
328E	-	-		
339F	-	-		
340F	-	-		
342F	-	-		
343F	-	-		
346E	-	-		
348E	-	-		
349E	-	-		
350E	-	-		
419C	-	-		
437D	X	-	EXISTING RW CENTERLINE LIGHT. EXISTING SIMILAR TO SECTION A / C14.05	RW LT.-SECTION 4 / C14.07



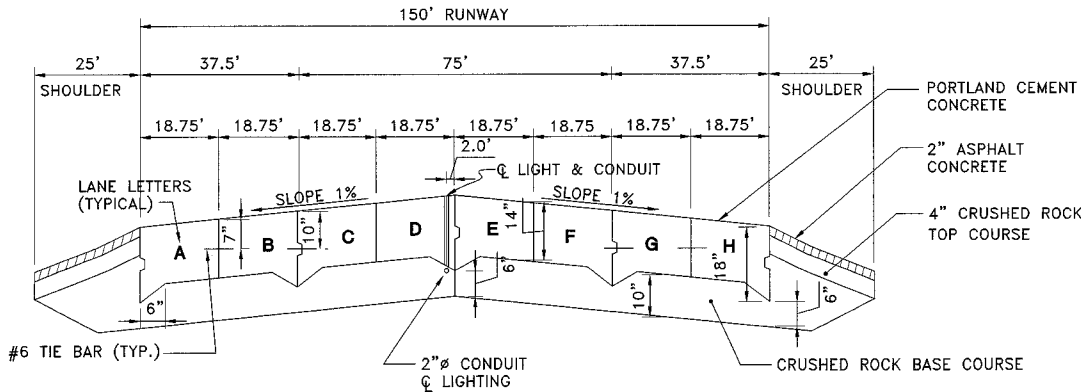
ABOVE IS SAMPLE PLAN ONLY. SEE PLAN SHEETS FOR ACTUAL WORK REQUIRED IN THIS AREA.

NOTE: MARKING NOT SHOWN.

**PLAN**  
TYPICAL EXISTING PARTIAL RUNWAY PLAN  
SCALE: 1" = 20'

**NOTES:**

TRANSVERSE NORTHING	EXPANSION JOINTS LOCATED AT SLABS AFFECTED	TRANSVERSE NORTHING	SLABS AFFECTED
11500	NONE	17247	NONE
14180	NONE	17657	NONE
14840	302D	20595	NONE
16587	NONE		



**SECTION**

TYPICAL EXISTING RUNWAY SECTION  
LOOKING SOUTH  
SCALE: HORIZ. 1" = 20'  
VERT. 1" = 2'

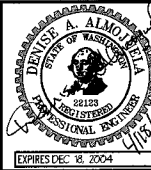
- NOTES:
1. TYPICAL SECTION SHOWN IS FROM ORIGINAL RUNWAY CONSTRUCTION. ANY SLABS REPLACED IN 1994/1995/1997/2000/2001 ARE 18" THICK.
  2. THE CONTRACTOR SHALL ASSUME THAT ALL 1994/1995/1997/2000/2001 SLAB JOINTS ARE DOWELLED ALONG ALL EDGES WITH 1-1/2" Ø DOWELS AT 15" O.C.

**TYPICAL EXISTING RW PLAN AND SECTION**

CALL 48 HOURS  
BEFORE YOU DIG  
1-800-424-5555

PROJECT ENGR./ARCH:  
DESIGNER:  
DRAWN BY:  
SCALE:  
DATE:  
CHECKED BY:  
APPROVED BY:

REVISIONS									
NO.	DATE	BY	DESCRIPTION	APP'D	NO.	DATE	BY	DESCRIPTION	APP'D

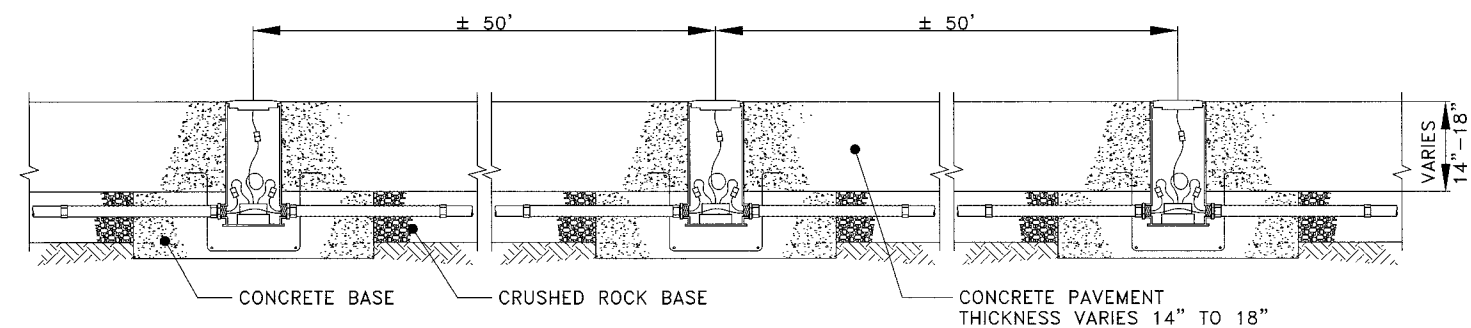


PROJECT MANAGER:  
JOHN R. ROTHNIE  
PROJECT ENGINEER:  
DENISE A. ALMOJUELA  
DESIGN ENGINEER:  
DENISE A. ALMOJUELA  
DRAFTER:  
MICHAEL A. CORPUZ  
SCALE:  
AS NOTED  
DATE:  
04/21/03  
CHECKED/APPROVED BY:  
JOHN R. ROTHNIE

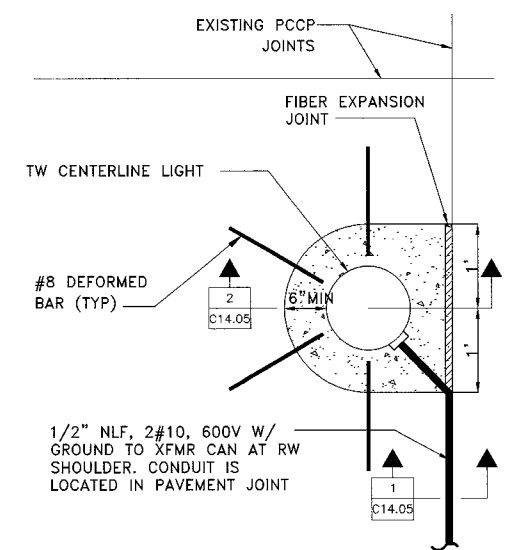
**Port of Seattle**  
**SEA-TAC INTERNATIONAL AIRPORT**  
PROJECT: **2003 AIRFIELD IMPROVEMENT PROJECTS - CONTRACT 2**  
**RW 16R-34L SLAB REPLACEMENT**  
SHEET TITLE: **REPLACEMENT SLABS / LIGHTING**  
**LIST / EXISTING RW SECTIONS**

WORK ORDER NO.  
101646  
CONSULTANT'S NO.  
C14.04  
PORT OF SEATTLE NO.  
STIA-0302-C14.04

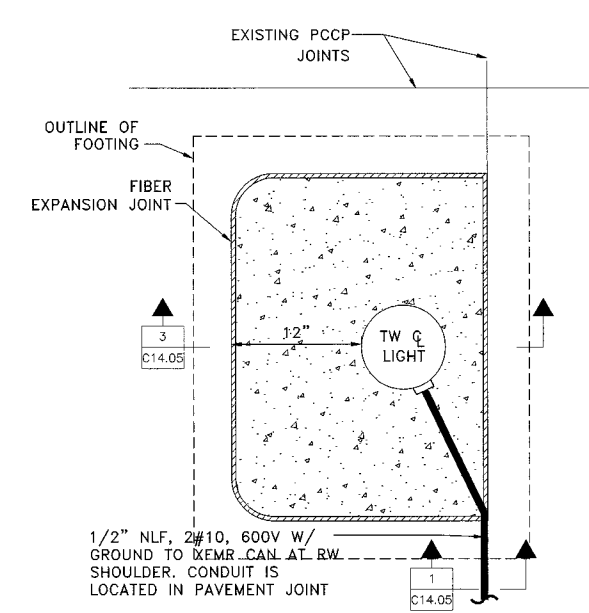




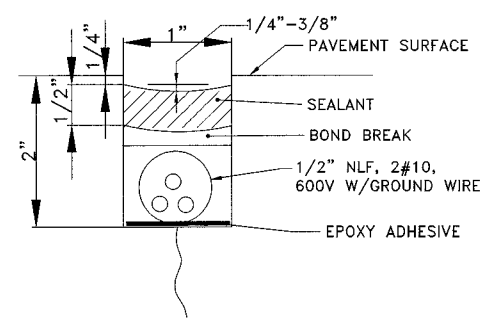
**SECTION** A  
 TYPICAL EXISTING RW CENTERLINE  
 LIGHT INSTALLATION - NTS  
 (TAXIWAYS A, H, N & Q CENTERLINE  
 LIGHT INSTALLATION SIMILAR-LIGHT SPACING VARIES)  
C14.04



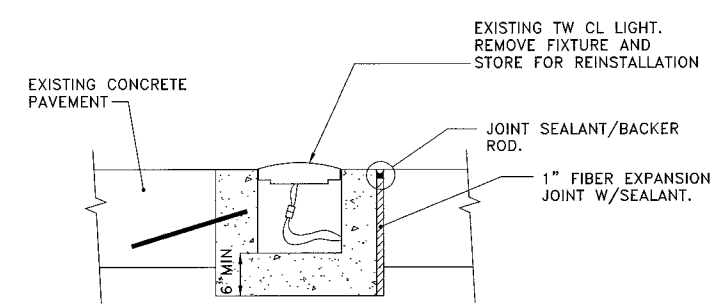
**DETAIL** 1  
 TYPICAL CUT-IN TW CENTERLINE  
 LIGHT - NTS  
C14.04



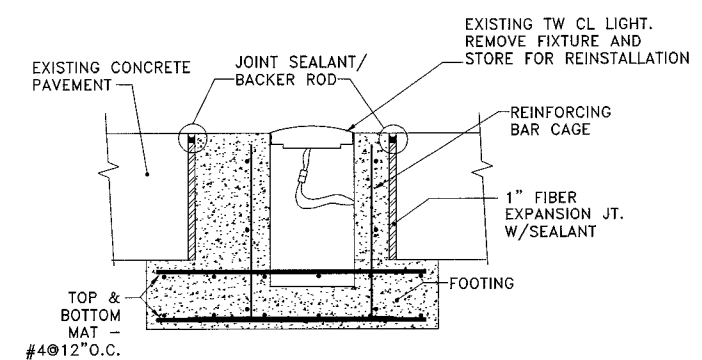
**DETAIL** 2  
 TYPICAL CUT-IN TW CENTERLINE  
 LIGHT - REPAIRED  
 NTS  
C14.04



**SECTION** 1  
 EXISTING CONDUIT INSTALLATION  
 NTS  
C14.05



**SECTION** 2  
 TYPICAL CUT-IN TW CENTERLINE  
 LIGHT - NTS  
C14.05

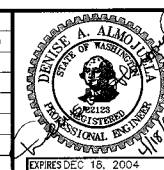


**SECTION** 3  
 TYPICAL CUT-IN TW CENTERLINE  
 LIGHT - REPAIRED  
 NTS  
C14.05

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PROJECT ENGR./ARCH:  
 DESIGNER:  
 DRAWN BY:  
 SCALE:  
 DATE:  
 CHECKED BY:  
 APPROVED BY:

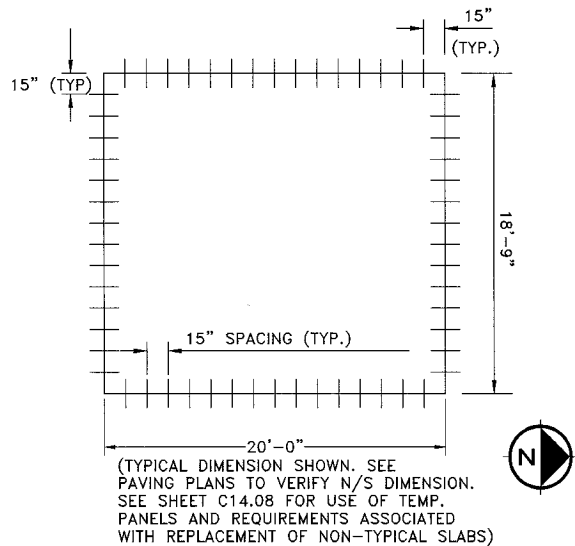
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NO.	DATE	BY	DESCRIPTION	APP'D	NO.	DATE	BY	DESCRIPTION	APP'D



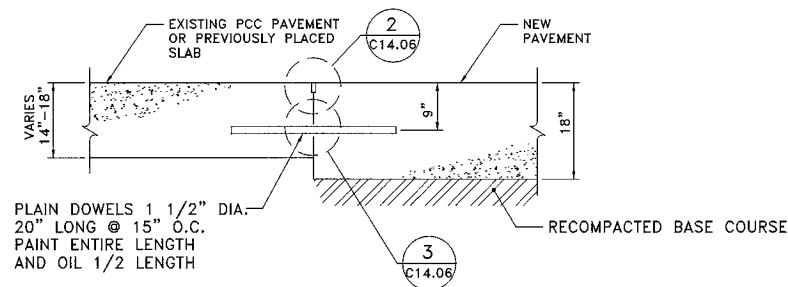
PROJECT MANAGER:  
 JOHN R. ROTHNIE  
 PROJECT ENGINEER:  
 DENISE A. ALMOJUELA  
 DESIGN ENGINEER:  
 DENISE A. ALMOJUELA  
 DRAFTER:  
 MICHAEL A. CORPUZ  
 SCALE:  
 AS NOTED  
 DATE:  
 04/21/03  
 CHECKED/APPROVED BY:  
 JOHN R. ROTHNIE

**Port of Seattle**  
**SEA-TAC INTERNATIONAL AIRPORT**  
 PROJECT: **2003 AIRFIELD IMPROVEMENT PROJECTS - CONTRACT 2**  
**RW 16R-34L SLAB REPLACEMENT**  
 SHEET TITLE: **EXISTING RW LIGHTING DETAILS**

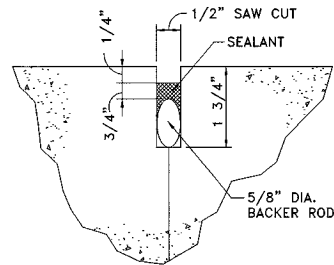
WORK ORDER NO.  
 101646  
 CONSULTANT'S NO.  
 C14.05  
 PORT OF SEATTLE NO.  
 STIA-0302-C14.05



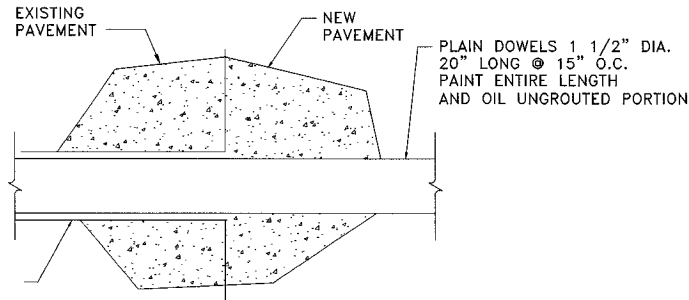
**DETAIL**  
DOWEL SPACING FOR TYPICAL  
SLAB  
SCALE: NTS



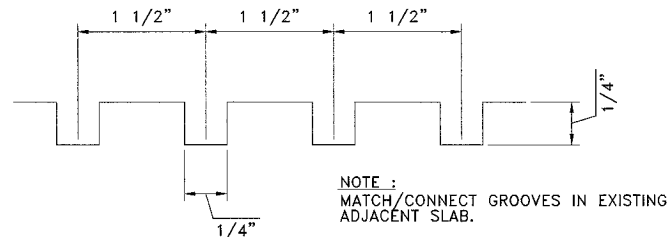
**TYPICAL SECTION AT JOINT**  
NEW SLAB TO EXISTING PAVEMENT  
SCALE: NTS  
CONSTRUCTION JOINT (DOWELLED)



**DETAIL**  
SCALE: NTS



**DETAIL**  
SCALE: NTS



**DETAIL**  
GROOVING NEW SLAB  
SCALE: NTS

#### GENERAL NOTES

1. T = 18" FOR ALL NEW RUNWAY CONCRETE PAVEMENT
2. PCC = PORTLAND CEMENT CONCRETE (EXISTING)
3. FOR SLAB SIZES NOT CONFORMING TO THE DETAIL SHOWN, DOWEL BARS SHALL BE SPACED AT LEAST 15" ON CENTER. DOWEL BARS SHALL BE SPACED AT LEAST 15" FROM ANY SLAB CORNER, AND THE SPACING FROM THE LAST DOWEL BARS ON A SIDE TO THE ADJACENT CORNERS SHALL BE THE SAME AT BOTH ENDS OF THE SLAB.
4. THE CONTRACTOR SHALL NOT REMOVE AND REPLACE ADJACENT SLABS SIMULTANEOUSLY. SLAB REMOVAL AND REPLACEMENT SHALL BE SEQUENCED SUCH THAT THE CONCRETE FOR THE NEW SLAB IS ALWAYS PLACED AGAINST EXISTING OR PREVIOUSLY RECONSTRUCTED SLABS.
5. WHERE NEW CONCRETE IS BEING PLACED AGAINST EXISTING PAVEMENT OR PREVIOUSLY RECONSTRUCTED SLABS, HOLES SHALL BE DRILLED INTO THE EXISTING SLAB TO RECEIVE DOWELS. SEE DETAIL 3.
6. SEE SHEET C14.05 FOR EXISTING IN-PAVEMENT LIGHT INSTALLATION DETAILS AND C14.07 FOR NEW IN-PAVEMENT LIGHT INSTALLATION DETAILS.

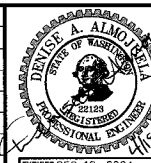
#### RUNWAY 16R-34L CONCRETE SLAB REPLACEMENT SUGGESTED SEQUENCE

- A. SLAB SAWCUTTING
  1. PRIOR TO SAWCUTTING & REMOVING SLAB, MEASURE SLAB SIZE AND VERIFY TEMPORARY PANELS WILL FIT, IF TO BE USED AT THIS LOCATION.
  2. CONCRETE SLABS SHALL BE CUT FULL DEPTH.
  3. WITH THE EXCEPTION AT AN EXISTING PAVEMENT JOINT, SAWCUTTING SHALL NOT PENETRATE AN ADJACENT SLAB THAT WILL REMAIN.
  4. IN PLACE DEMOLITION OF CONCRETE (I.E. CHIPPING OR BREAKING) WILL NOT BE ALLOWED. REMOVAL SHALL BE BY LIFT OUT METHOD. INSTALL EMBEDMENT ANCHORS IN THE SLAB SECTION(S) AS REQUIRED TO FACILITATE LIFT OUT. ANCHORS SHALL BE FLUSH WITH PAVEMENT SURFACE.
  5. CONCRETE SLABS TO REMAIN SHALL BE PROTECTED AT ALL TIMES. DAMAGE TO A SLAB NOT SPECIFIED IN THE CONTRACT DOCUMENTS TO BE REPLACED WILL REQUIRE REPLACEMENT OF THE SLAB AT NO COST TO THE PORT.
  6. SAWCUTTING OF SLABS SHALL NOT PRECEDE THE SLAB REMOVAL BY MORE THAN 72 HOURS.
- B. SLAB REMOVAL/TEMPORARY PANEL INSTALLATION
  1. SET LIFTING HARDWARE AND LIFT OUT SLAB SECTION(S).
  2. EXCAVATE, GRADE AND COMPACT EXISTING CRUSHED ROCK BASE FOR AN 18" CONCRETE SECTION. PROTECT EXISTING ELECTRICAL CONDUIT LOCATED BENEATH THE SLABS AS SHOWN ON THE DRAWINGS.
  3. AT SLABS CONTAINING RUNWAY CENTERLINE LIGHTS AND/OR TAXIWAY A, H, N OR Q CENTERLINE LIGHTS:
    - a. REMOVE EXISTING LIGHT FIXTURE(S) AND TRANSFORMER(S). STORE RW CENTERLINE LIGHT FIXTURES AND TRANSFORMERS FOR REINSTALLATION. SALVAGE TAXIWAY CENTERLINE LIGHT FIXTURES AND TRANSFORMERS.
    - b. DISCONNECT/CUT CONDUCTORS AND PULL BACK TO THE TWO LIGHTS ADJACENT TO THE LIGHT TO BE DEMOLISHED.
    - c. CUT CONDUIT EITHER SIDE OF LIGHT BASE. DEMOLISH LIGHT BASE AND LIGHT BASE FOOTING.
    - d. PLACE, GRADE AND COMPACT CRUSHED ROCK IN AREA OF REMOVED LIGHT BASE FOOTING.
    - e. INSTALL TEMPORARY CONDUIT AT REMOVED LIGHT BASE. PULL CONDUCTORS AND INSTALL CONNECTORS AT ADJACENT LIGHT BASES TO RECONNECT THE LIGHTING CIRCUIT.
  4. AT SLABS CONTAINING TAXIWAY F, K, M OR P CENTERLINE LIGHTS:
    - a. REMOVE AND SALVAGE EXISTING LIGHT FIXTURE(S).
    - b. DISCONNECT/CUT CONDUCTORS AND PULL BACK TO THE TRANSFORMER AND TRANSFORMER CAN LOCATED IN EAST RUNWAY SHOULDER.
    - c. CUT CONDUIT AT EAST JOINT OF SLAB AS INDICATED ON THE DRAWINGS. DEMO LIGHT BASE AND SURROUNDING CONCRETE.
    - d. PLACE, GRADE AND COMPACT CRUSHED ROCK IN AREA OF REMOVED LIGHT CONCRETE (WHERE APPLICABLE).
  5. DRILL HOLES FOR DOWELS.
  6. INSTALL TEMPORARY PRECAST PANELS, ADJUST PANELS TO MATCH ELEVATIONS OF THE ADJACENT SLABS. SET PANELS ON GRADE TO PREVENT ROCKING.
- C. CONCRETE PLACEMENT - NEW PANEL
  1. REMOVE TEMPORARY PRECAST PANEL SECTIONS.
  2. AT SLABS CONTAINING RUNWAY CENTERLINE LIGHTS AND/OR TAXIWAY A, H, N OR Q CENTERLINE LIGHTS:
    - a. REMOVE TEMPORARY SPLICE CABLES BETWEEN ADJACENT LIGHTS. REMOVE TEMPORARY CONDUIT SPLICE.
    - b. EXCAVATE FOR NEW LIGHT BASE FOOTING AND SET FORMWORK. SET LIGHT BASE, CONNECT CONDUIT AND SET JIG TO ALIGN LIGHT BASE OFF THE ADJACENT PAVEMENT. INSTALL REBAR CAGE AND PLACE APPROVED CONCRETE MIX FOR FOOTING.
    - c. REINSTALL TEMPORARY SPLICE CABLE THROUGH NEW LIGHT BASE. INSTALL FLANGE RING WITH PAVEMENT DAM AND WITH 3/4" STEEL COVER PLATE ON LIGHT BASE.
  3. AT SLABS THAT CONTAINING TAXIWAY F, K, M OR P CENTERLINE LIGHTS:
    - a. EXCAVATE FOR NEW LIGHT BASE FOOTING AND SET FORMWORK. SET LIGHT BASE, CONNECT CONDUIT AND SET JIG TO ALIGN LIGHT BASE OFF THE ADJACENT PAVEMENT. INSTALL REBAR CAGE AND PLACE APPROVED CONCRETE MIX FOR FOOTING.
    - b. INSTALL FLANGE RING WITH PAVEMENT DAM AND WITH 3/4" STEEL COVER PLATE ON LIGHT BASE.
  4. INSTALL AND EPOXY DOWELS.
  5. PLACE APPROVED CONCRETE MIX FOR SLAB.
  6. FINISH CONCRETE AND CONTINUE TO CURE SURFACE FOR A MINIMUM OF 3 HOURS FOLLOWING PLACEMENT.
- D. LIGHT INSTALLATION
  1. AT SLABS CONTAINING RUNWAY CENTERLINE LIGHTS AND/OR TAXIWAY A, H, N OR Q CENTERLINE LIGHTS:
    - a. REMOVE 3/4" COVER PLATE ON LIGHT BASE AND DISCONNECT AND REMOVE TEMPORARY SPLICE CABLES.
    - b. INSTALL 2-#6+GRD CABLES FROM ADJACENT LIGHTS TO THE LIGHT AND TRANSFORMER. INSTALL TRANSFORMER, REQUIRED CONNECTIONS AND LIGHT FIXTURE. INSTALL SHIMS(S) AS REQUIRED. AT RW CENTERLINE LIGHTS, THE STORED RW CENTERLINE LIGHT FIXTURE AND TRANSFORMER SHALL BE INSTALLED. AT TW CENTERLINE LIGHTS, THE PORT PROVIDED CENTERLINE LIGHT FIXTURE AND TRANSFORMER SHALL BE INSTALLED.
  2. AT SLABS THAT CONTAINING TAXIWAY F, K, M OR P CENTERLINE LIGHTS:
    - a. REMOVE 3/4" COVER PLATE ON LIGHT BASE.
    - b. INSTALL 2-#10+GRD CABLES FROM THE PORT PROVIDED TRANSFORMER LOCATED IN THE TRANSFORMER CAN IN THE EAST RUNWAY SHOULDER TO THE PORT PROVIDED LIGHT FIXTURE. INSTALL REQUIRED CONNECTORS, CONNECTIONS AND INSTALL LIGHT FIXTURE. INSTALL SHIM(S) AS REQUIRED.
- E. MARKING AND GROOVING - NEW SLABS
  1. REPAINT PAVEMENT MARKINGS TO MATCH EXISTING ON A WEEKLY BASIS.
  2. GROOVE SLAB REPLACEMENTS BY SAW CUTTING. GROOVING MAY BE DONE AFTER ALL SLABS ARE INSTALLED.
  3. PERMANENTLY MARK SLABS FOLLOWING GROOVING.

CALL 48 HOURS  
BEFORE YOU DIG  
1-800-424-5555

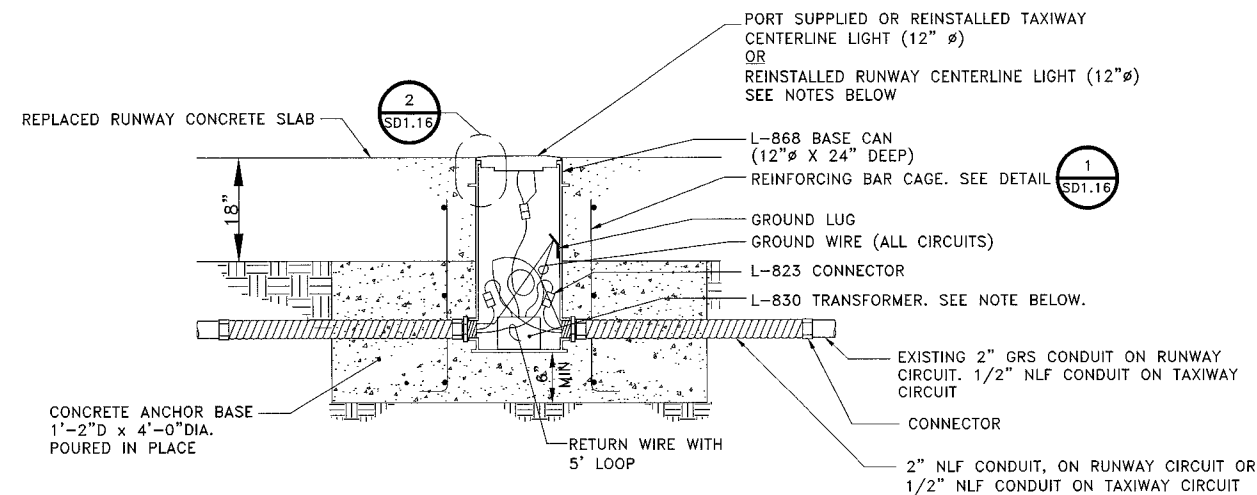
PROJECT ENGR./ARCH:  
DESIGNER:  
DRAWN BY:  
SCALE:  
DATE:  
CHECKED BY:  
APPROVED BY:

REVISIONS									
NO.	DATE	BY	DESCRIPTION	APP'D	NO.	DATE	BY	DESCRIPTION	APP'D



PROJECT MANAGER:  
JOHN R. ROTHNIE  
PROJECT ENGINEER:  
DENISE A. ALMOJUELA  
DESIGN ENGINEER:  
DENISE A. ALMOJUELA  
GRADER:  
MICHAEL A. CORPUZ  
SCALE:  
AS NOTED  
DATE:  
04/21/03  
CHECKED/APPROVED BY:  
JOHN R. ROTHNIE

	PROJECT:	2003 AIRFIELD IMPROVEMENT PROJECTS - CONTRACT 2
		RW 16R-34L SLAB REPLACEMENT
	SHEET TITLE:	RUNWAY REPLACEMENT SECTIONS AND DETAILS
	WORK ORDER NO.	101646
	CONSULTANT'S NO.	C14.06
	PORT OF SEATTLE NO.	STIA-0302-C14.06



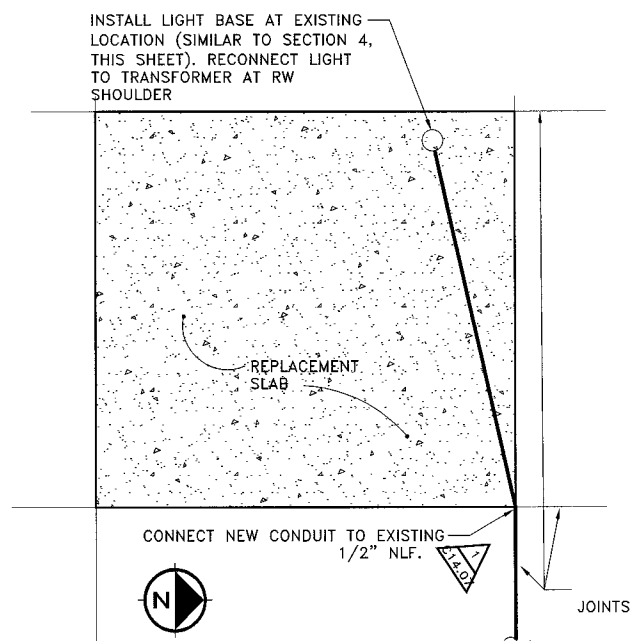
# SECTION

TYPICAL RW/TW CENTERLINE LIGHT  
INSTALLATION IN NEW CONCRETE  
NTS

4
C14.04

## NOTES:

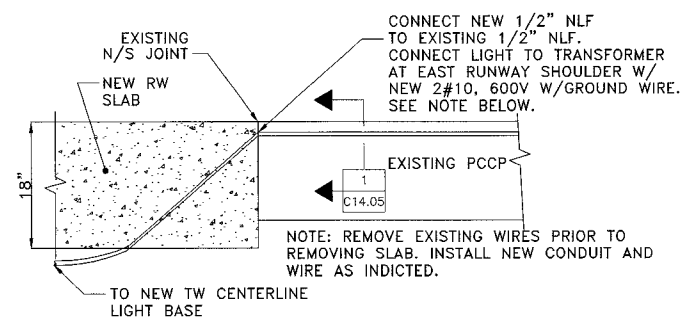
1. RW CENTERLINE LIGHTS: REINSTALL EXISTING LIGHT FIXTURE AND EXISTING TRANSFORMER.
2. TW CENTERLINE LIGHTS: INSTALL PORT SUPPLIED LIGHT FIXTURE AND TRANSFORMER.



# DETAIL

TW CENTERLINE LIGHT IN NEW  
RW SLAB (PREVIOUSLY CUT-IN  
LIGHT) - NTS

3
C14.04



# ELEVATION

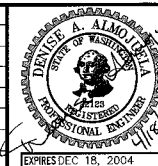
CONDUIT INTO NEW RW SLAB  
FOR NEW TW CL LIGHT  
NTS

1
C14.07

CALL 48 HOURS  
BEFORE YOU DIG  
1-800-424-5555

PROJECT ENGR./ARCH.  
DESIGNER:  
DRAWN BY:  
SCALE:  
DATE:  
CHECKED BY:  
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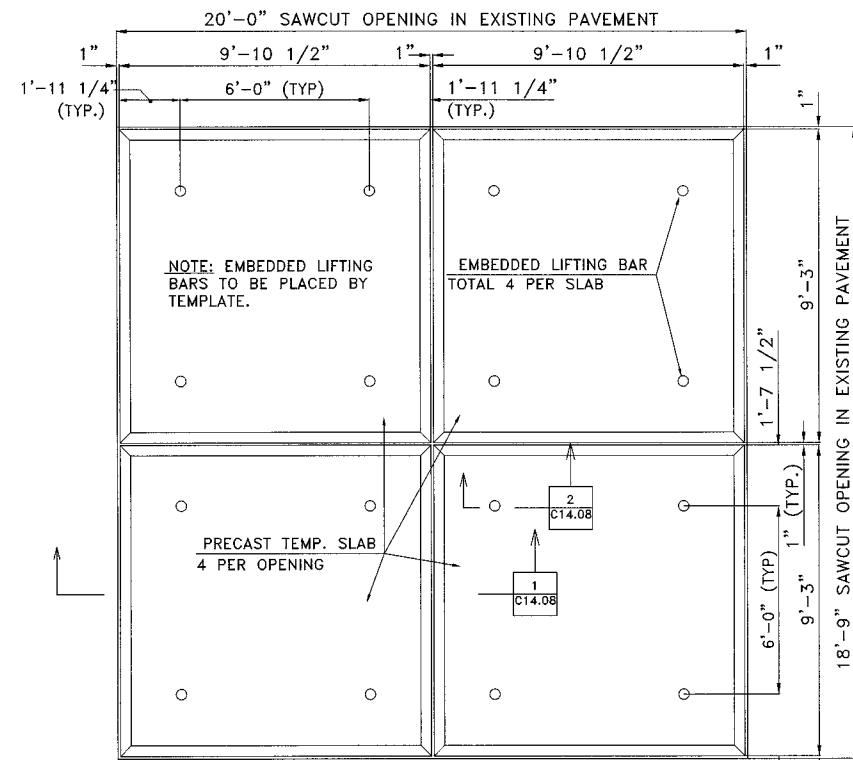
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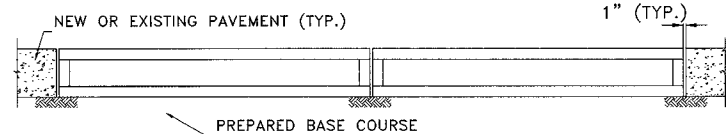
PROJECT MANAGER:  
JOHN R. ROTHNIE  
PROJECT ENGINEER:  
DENISE A. ALMOJUELA  
DESIGN ENGINEER:  
DENISE A. ALMOJUELA  
DRAFTER:  
MICHAEL A. CORPUZ  
SCALE:  
AS NOTED  
DATE:  
04/21/03  
CHECKED/APPROVED BY:  
JOHN R. ROTHNIE

**Port of Seattle**  
**SEA-TAC INTERNATIONAL AIRPORT**  
PROJECT: 2003 AIRFIELD IMPROVEMENT PROJECTS - CONTRACT 2  
RW 16R-34L SLAB REPLACEMENT  
SHEET TITLE: RW LIGHTING - NEW LIGHTING INSTALLATIONS

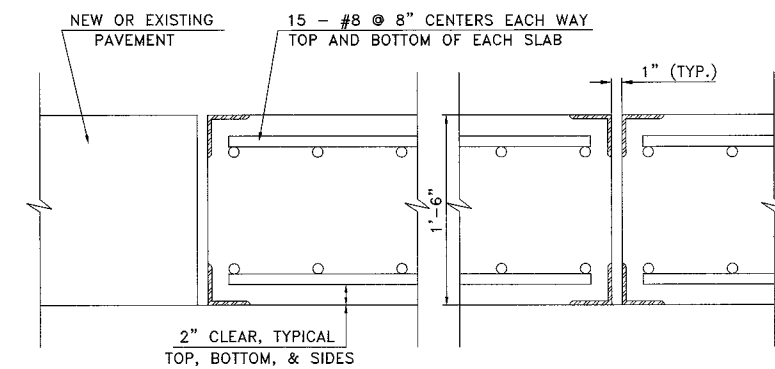
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CONSULTANT'S NO.  
C14.07  
PORT OF SEATTLE NO.  
STIA-0302-C14.07



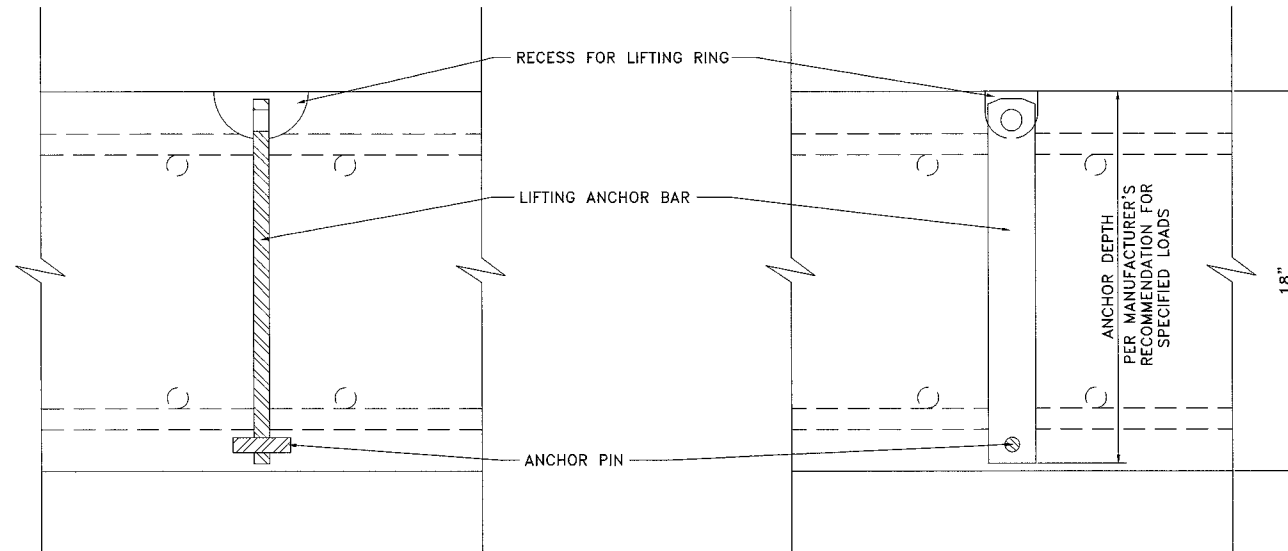
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PRECAST TEMPORARY PANELS  
SCALE: NOT TO SCALE



ELEVATION  
PRECAST TEMPORARY PANELS  
SCALE: NOT TO SCALE

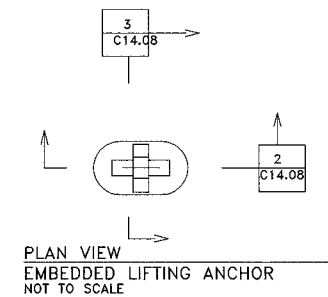


CROSS-SECTION  
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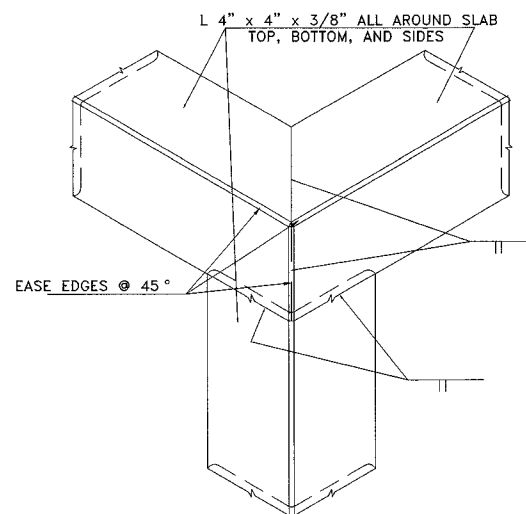


SECTION  
EMBEDDED LIFTING ANCHOR  
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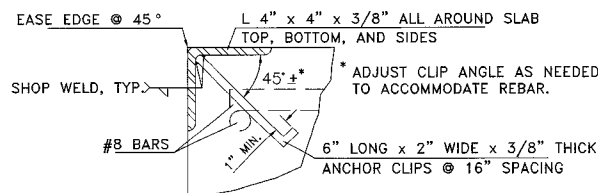
SECTION  
EMBEDDED LIFTING ANCHOR  
NOT TO SCALE



PLAN VIEW  
EMBEDDED LIFTING ANCHOR  
NOT TO SCALE



STEEL CORNER ARMOR  
FRAME CONNECTION DETAIL  
NOT TO SCALE



STEEL CORNER ARMOR  
ANCHOR DETAIL  
NOT TO SCALE

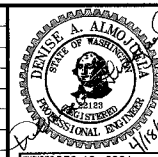
#### GENERAL NOTES

1. THE PLAN VIEW INDICATES FOUR PRECAST PANELS OF EQUAL SIZE TO TEMPORARILY FILL THE SPACE OF THE STANDARD 20'-0" X 18'-9" PERMANENT CONCRETE SLABS IN THE VARIOUS WORK AREAS. FOUR PANELS NOT EQUAL IN SIZE MAY BE USED AS LONG AS THE UNFILLED SPACES ON ALL SIDES OF EACH PANEL ARE NOT WIDER THAN ONE INCH.
2. EXISTING SLAB DIMENSIONS AND SHAPE VARY THROUGHOUT THE WORK AREAS. EXISTING SLABS SHALL BE SAWCUT AND THE SLAB REPLACEMENT SEQUENCED TO ACCOMMODATE TEMPORARY PANELS WHILE STILL PROVIDING A USEABLE SURFACE CAPABLE OF HANDLING AIRCRAFT TRAFFIC DURING NON-WORKING HOURS.
3. REPLACEMENT OF SOME CONCRETE SLABS WITH NON-STANDARD DIMENSIONS ARE REQUIRED AND ARE INDICATED ON THE PLANS. AT THESE LOCATIONS, THE CONTRACTOR SHALL PROVIDE TEMPORARY SPECIAL PRECAST PANELS OR PROPOSE OTHER MEANS OF PAVEMENT REMOVAL AND REPLACEMENT TO KEEP THE PAVEMENT USEABLE BY AIRCRAFT AND VEHICLES DURING NON-WORKING HOURS.
4. EACH TEMPORARY PANEL SHALL INCLUDE FOUR SYMMETRICALLY PLACED LIFTING ANCHORS. THE DRAWING INDICATES ONE SUGGESTED LIFTING SYSTEM. OTHER SYSTEMS MEETING REQUIREMENTS MAY BE PROPOSED BY THE CONTRACTOR. A LIFTING DEVICE WITH FOUR LIFTING POINTS SHALL BE PROVIDED SUCH THAT THE FORCE AT EACH LIFTING CONNECTION IN THE PANEL IS VERTICAL.
5. THE EMBEDDED ANCHORS AND OTHER LIFTING COMPONENTS SHALL BE DESIGNED FOR A CAPACITY OF AT LEAST FOUR TIMES THE ASSOCIATED PANEL DEAD LOAD.
6. NO PORTION OF THE EMBEDDED LIFTING ANCHORS SHALL EXTEND ABOVE THE TOP SURFACE OF THE PANELS. A SMALL RECESSED SPACE MAY BE FORMED AROUND THE EMBEDDED ANCHORS TO ALLOW THE CONNECTION OF LIFTING DEVICES. THE RECESSED SPACE SHALL NOT ALLOW AIRCRAFT AND VEHICLE TIRES TO COME IN CONTACT WITH THE LIFTING ANCHORS. COVER PLATES ATTACHED TO THE ANCHORS SHALL BE USED IF REQUIRED.
7. THE TOLERANCE FOR THE OVERALL HORIZONTAL AND VERTICAL DIMENSIONS OF THE PRECAST PANELS IS PLUS OR MINUS 1/4 INCH. PANELS OUT OF TOLERANCE WILL BE REJECTED.
8. ALL STEEL SHAPES SHALL BE ASTM A36 UNLESS OTHERWISE NOTED. ALL REINFORCING BARS SHALL BE GRADE 60. WELDING SHALL CONFORM TO ANSI/AWS D1.1-90.
9. THE CONTRACTOR'S SUBMITTAL SHALL INCLUDE THE DETAILS OF PANEL FABRICATION, LIFTING ANCHORS, LIFTING DEVICES AND COUPLINGS AND A MANUFACTURER'S CERTIFICATION THAT ALL COMPONENTS OF THE SYSTEM WILL MEET THE LOADING REQUIREMENTS WITH REPETITIVE USE. IN LIEU OF A CERTIFICATION, THE SUBMITTAL SHALL INCLUDE DESIGN CALCULATIONS PREPARED AND SEALED BY A STRUCTURAL ENGINEER LICENSED IN THE STATE OF WASHINGTON.
10. DURING EACH DAY OF USE, THE PRECAST PANELS SHALL BE INSPECTED BY THE CONTRACTOR FOR DAMAGE THAT COULD RESULT IN A LIFTING FAILURE, DEBRIS OR OTHER HAZARDS TO AIRCRAFT AND VEHICLES. DAMAGED PANELS SHALL BE REPAIRED OR REPLACED AT THE CONTRACTOR'S EXPENSE.
11. DETAILS SHOWN ON THIS DRAWING ARE REFERENCED AND APPLICABLE TO ALL PORTIONS OF WORK INCLUDED IN THIS CONTRACT.

CALL 48 HOURS  
BEFORE YOU DIG  
1-800-424-5555

PROJECT ENGR./ARCH:  
DESIGNER:  
DRAWN BY:  
SCALE:  
DATE:  
CHECKED BY:  
APPROVED BY:

REVISIONS									
NO.	DATE	BY	DESCRIPTION	APP'D	NO.	DATE	BY	DESCRIPTION	APP'D



PROJECT MANAGER:  
JOHN R. ROTHNIE  
PROJECT ENGINEER:  
DENISE A. ALMOJUELA  
DESIGN ENGINEER:  
DENISE A. ALMOJUELA  
DRAFTER:  
MICHAEL A. CORPUZ  
SCALE:  
AS NOTED  
DATE:  
04/21/03  
CHECKED/APPROVED BY:  
JOHN R. ROTHNIE

**Port of Seattle**  
**SEA-TAC INTERNATIONAL AIRPORT**  
PROJECT: **2003 AIRFIELD IMPROVEMENT PROJECTS - CONTRACT 2**  
**RW 16R-34L SLAB REPLACEMENT**  
SHEET TITLE: **TEMPORARY PANELS**

WORK ORDER NO.  
101646  
CONSULTANT'S NO.  
C14.08  
PORT OF SEATTLE NO.  
STIA-0302-C14.08

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## **Washington Dulles International Airport Runway 12-30 Slab Replacements**

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### **General Information**

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Airport: Washington Dulles International Airport

Owner: Metropolitan Washington Airport Authority

Airport Classification: Large Hub

Climatic Region: Wet Freeze

FAA Region: Eastern

Facility: Runway 12-30

Description of project: Major slab replacement and patching project performed over 40-hour weekend closure

Dates of construction: September/October 2002

Engineer/Designer: Burns & McDonnell

Program Manager/Construction Manager: Parsons Management Consultants

Prime Contractor: Cherry Hill Construction, Inc.

### **Project Overview**

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Continued deterioration and potential damage from foreign object debris (FOD) on Runway 12-30 at Dulles International Airport forced the Metropolitan Washington Airport Authority (MWAA) to initiate a pavement repair program even though the runway was slated for reconstruction within 2 years. Heavy traffic demands on Runway 12-30, the airport's primary departure runway, meant that measures had to be taken to limit the impact of the repairs on airport operations. The project was originally planned for night closures over four weekends, but ultimately ended up occurring over one 40-hour weekend closure.

The project included replacement of 27 portland cement concrete (PCC) slabs, as well as patching, joint sealing, and replacement of three lights. The project area is shown in figure A-31.

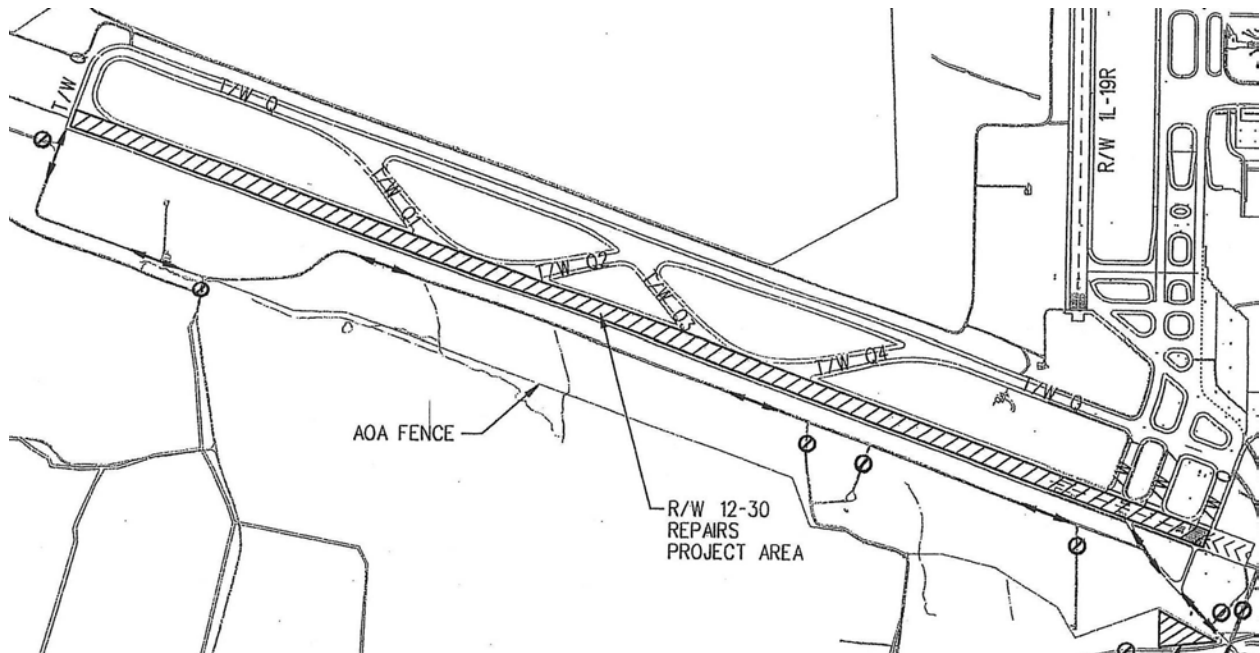


Figure A-31. Dulles International Airport project area.

## Key Project Components

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The key components to the success of this project are noted below and discussed in more detail in this case study document:

- Coordination of planning and phasing with all parties involved with the project.
- Use of high early strength concrete.
- Accelerated construction schedule over a 40-hour runway closure.
- Proper preparation by discussing all construction aspects and developing contingency plans.
- Construction schedule for a fast-track project.

## Planning

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Time constraints were the driving force when planning this runway project. Runway 12-30 is the primary departure runway at Dulles International Airport and is critical to the airport's overall operations. The project was originally designed and issued for bid during night closures (from 11:00 pm to 5:00 am) spread out over four weekends. Although the design team encouraged the Air Traffic Control Tower (ATCT) to be as liberal as possible in considering closure options, they would not agree to anything longer than a 12-hour per night closure. However, once the contract was awarded, the contractor was able to convince the airport that they could complete the entire project with a single 40-hour closure window with much less impact to operations. To address this issue on future projects, airport staff suggested that pricing be obtained from the contractor on various options as part of the bid process.

MWAA requests proposals rather than just bids, which allows them to make the selection based on the contractor's proposed plan and qualifications rather than simply accepting the lowest bid. This allows them to identify unqualified contractors and those with unreasonable bids, resulting in a better end product. On this particular project, one contractor came in with a significantly lower bid than all the other contractors, which raised a red flag about their understanding of the project.

The Program Manager/Construction Manager understood the importance of good communication on a construction project, especially a fast-track project. Two pre-construction meetings were held to work out all of the details for each construction step. Contingency plans were outlined, and questions such as the following were addressed before they became issues in the field:

- How will full-depth sawing be handled such that it does not consume a large portion of the closure time?
- If water is encountered under the PCC slabs, how will it be handled?
- What if there are electrical problems during the project?

Basically, a lot of “what if” questioning was done to ensure that everyone was prepared for potential problems that might be encountered in the field. All parties also recognized the need to have decision-makers on site at all times during construction.

Some of the items that came out of those meetings included the following:

- The contractor would employ multiple crews and foremen to remove the burden from a single crew and to prevent crews from working excessively long shifts.
- Light towers would be setup at every slab replacement, so work could be performed at any location at any time.
- All electrical lines would be located ahead of time.
- The contractor would keep electricians on hand in case of a power outage.
- Multiple pumps would be available in case water was observed in the hole after slab removal.

Most of these preparations proved to be useful during construction.

## **Design**

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The project required the replacement of 27 PCC slabs, with an existing PCC pavement thickness of 15 inches in the keel and 12 inches outside the keel. For slabs with an underlying cement-treated base (CTB), which was generally in good condition, the base was left in place and the 15-inch PCC pavement was replaced. For slabs with an underlying aggregate base, 3 inches of the base material were removed and either 15 or 18 inches of PCC was placed, depending on the original slab thickness. The slab replacement details are included at the end of this case study.

The specifications required a flexural strength of 500 psi for opening to traffic and a flexural strength of 725 psi at 28 days. The PCC mix design included 900 lbs of cementitious material, a superplasticizer, a high-range water reducer (24 oz), and an air-entraining agent (8 oz). This mix design was developed when the slab replacements were planned as night closures. The mix design could have, and probably should have, been altered once a longer weekend closure was granted. The inspector reported that the contractor encountered problems with the admixture in the field. Three sets of beams were required each night, and the contractor made two extra sets in case they were needed. The airport warned against specifying higher strengths than needed. The PCC P-501 specification used for this project is included at the end of this case study.

## **Construction**

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To help ensure that the work could be completed during the 40-hour closure, the airport allowed sawing to be performed during multiple nights before the scheduled closure. Sawcuts were made to the full depth of the existing pavement outside the keel and to half the slab thickness within the keel (to avoid rocking under traffic). The slabs were sawed into quarter panels, with an additional cut made 1 foot from the edge to avoid spalling of adjacent slabs during removal. The contractor used three saw crews, each using a successively larger blade (18-, 24-, and 36-inch diameter blades). The slabs with the full-depth sawcuts dropped about  $\frac{3}{4}$  to 1 inch, but did not pose a problem because as noted previously they were all located in the outer portion of the runway. After initial sawing, sand was placed in the joints to keep them from moving or rocking under traffic. The sand worked as intended, and also helped reduce damage to adjacent slabs during the slab removal stage.

The contractor used two 80-ton cranes to remove the PCC panels and reports that 60-ton cranes would not have been sufficient due to the suction created from the wet subgrade. The contractor drilled 2-inch I-pins at a 45-degree angle for lift supports. The inspector reported that the angled lifting pins can be a problem if the piece breaks during lifting, which happened several times on this project. The first panel within the slab was always the most difficult to remove due to the suction from the water underneath the slab. Once the first panel was removed, the remaining panels were removed more easily. Finally, the contractor used a grade-all to remove the smaller concrete pieces and to restore grade. The biggest issue was dealing with the water under the slabs. Pumps were often placed in the hole and in some cases ran continuously. Figures A-32 and A-33 are photos of the pavement removal process.





Figure A-32. Pavement removal process.



Figure A-33. Pavement removal

Dowels were placed in a typical manner. Two gang drills were used to drill holes for the dowel bars, which were 20-inch long, 1.25-inch diameter dowels placed at 12-inch centers. The crew placed dowels by dipping them into a bucket of two-part epoxy and inserting them into the hole. The contractor had chairs on site if needed to hold dowels in place, but they were not used often.

After the removal stage, a second crew, consisting of one superintendent and three foremen, arrived at about 9:00 am Saturday morning to start pouring the concrete (figure A-34). The first concrete truck arrived about 10:00 am. The contractor also had three finishing crews and one cover crew (for plastic and burlap) and had light plants set up at every hole. The importance of not only having enough people, but also having the right people to accomplish the work, was stressed.



Figure A-34. PCC placement on existing aggregate base course.

The concrete plant was located 4 miles from the airport, so delivery time was not an issue. The mix started with a slump of 3 to 4 inches in order to get down to 1.5 inches at the time of the pour. Additives were added on site, and the working time was limited to about 10 to 12 minutes. Because of the quick setting time of the mix, the contractor did not start any pour until enough trucks were on site to finish the hole. The crews had not worked with the mix until this project, which became apparent. In retrospect, the airport wishes they had required a test section be placed prior to the project. The finishers need to have experience with the available material and its handling and setting characteristics.

Plastic and wet burlap were used to facilitate curing, and the burlap was wet four times before re-opening to traffic. In some locations, multiple slabs were placed together. In these cases, joints were sawed 3 hours after paving. Joints were supposed to be sealed at a later date under a night closure, but that never happened.

The construction inspectors indicated that the contractor paved late Saturday night and into early Sunday morning, finishing later than planned and about 12 hours before re-opening. Due to the extended paving time, the crews were tired from the long shift, and the contractor had to bring in food for the crews during the long shift.

## **Other Issues**

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Based on their experience on this and other projects, project team members made the following suggestions for future projects:

- A test panel should be constructed in a non-critical area (such as an apron) to ensure that the contractor/crew fully understand the construction process and to give the crew experience working with the concrete (especially in cases when a rapid-set material is being used).
- For sawcutting existing PCC slabs, establish a pattern based on the existing cracks rather than using a standard saw pattern for each slab.
- TechCrete can be used for patching when time constraints dictate. It was not used on this particular project, but it has been successfully used for patching on other projects at Dulles International Airport.
- There is a need to have decision makers from all parties on site to quickly make decisions.

One problem that was encountered after replacing the slabs is that some panels cracked in the same location, indicating the cause(s) of the problem had not been addressed. Because this project was only intended to “buy some time” before the runway was reconstructed, it was not a problem on this particular project.

## **Summary**

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The project served its purpose by keeping the runway operational until it was reconstructed 2 years later. And there were positive experiences on this project that can be used on other projects. However, there were some specific processes during construction that could have been improved. For example, the concrete mix design should have been altered once it was decided to use a 40-hour weekend closure rather than multiple night closures. In addition, the airport wishes that it had required the contractor to construct a test section to allow them to get familiar with the construction process and the handling and setting characteristics of the concrete mix.

## **Available Sources of Information**

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The project team would like to acknowledge the valuable input and contributions of the following individuals for providing much of the information presented in this case study document:

- Sam Cramer, Cherry Hills Construction, Construction Superintendent
- Gary Fuselier, Metropolitan Washington Airport Authority
- Mike Hewitt, Parson Management Consultants
- Mark Petruso, Parsons Management Consultant, Construction Inspector

The following documents also provided valuable information used in this summary:

- General Requirements and Technical Specifications for Runway 12-30 Repairs FY02 developed by Burns & McDonnell.
- Project plans and drawings.
- Photographs provided by Mark Petruso.

## Contacts

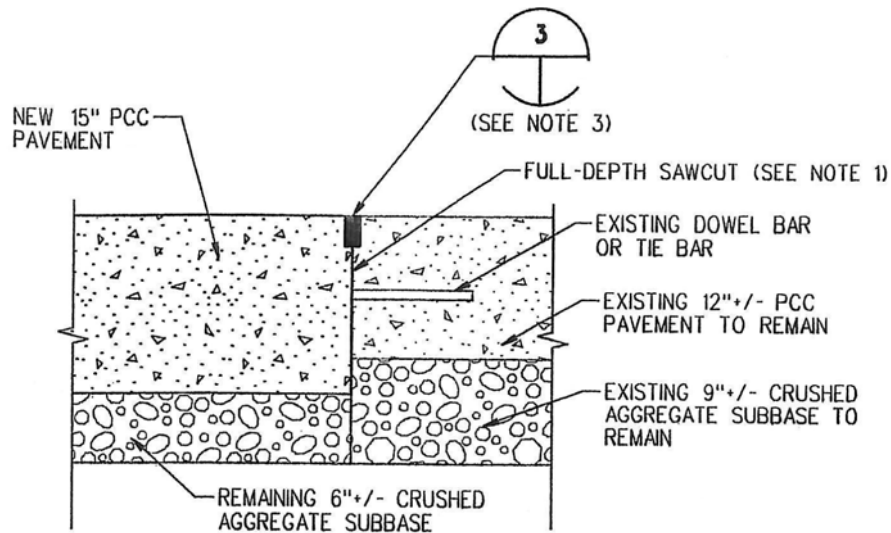
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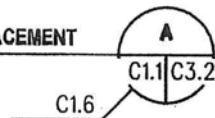
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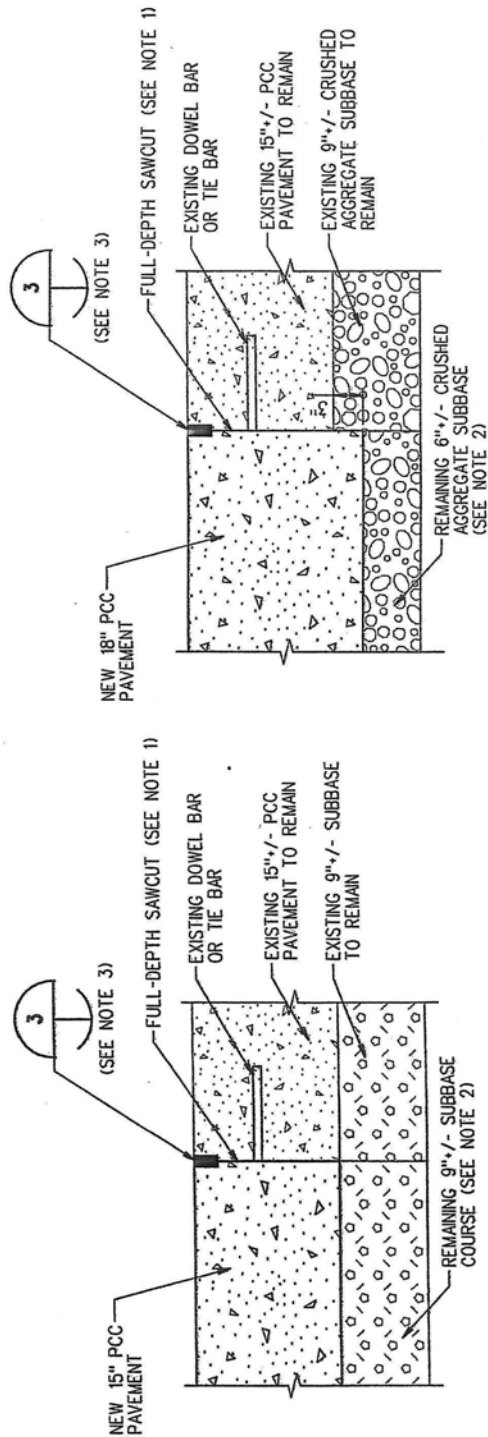
#### EXISTING 12" PCC SLAB REPLACEMENT

NOT TO SCALE



#### NOTES:

1. PRIOR TO REMOVAL OF EXISTING PCC PANELS, CONTRACTOR SHALL PERFORM TWO FULL-DEPTH SAWCUT OPERATIONS. THE FIRST FULL-DEPTH SAWCUT SHALL BE AT THE EXISTING EDGE JOINTS. THE SECOND FULL-DEPTH SAWCUT SHALL BE MADE ON THE SLAB INTERIOR 6 INCHES FROM THE INITIAL FULL-DEPTH SAWCUT.
2. CONTRACTOR SHALL REMOVE EXISTING 12" +/- PCC PAVEMENT AND REPLACE WITH 15" PCC PAVEMENT. TOP 3" OF EXISTING CRUSHED AGGREGATE SUBBASE COURSE SHALL BE REMOVED TO ACCOMMODATE NEW PCC PAVEMENT. EXISTING AGGREGATE SHALL BE COMPACTED WITH COMBINATION OF MECHANICAL PLATE TAMPER AND MANUAL HAND TAMPER TO THE SATISFACTION OF THE COTR TO CONSOLIDATE THE SURFACE.
3. ALL JOINTS AROUND THE PERIMETER OF THE SLAB SHALL BE RESEALED. RESEALING OF JOINTS SHALL BE INCIDENTAL TO THE SLAB REPLACEMENT.
4. PAYMENT SHALL BE MADE UNDER P-501-5.1.



SCENARIO A

SCENARIO B

EXISTING 15" PCC SLAB REPLACEMENT

NOT TO SCALE

C1.5, C1.6, C1.7

C1.4 C3.2

**NOTES:**

1. PRIOR TO REMOVAL OF EXISTING PCC PANELS, CONTRACTOR SHALL PERFORM TWO FULL-DEPTH SAWCUT OPERATIONS. THE FIRST FULL-DEPTH SAWCUT SHALL BE AT THE EXISTING EDGE JOINTS. THE SECOND FULL-DEPTH SAWCUT SHALL BE MADE ON THE SLAB INTERIOR 6 INCHES FROM THE INITIAL FULL-DEPTH SAWCUT.
2. THE SUBBASE COURSE MATERIAL IS INDICATED ON THE LAYOUT PLAN SHEETS. THE CONTRACTOR SHALL PLACE NEW PCC PAVEMENT THICKNESS PER THE CRITERIA BELOW:

**SCENARIO A.** IF THE EXISTING 9" +/- SUBBASE COURSE MATERIAL IS EITHER CEMENT-TREATED, ECONOCRETE, OR LEAN CONCRETE, THEN CONTRACTOR SHALL PLACE NEW 15" PCC PAVEMENT. IF SUBBASE IS DISTURBED DURING PCC PAVEMENT REMOVAL, THEN CONTRACTOR SHALL REMOVE SUBBASE MATERIAL AND PLACE 24" PCC PAVEMENT. EXISTING AGGREGATE SHALL BE COMPACTED WITH COMBINATION OF MECHANICAL PLATE TAMPER AND MANUAL HAND TAMPER TO THE SATISFACTION OF THE CONTRACTOR TO CONSOLIDATE THE SURFACE.

**SCENARIO B.** IF THE EXISTING 9" +/- SUBBASE COURSE MATERIAL IS CRUSHED AGGREGATE, THEN CONTRACTOR SHALL PLACE NEW 18" PCC PAVEMENT. CONTRACTOR SHALL REMOVE TOP 3" OF CRUSHED AGGREGATE SUBBASE TO ACCOMMODATE NEW PCC PAVEMENT. SUBGRADE SHALL BE COMPACTED WITH COMBINATION OF MECHANICAL PLATE TAMPER AND MANUAL HAND TAMPER TO THE SATISFACTION OF THE CONTRACTOR TO CONSOLIDATE THE SURFACE.

3. ALL JOINTS AROUND THE PERIMETER OF THE SLAB SHALL BE SEALED. SEALING OF JOINTS SHALL BE INCIDENTAL TO THE SLAB REPLACEMENT.
4. PAYMENT SHALL BE MADE UNDER P-501-5.2.

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ITEM P-501 - PORTLAND CEMENT CONCRETE PAVEMENT

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DESCRIPTION

501-1.1 This Work shall consist of pavement composed of portland cement concrete, with and without reinforcement constructed on a prepared underlying surface in accordance with these specifications and shall conform to the lines, grades, thickness, and typical cross sections shown on the plans.

501-1.2 QUALITY ASSURANCE.

a. Reference Standards. Meet requirements of the referenced standards except to the extent more detailed or stringent requirements are indicated by the Contract Documents, including requirements of this Section and of governing codes and regulations.

b. Compliance with Laws, Codes, Rules, and Regulations. Comply with all local, State, and Federal laws, rules, and regulations applicable to this Section and to the selective demolition work to be done.

501-1.3 SUBMITTALS. Furnish shop drawings, manufacturer's data, test reports and materials certifications for all materials required in the referenced section, including:

- a. Aggregates.
- b. Cement.
- c. Cementitious Materials.
- d. Premolded Joint Filler.
- e. Steel Reinforcement.
- f. Dowel and Tie Bars.
- g. Dowel Bar Paint.
- h. Dowel Bar Assembly.
- i. Water.
- j. Liquid Curing Compound.
- k. Admixtures.
- l. Epoxy-resin.
- m. Mix-design.
- n. Testing Laboratory Certification.
- o. Testing laboratory personnel qualifications.
- p. Certifications for batch plant, mixers and transportation equipment.
- q. Freight and weigh bills.
- r. Concrete Batch Tickets.

PORTLAND CEMENT CONCRETE PAVEMENT  
INHP501.FIN

P-501 - 1

## MATERIALS

### 501-2.1 AGGREGATES.

a. Reactivity. Aggregate shall be free of substances that are deleteriously reactive with the alkalis in the cement in an amount sufficient to cause excessive expansion of the concrete. Acceptable aggregate shall be based on satisfactory evidence furnished by the Contractor that the aggregate is free from such materials. This evidence shall include service records of concrete of comparable properties under similar conditions of exposure and/or certified records of tests by a testing laboratory that meets the requirements of ASTM C 1077. Tests shall be made in accordance with ASTM C 295 and ASTM C 289.

b. Fine Aggregate. Fine aggregate shall conform to the requirements of ASTM C 33. Gradation shall meet the requirements of Table 1 when tested in accordance with ASTM C 136, except as may otherwise be qualified under Section 5 of ASTM C 33.

TABLE 1. GRADATION FOR FINE AGGREGATE  
(ASTM C 33)

<u>Sieve Designation</u> <u>(Square Openings)</u>	<u>Percentage by Weight</u> <u>Passing Sieves</u>
3/8 in.	100
No. 4	95-100
No. 8	80-100
No. 16	50-85
No. 30	25-60
No. 50 (300 micro-m)	10-30
No. 100 (150 micro-m)	2-10

c. Coarse Aggregate. Coarse aggregate shall conform to the requirements of ASTM C 33. Gradation, within the separated size groups, shall meet the requirements of Table 2 when tested in accordance with ASTM C 136. When the nominal maximum size of the aggregate is greater than 1 inch, the aggregates shall be furnished in two size groups.

Aggregates delivered to the mixer shall consist of crushed stone, crushed or uncrushed gravel, air-cooled blast furnace slag, crushed recycled concrete pavement, or a combination thereof. The aggregate shall be composed of clean, hard, uncoated particles and shall meet the requirements for deleterious substances contained in ASTM C 33, Class 4S. Dust and other coating shall be removed from the aggregates by washing. The aggregate in any size group shall not contain more than 8 percent by weight of flat or elongated pieces when tested in accordance with ASTM D 4791. A flat or elongated particle is one having a ratio between the maximum and the minimum dimensions of a circumscribing rectangular prism exceeding 5 to 1.



The percentage of wear shall be no more than 40 when tested in accordance with ASTM C 131 or ASTM C 535.

TABLE 2. GRADATION FOR COARSE AGGREGATE

(ASTM C 33)

<u>Sieve Designations</u> <u>(square openings)</u>	<u>Percentage by Weight Passing Sieves</u>
in.	1"-No.4
2-1/2	---
2	---
1-1/2	100
1	95-100
3/4	---
1/2	25-60
3/8	---
No. 4	0-10
No. 8	0-5

D. Aggregate Certifications. Certifications and testing results shall be provided for the referenced criteria and standards. The certifications and test results shall be no older than 6 months.

**501-2.2 CEMENT.** Cement shall conform to the requirements of ASTM C 150 Type III or specialty cements. If specialty cements are proposed, a manufacturer's representative shall be on site during the test panel replacement and the first full night of panel replacement work. Only cements containing less than 0.7% equivalent alkali or cements which can demonstrate a positive reduction in the expansion created by alkali-silica reactions shall be used.

If for any reason, cement becomes partially set or contains lumps of caked cement, it shall be rejected. Cement salvaged from discarded or used bags shall not be used.

**501-2.3 CEMENTITIOUS MATERIALS.**

a. Fly Ash. Fly ash shall meet the requirements of ASTM C 618, Class C, F, or N with the exception of loss of ignition, where the maximum shall be less than 6 percent for Class F or N. The supplementary optional chemical and physical properties of Tables 1A and 2A contained in ASTM C 618 shall apply. Fly ash as is produced in furnace operations utilizing liming materials or soda ash (sodium carbonate) as an additive shall not be acceptable.

b. Blast Furnace Slag. Ground blast furnace slag will be considered for use upon submittal of technical data and appropriate cost credit from the Contractor. If approved for use, ground blast furnace slag shall meet the requirements of ASTM C989, Grade 120.

**501-2.4 PREMOLDED JOINT FILLER.** Premolded joint filler for expansion joints shall conform to the requirements of ASTM D 1751 or ASTM D 1752, Type II or III and shall be punched to admit the dowels where called for on the plans. The filler for each joint shall be furnished in a single piece for the full depth and width required for the joint, unless otherwise specified by the COTR. When the use of more than one piece is required for a joint, the abutting ends shall be fastened securely and held accurately to shape by stapling or other positive fastening means satisfactory to the COTR.

**501-2.5 JOINT SEALER.** The joint sealer for the joints in the concrete pavement shall meet the requirements of Item P-605 and shall be of the type(s) specified in the plans.

**501-2.6 STEEL REINFORCEMENT.** Reinforcing shall consist of welded steel wire fabric conforming to the requirements of ASTM A 185. Welded wire fabric shall be furnished in flat sheets only. Reinforcing bars shall consist of deformed steel conforming to the requirements of ASTM A 615, grade 60, as shown on the plans.

**501-2.7 DOWEL AND TIE BARS.** Tie bars shall be deformed steel bars and conform to the requirements of ASTM A 615, ASTM A 616, or ASTM A 617, except that rail steel bars, Grade 50 or 60, shall not be used for tie bars that are to be bent or restraightened during construction. Tie bars designated as Grade 40 in ASTM A 615 can be used for construction requiring bent bars.

Dowel bars shall be plain steel bars conforming to ASTM A 615, ASTM A 616 or ASTM A 617 and shall be free from burring or other deformation restricting slippage in the concrete. High strength dowel bars shall conform to ASTM A 714, Class 2, Type S, Grade I, II or III, Bare Finish. Before delivery to the construction site each dowel bar shall be painted on all surfaces with one coat of paint meeting Federal Specification TT-P-664. If plastic or epoxy-coated steel dowels are used no paint coating is required, except when specified for a particular situation on the plans. Coated dowels shall conform to the requirements of AASHTO M 254.

**501-2.8 WATER.** Water used in mixing or curing shall be clean and free of oil, salt, acid, alkali, sugar, vegetable, or other substances injurious to the finished product. Water will be tested in accordance with the requirements of AASHTO T 26. Water known to be of potable quality may be used without testing.

**501-2.9 COVER MATERIAL FOR CURING.** Only the following curing material shall be used:

Liquid membrane-forming compounds for curing concrete shall conform to the requirements of ASTM C 309, Type 2, Class B.

**501-2.10 ADMIXTURES.** The use of any material added to the concrete mix shall be approved by the COTR. The Contractor shall submit certificates indicating that the material to be furnished meets all of the requirements indicated below. In addition, the COTR may require the Contractor to submit complete test data from an approved laboratory showing that the material to be furnished meets all of the requirements of the cited specifications. Subsequent tests may be made of samples taken by the COTR from the supply of the

material being furnished or proposed for use on the work to determine whether the admixture is uniform in quality with that approved.

a. Air-Entraining Admixtures. Air-entraining admixtures shall meet the requirements of ASTM C 260 and shall consistently entrain the air content in the specified ranges under field conditions. The air-entrainment agent and any water reducer admixture shall be compatible.

b. Chemical Admixtures. Water-reducing, set retarding, and set-accelerating admixtures shall meet the requirements of ASTM C 494, including the flexural strength test. If specialty admixtures are used to obtain set-acceleration, the Contractor's representative shall be on site during the test panel replacement and the first night of full night of panel replacement work.

**501-2.11 EPOXY-RESIN.** Epoxy-resin used to anchor dowels and tie bars in pavements shall conform to the requirements of ASTM C 881, Type I, Grade 3, Class C. Class A or B shall be used when the surface temperature of the hardened concrete is below 60 degrees F. In addition, the materials shall meet the following requirements:

(1) All materials shall have a 24 hour absorption not greater than 1.0 percent.

(2) Epoxy Resin Materials for bonding freshly mixed portland cement concrete or mortar or freshly mixed epoxy resin concrete or mortar to hardened concrete shall be Type II materials, grade as approved.

(3) Epoxy Resin Materials for use as patching materials for complete filling of spalls, wide cracks and other voids, for use for embedding dowels and anchor bolts, and for use as a binder in preparing epoxy resin mortars and concretes shall be Type III materials and shall in addition meet the following requirements:

A. The bond strength at 14 days (moist cure) shall be at least 1000 psi.

B. The volatile content, cured system, shall not exceed 3.0 percent. Grade shall be approved except that Grade 3 shall be used for embedding dowels in hardened concrete.

**501-2.12 MATERIAL ACCEPTANCE.** Prior to use of materials, the Contractor shall submit certified test reports to the COTR for those materials proposed for use during construction. The certification shall show the appropriate ASTM test(s) for each material, the test results, and a statement that the material passed or failed.

The COTR may request samples for testing, prior to and during production, to verify the quality of the materials and to ensure conformance with the applicable specifications.

**501-2.13** Each truckload of Ready Mix Cement Concrete shall furnish a ticket or tape that shall provide the following information:

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**INHP501.FIN**

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- a. The quantity or batched weights and respective contract tolerances of each aggregate, cement, water, and admixture.
  - b. The water/cement ratio of the concrete.
  - c. The zero balance conditions of each scale after batches have been discharged, or prior to start of the batching operations.
  - d. A means of identifying each admixture required.
  - e. The time and date that cementitious material was added to the mix.
  - f. The time and date of each batch delivered.
  - g. Identification of each class of concrete.
  - h. Batch number for each batch delivered.
  - i. The number of the truck delivering the concrete.
  - j. Contract identification.

#### MIX DESIGN

**501-3.1 PROPORTIONS.** Concrete shall be designed to achieve a 28-day flexural strength that meets or exceeds the acceptance criteria contained in paragraph 501-5.2 for a flexural strength of 725 psi. The concrete shall also be designed to achieve a flexural strength of 500 psi in 6 hours or prior to the end of the work shift if it occurs less than 6 hours after placement. The mix shall be designed using the procedures contained in Chapter 7 of the Portland Cement Association's manual, "Design and Control of Concrete Mixtures".

The Contractor shall note that to ensure that the concrete actually produced will meet or exceed the acceptance criteria for the specified strength, the mix design average strength must be higher than the specified strength. The amount of overdesign necessary to meet specification requirements depends on the producer's standard deviation of flexural test results and the accuracy which that value can be estimated from historic data for the same or similar materials.

The minimum cementitious material (cement plus fly ash) shall be 611 pounds per cubic yard. The ratio of water to cementitious material, including free surface moisture on the aggregates but not including moisture absorbed by the aggregates shall not be more than 0.45 by weight.

Prior to the start of paving operations and after approval of all material to be used in the concrete, the Contractor shall submit a mix design showing the proportions and flexural strength obtained from the concrete at 4 hours, 6 hours, 8 hours and 28 days. The mix design shall include copies of test reports, including test dates, and a complete list of materials including type, brand, source, and amount of; cement, fly ash, ground slag, coarse aggregate, fine aggregate, water, and admixtures. The fineness modulus of the fine aggregate and the air content shall also be shown. The mix design shall be submitted to the COTR at least 15 days prior to the start of operations. Production shall not begin until the mix design is approved in writing by the COTR.

Should a change in sources be made, or admixtures added or deleted from the mix, a new mix design must be submitted to the COTR for approval. Mix designs older than 90 days shall not be used.

Flexural strength test specimens shall be prepared in accordance with ASTM C 31 and tested in accordance with ASTM C 78. The mix determined shall be workable concrete having a slump for side-form concrete between 1 and 2 inches as determined by ASTM C 143.

#### 501-3.2 CEMENTITIOUS MATERIALS.

a. Fly Ash. Fly ash may be used in the mix design. When fly ash is used as a partial replacement for cement, the minimum cement content may be met by considering portland cement plus fly ash as the total cementitious material. The replacement rate shall be determined from laboratory trial mixes, but shall not exceed 15 percent by weight of the total cementitious material.

b. Ground Slag. If approved for use, ground blast furnace slag may be used in a mix design containing Type I or Type II cement. The slag, or slag plus fly ash if both are used, may constitute between 25 to 55 percent (subject to COTR approval) of the total cementitious material by weight. If the concrete is to be used for slipforming operations and the air temperature is expected to be lower than 55 degrees F the percent slag shall not exceed 30 percent by weight.

#### 501-3.3 ADMIXTURES.

a. Air-Entraining. Air-entraining admixture shall be added in such a manner that will insure uniform distribution of the agent throughout the batch. The air content of freshly mix air-entrained concrete shall be based upon trial mixes with the materials to be used in the work adjusted to produce concrete of the required plasticity and workability. The percentage of air in the mix shall be 6.0 percent  $\pm$  1 percent. Air content shall be determined by testing in accordance with ASTM C 231 for gravel and stone coarse aggregate and ASTM C 173 for slag and other highly porous coarse aggregate.

b. Chemical. Water-reducing, set-controlling, and other approved admixtures shall be added to the mix in the manner recommended by the manufacturer and in the amount necessary to comply with the specification requirements. Tests shall be conducted on trial mixes, with the materials to be used in the work, in accordance with ASTM C 494.

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**501-3.4 TESTING LABORATORY.** The laboratory used to develop the mix design shall meet the requirements of ASTM C 1077. A certification that it meets these requirements shall be submitted to the COTR prior to the start of mix design and shall contain as a minimum:

- a. Qualifications of personnel; laboratory manager, supervising technician, and testing technicians.
- b. A statement that the equipment used in developing the mix design is in calibration.
- c. A statement that each test specified in developing the mix design is offered in the scope of the laboratory's services.
- d. A copy of the laboratory's quality control system.

#### **CONSTRUCTION METHODS**

**501-4.1 EQUIPMENT.** The Contractor shall furnish all equipment and tools necessary for handling materials and performing all parts of the work.

- a. Batch Plant and Equipment. The batch plant and equipment shall conform to the requirements of ASTM C 94.

- b. Mixers and Transportation Equipment.

(1) General. Concrete may be mixed at a central plant, or wholly or in part in truck mixers. Each mixer shall have attached in a prominent place a manufacturer's nameplate showing the capacity of the drum in terms of volume of mixed concrete and the speed of rotation of the mixing drum or blades.

(2) Central plant mixer. Central plant mixers shall conform to the requirements of ASTM C 94.

The mixer shall be examined daily for changes in condition due to accumulation of hard concrete or mortar or wear of blades. The pickup and throwover blades shall be replaced when they have worn down 3/4 inch or more. The Contractor shall have a copy of the manufacturer's design on hand showing dimensions and arrangement of blades in reference to original height and depth.

(3) Truck mixers and truck agitators. Truck mixers used for mixing and hauling concrete and truck agitators used for hauling central-mixed concrete shall conform to the requirements of ASTM C 94.

(4) Nonagitator trucks. Nonagitating hauling equipment shall conform to the requirements of ASTM C 94.

c. **Finishing Equipment.** The finishing equipment shall be sufficient for proper finishing of the concrete. The finishing equipment shall be designed and operated to strike off, screed and consolidate the concrete such that laitance on the surface is less than 1/8-inch thick.

d. **Vibrators.** Vibrator shall be surface type vibrating pan or screed. Operating frequencies for surface vibrators shall be between 3,000 and 6,000 vibrations per minute.

Hand held vibrators shall be used in combination with surface type vibrators. The combination and use of vibrators shall be as necessary to provide a dense and homogeneous pavement.

e. **Concrete Saws.** The Contractor shall provide sawing equipment adequate in number of units and power to complete the sawing to the required dimensions. The Contractor shall provide at least one standby saw in good working order and a supply of saw blades at the site of the work at all times during sawing operations.

**501-4.2 FORM SETTING.** Not Used.

**501-4.3 CONDITIONING OF UNDERLYING SURFACE, SLIP-FORM CONSTRUCTION.** Not Used.

**501-4.4 CONDITIONING OF UNDERLYING SURFACE.** The prepared underlying surface shall be moistened with water, without saturating, immediately ahead of concrete placement to prevent rapid loss of moisture from the concrete. Damage caused by hauling or usage of other equipment shall be corrected and retested at the option of the COTR. If damage occurs to a stabilized subbase, it shall be corrected full depth by the Contractor. All excess material shall be removed and wasted. Low areas shall be filled and compacted to a condition similar to that of the surrounding grade. The underlying surface shall be protected so that it will be entirely free from frost when the concrete is placed. The use of chemicals to eliminate frost in the underlying surface shall not be permitted.

**501-4.5 HANDLING, MEASURING, AND BATCHING MATERIAL.** The batch plant site, layout, equipment, and provisions for transporting material shall assure a continuous supply of material to the work. Stockpiles shall be constructed in such a manner that prevents segregation and intermixing of deleterious materials.

Aggregates that have become segregated or mixed with earth or foreign material shall not be used. All aggregates produced or handled by hydraulic methods, and washed aggregates, shall be stockpiled or binned for draining at least 12 hours before being batched. Rail shipments requiring more than 12 hours will be accepted as adequate binning only if the car bodies permit free drainage.

Batching plants shall be equipped to proportion aggregates and bulk cement, by weight, automatically using interlocked proportioning devices of an approved type. When bulk cement is used, the Contractor shall use a suitable method of handling the cement from weighing hopper to transporting container or into the batch itself for transportation to the mixer, such as a chute,



boot, or other approved device, to prevent loss of cement. The device shall be arranged to provide positive assurance that the cement content specified is present in each batch.

**501-4.6 MIXING CONCRETE.** The concrete may be mixed at the work site, in a central mix plant or in truck mixers. The mixer shall be of an approved type and capacity. Mixing time shall be measured from the time all materials, except water, are emptied into the drum. All concrete shall be mixed and delivered to the site in accordance with the requirements of ASTM C 94. Mixed concrete from the central mixing plant shall be transported in truck mixers, truck agitators, or nonagitator trucks. The elapsed time from the addition of cementitious material to the mix until the concrete is deposited in place at the work site shall not exceed 30 minutes when the concrete is hauled in nonagitator trucks, nor 90 minutes when the concrete is hauled in truck mixers or truck agitators. Retempering concrete by adding water or by other means will not be permitted, except when concrete is delivered in transit mixers. With transit mixers additional water may be added to the batch materials and additional mixing performed to increase the slump to meet the specified requirements provided the addition of water is performed within 45 minutes after the initial mixing operations and provided the water/cementitious ratio specified in the mix design is not exceeded.

**501-4.7 LIMITATIONS ON MIXING AND PLACING.** No concrete shall be mixed, placed, or finished when the natural light is insufficient, unless an adequate and approved artificial lighting system is operated.

a. Cold Weather. Unless authorized in writing by the COTR, mixing and concreting operations shall be discontinued when a descending air temperature in the shade and away from artificial heat reaches 40 degrees F and shall not be resumed until an ascending air temperature in the shade and away from artificial heat reaches 35 degrees F.

The aggregate shall be free of ice, snow, and frozen lumps before entering the mixer. The temperature of the mixed concrete shall not be less than 50 degrees F at the time of placement. Concrete shall not be placed on frozen material nor shall frozen aggregates be used in the concrete.

When concreting is authorized during cold weather, water and/or the aggregates may be heated to not more than 150 degrees F. The apparatus used shall heat the mass uniformly and shall be arranged to preclude the possible occurrence of overheated areas which might be detrimental to the materials.

b. Hot Weather. During periods of hot weather when the maximum daily air temperature exceeds 85 degrees F, the following precautions shall be taken.

(1) The forms and/or the underlying surface shall be sprinkled with water immediately before placing the concrete. The concrete shall be placed at the coolest temperature practicable, and in no case shall the temperature of the concrete when placed exceed 95 degrees F. The aggregates and/or mixing water shall be cooled as necessary to maintain the concrete temperature at or not more than the specified maximum.

(2) The finished surfaces of the newly laid pavement shall be kept damp by applying a water-fog or mist with approved spraying equipment until the pavement is covered by the curing medium. If necessary, wind screens shall be provided to protect the concrete from an evaporation rate in excess of 0.2 psf per hour.



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as determined in accordance with Figure 2.1.5 in ACI 305R, Hot Weather Concreting, which takes into consideration relative humidity, wind velocity, and air temperature.

(3) When conditions are such that problems with plastic cracking can be expected, and particularly if any plastic cracking begins to occur, the Contractor shall immediately take such additional measures as necessary to protect the concrete surface. Such measures shall consist of wind screens, more effective fog sprays, and similar measures commencing immediately behind the paver. If these measures are not effective in preventing plastic cracking, paving operations shall be immediately stopped.

**501-4.8 PLACING CONCRETE.** At any point in concrete conveyance, the free vertical drop of the concrete from one point to another or to the underlying surface shall not exceed 3 feet.

All embedments such as tie bars, dowels, transformer bases, conduits, sleeves, underdrains, and all other items indicated on the plans or directed to be embedded shall be placed and/or securely anchored before concrete is placed. Concreting shall not be started until the embedment items have been checked and approved for alignment and location. All embedded items must be secured and/or protected so as not to be disturbed by concrete operations.

Hauling equipment or other mechanical equipment can be permitted on adjoining previously constructed pavement when the concrete strength reaches a flexural strength of 550 psi based on the average of two field cured specimens per lot of concrete placed.

The concrete shall be deposited on the moistened grade to require as little rehandling as possible. Unless truck mixers, truck agitators, or nonagitating hauling equipment are equipped with means for discharge of concrete without segregation of the materials, the concrete shall be placed and spread using an approved mechanical spreading device that prevents segregation of the materials. Placing shall be continuous between transverse joints without the use of intermediate bulkheads. Necessary hand spreading shall be done with shovels--not rakes. Workmen shall not be allowed to walk in the freshly mixed concrete with boots or shoes coated with earth or foreign substances.

Concrete shall be deposited as near to expansion and contraction joints as possible without disturbing them but shall not be dumped from the discharge bucket or hopper onto a joint assembly unless the hopper is centered above the joint assembly.

Concrete shall be thoroughly consolidated against and along the faces of all existing concrete and along the full length and on both sides of all joint assemblies by means of vibrators inserted in the concrete. Vibrators shall not be permitted to come in contact with a joint assembly, the grade, or a side form. In no case shall the vibrator be operated longer than 20 seconds in any one location, nor shall the vibrators be used to move the concrete.

**501-4.9 STRIKE-OFF OF CONCRETE AND PLACEMENT OF REINFORCEMENT.** Following the placing of the concrete, it shall be struck off to conform to the cross section shown on the plans and to an elevation such that when the concrete is properly consolidated and finished, the surface of the pavement shall

be at the elevation shown on the plans. When reinforced concrete pavement is placed in two layers, the bottom layer shall be struck off to such length and depth that the sheet of reinforcing steel fabric or bar mat may be laid full length on the concrete in its final position without further manipulation. The reinforcement shall then be placed directly upon the concrete, after which the top layer of the concrete shall be placed, struck off, and screeded. If any portion of the bottom layer of concrete has been placed more than 30 minutes without being covered with the top layer or if initial set has taken place, it shall be removed and replaced with freshly mixed concrete at the Contractor's expense. When reinforced concrete is placed in one layer, the reinforcement may be positioned in advance of concrete placement or it may be placed in plastic concrete by mechanical or vibratory means after spreading.

Reinforcing steel, at the time concrete is placed, shall be free of mud, oil, or other organic matter that may adversely affect or reduce bond. Reinforcing steel with rust, mill scale or a combination of both will be considered satisfactory, provided the minimum dimensions, weight, and tensile properties of a hand wire-brushed test specimen are not less than the applicable ASTM specification requirements.

**501-4.10 JOINTS.** Joints shall be constructed as shown on the plans and in accordance with these requirements. All joints shall be constructed with their faces perpendicular to the surface of the pavement and finished or edged as shown on the plans. Joints shall not vary more than 1/2 inch from their designated position and shall be true to line with not more than 1/4-inch variation in 10 feet. The surface across the joints shall be tested with a 10-foot straightedge as the joints are finished and any irregularities in excess of 1/4 inch shall be corrected before the concrete has hardened. All joints shall be so prepared, finished, or cut to provide a groove of uniform width and depth as shown on the plans.

a. Construction. Construction joints shall be formed against existing concrete as shown in the plans.  
b. Contraction. Contraction joints shall be installed at the locations and spacing as shown on the plans. Contraction joints shall be installed to the dimensions required by forming a groove or cleft in the top of the slab while the concrete is still plastic or by sawing a groove into the concrete surface after the concrete has hardened. When the groove is formed in plastic concrete the sides of the grooves shall be finished even and smooth with an edging tool. If an insert material is used, the installation and edge finish shall be according to the manufacturer's instructions. The groove shall be finished or cut clean so that spalling will be avoided at intersections with other joints. Grooving or sawing shall produce a slot at least 1/8 inch wide and to the depth shown on the plans.

c. Tie bars. Tie bars shall consist of deformed bars installed in joints as shown on the plans. Tie bars shall be placed at right angles to the centerline of the concrete slab and shall be spaced at intervals shown on the plans. They shall be held in position parallel to the pavement surface and in the middle of the slab depth. When tie bars extend into an unpaved lane, they may be bent against the form at longitudinal construction joints, unless threaded bolt or other assembled tie bars are specified. These bars shall not be painted, greased, or enclosed in sleeves. When slip-form operations call for tie bars, two-piece hook bolts can be installed in the female side of the keyed joint provided the installation is made without distorting the keyed dimensions or causing edge slump. If a bent tie bar installation is used, the tie bars shall be inserted through the keyway liner only on the female side of the joint. In no case shall a bent tie bar installation for male keyways be permitted.

d. Dowel bars. Dowel bars or other load-transfer units of an approved type shall be placed across joints in the manner as shown on the plans. They shall be of the dimensions and spacings as shown and held rigidly in the middle of the slab depth in the proper horizontal and vertical alignment by an approved assembly device to be left permanently in place. The dowel or load-transfer and joint devices shall be rigid enough to permit complete assembly as a unit ready to be lifted and placed into position. The portion of each dowel painted with rust preventative paint, as required under paragraph 501-2.7, shall be thoroughly coated with grease, oil, or an approved lubricant, to prevent the concrete from bonding to that portion of the dowel. If free-sliding plastic-coated or epoxy-coated steel dowels are used, a lubrication bond breaker shall be used except when approved pullout tests indicate it is not necessary. Where butt-type joints with dowels are designated, the exposed end of the dowel shall be oiled.

Dowel bars at contraction joints may be placed in the full thickness of pavement by a mechanical device approved by the COTR. The device shall be capable of installing dowel bars within the maximum permissible alignment tolerances. Dowels bars at longitudinal construction joints shall be bonded in drilled holes.

The top of an assembled joint device shall be set at the proper distance below the pavement surface and the elevation shall be checked. Such devices shall be set to the required position and line and shall be securely held in place by stakes or other means to the maximum permissible tolerances during the pouring and finishing of the concrete. The premolded joint material shall be placed and held in a vertical position; if constructed in sections, there shall be no offsets between adjacent units.

Dowel bars and assemblies shall be checked for position and alignment. The maximum permissible tolerances on dowel bar alignment shall be in accordance with paragraph 501-5.2e(6). During the concrete placement operation, it is advisable to place plastic concrete directly on dowel assemblies immediately prior to passage of the paver to help maintain dowel position and alignment within maximum permissible tolerances.

Dowels and tie bars shall be placed in existing concrete as illustrated on the plans by bonding the dowels or tie bars into holes drilled into the hardened concrete. Holes approximately 1/8-inch to 1/4-inch greater in diameter than the dowel or tie bar shall be drilled with rotary-type core drills that must be held securely in place to drill perpendicularly into the vertical face of the pavement slab. Rotary-type percussion drills may be used provided that spalling of concrete does not occur and the concrete has cured a minimum of 48 hours. Any damage of the concrete shall be repaired by the Contractor in a method approved by the COTR. Dowels or tie bars shall be bonded in the drilled holes using an epoxy resin material. Installation procedures shall be adequate to insure that the area around dowels is completely filled with epoxy grout. Epoxy shall be injected into the back of the hole and displaced by the insertion of the dowel bar. Bars shall be completely inserted into the hole and shall not be withdrawn and reinserted creating air pockets in the epoxy around the bar. The Contractor shall furnish a template for checking the position and alignment of the dowels. Dowel bars shall not be less than 7-1/2 inches from a transverse joint and shall not interfere with dowels in the transverse direction.

e. Sawing of Joints. Joints shall be cut as shown on the plans. Equipment shall be as described in paragraph 501-4.1. The circular cutter shall be capable of cutting a groove in a straight line and shall produce

a slot at least 1/8 inch wide and to the depth shown on the plans. The top portion of the slot shall be widened by sawing to provide adequate space for joint sealers as shown on the plans. Sawing shall commence as soon as the concrete has hardened sufficiently to permit cutting without chipping, spalling, or tearing and before uncontrolled shrinkage cracking of the pavement occurs. Sawing shall be carried on both during the day and night as required. The joints shall be sawed at the required spacing, consecutively in sequence of the concrete placement.

#### 501-4.11 FINAL STRIKE-OFF, CONSOLIDATION, AND FINISHING.

a. Sequence. The sequence of operations shall be the strike-off, floating and removal of laitance, straightedging, and final surface finish. The addition of superficial water to the surface of the concrete to assist in finishing operations will not be permitted.

b. Finishing at Joints. The concrete adjacent to joints shall be compacted or firmly placed without voids or segregation against the joint material; it shall be firmly placed without voids or segregation under and around all load-transfer devices, joint assembly units, and other features designed to extend into the pavement. Concrete adjacent to joints shall be mechanically vibrated as required in paragraph 501-4.8.a. After the concrete has been placed and vibrated adjacent to the joints, the finishing machine shall be operated in a manner to avoid damage or misalignment of joints. If uninterrupted operations of the finishing machine, to, over, and beyond the joints, cause segregation of concrete, damage to, or misalignment of the joints, the finishing machine shall be stopped when the screed is approximately 8 inches from the joint. Segregated concrete shall be removed from the front of and off the joint; and the forward motion of the finishing machine shall be resumed. Thereafter, the finishing machine may be run over the joint without lifting the screed, provided there is no segregated concrete immediately between the joint and the screed or on top of the joint.

c. Hand Finishing. Concrete, as soon as placed, shall be struck off and screeded. An approved portable screed shall be used. A second screed shall be provided for striking off the bottom layer of concrete when reinforcement is used.

The screed for the surface shall be at least 2 feet longer than the maximum width of the slab to be struck off. It shall be of approved design, sufficiently rigid to retain its shape, and shall be constructed either of metal or of other suitable material covered with metal. Consolidation shall be attained by the use of suitable vibrators.

d. Floating. After the concrete has been struck off and consolidated, it shall be further smoothed and trued by means of a longitudinal float using one of the following methods:

(1) Hand Method. Long-handled floats shall not be less than 12 feet in length and 6 inches in width, stiffened to prevent flexibility and warping. The float shall be operated from foot bridges spanning but not touching the concrete or from the edge of the pavement. Floating shall pass gradually from one side of the pavement to the other. Forward movement along the centerline of the pavement shall be in successive advances of not more than one-half the length of the float. Any excess water or laitance in excess of 1/8-inch thick shall be removed and wasted.

(2) Mechanical method. The Contractor may use a machine composed of a cutting and smoothing float(s), suspended from and guided by a rigid frame and constantly in contact with, the side forms or underlying surface. If necessary, long-handled floats having blades not less than 5 feet in length and 6 inches in width may be used to smooth and fill in open-textured areas in the pavement. When the crown of the pavement will not permit the use of the mechanical float, the surface shall be floated transversely by means of a long-handled float. Care shall be taken not to work the crown out of the pavement during the operation. After floating, any excess water and laitance in excess of 1/8-inch thick shall be removed and wasted. Successive drags shall be lapped one-half the length of the blade.

e. Straight-edge Testing and Surface Correction. After the pavement has been struck off and while the concrete is still plastic, it shall be tested for trueness with a Contractor furnished 16-foot straightedge swung from handles 3 feet longer than one-half the width of the slab. The straightedge shall be held in contact with the surface in successive positions parallel to the centerline and the whole area gone over from one side of the slab to the other, as necessary. Advancing shall be in successive stages of not more than one-half the length of the straightedge. Any excess water and laitance in excess of 1/8-inch thick shall be removed from the surface of the pavement and wasted. Any depressions shall be immediately filled with freshly mixed concrete, struck off, consolidated, and refinished. High areas shall be cut down and refinished. Special attention shall be given to assure that the surface across joints meets the smoothness requirements of paragraph 501-5.2e(3). Straightedge testing and surface corrections shall continue until the entire surface is found to be free from observable departures from the straightedge and until the slab conforms to the required grade and cross section. The use of long-handled wood floats shall be confined to a minimum; they may be used only in emergencies and in areas not accessible to finishing equipment.

**501-4.12 SURFACE TEXTURE.** The surface of the pavement shall be finished with either a brush or broom, burlap drag, or artificial turf finish for all newly constructed concrete pavements.

a. Brush or Broom Finish. If the pavement surface texture is to be a type of brush or broom finish, it shall be applied when the water sheen has practically disappeared. The equipment shall operate transversely across the pavement surface, providing corrugations that are uniform in appearance and approximately 1/16 of an inch in depth. It is important that the texturing equipment not tear or unduly roughen the pavement surface during the operation. Any imperfections resulting from the texturing operation shall be corrected.

b. Burlap Drag Finish. If a burlap drag is used to texture the pavement surface, it shall be at least 15 ounces per square yard. To obtain a textured surface, the transverse threads of the burlap shall be removed approximately 1 foot from the trailing edge. A heavy buildup of grout on the burlap threads produces the desired wide sweeping longitudinal striations on the pavement surface. The corrugations shall be uniform in appearance and approximately 1/16 of an inch in depth.

c. Artificial Turf Finish. If artificial turf is used to texture the surface, it shall be applied by dragging the surface of the pavement in the direction of concrete placement with an approved full-width drag made with artificial turf. The leading transverse edge of the artificial turf drag will be securely fastened to a lightweight pole on a traveling bridge. At least 2 feet of the artificial turf shall be in contact with the concrete

surface during dragging operations. A variety of different types of artificial turf are available and approval of any one type will be done only after it has been demonstrated by the Contractor to provide a satisfactory texture. One type that has provided satisfactory texture consists of 7,200 approximately 0.85-inches-long polyethylene turf blades per square foot. The corrugations shall be uniform in appearance and approximately 1/16 of an inch in depth.

**501.4.13 SKID-RESISTANT SURFACES.** A skid-resistant surface shall be provided by construction of saw-cut grooves. Grooves shall be constructed in new full-depth panels only.

For new concrete pavements that have hardened, transverse grooves shall be saw-cut in the pavement forming a 1/4 inch wide by 1/4 inch deep by 1-1/2 inches center to center configuration. The grooves shall be continuous for the entire runway length. They shall be saw-cut transversely in the runway pavement to within 10 feet of the runway pavement edge to allow adequate space for equipment operation. The maximum transverse saw-cut grooves shall not exceed 130 feet. The tolerances for the saw-cut grooves shall meet the following:

Alignment tolerance.

Plus or minus 1-1/2 inches in alignment for 75 feet.

Groove tolerance.

Minimum depth 3/16 inch, except that not more than 60 percent of the grooves shall be less than 1/4 inch.

Maximum depth 5/16 inch.

Minimum width 3/16 inch.

Maximum width 5/16 inch.

Center-to-center spacing

Minimum spacing 1-3/8 inches

Maximum spacing 1-1/2 inches.

Saw-cut grooves shall not be closer than 3 inches or more than 9 inches to transverse paving joints. Grooves shall not be closer than 6 inches and no more than 18 inches from in-pavement light fixtures. Grooves may be continued through longitudinal joints. Where neoprene compression seals have been installed grooves, shall not be closer than 3 inches or more than 5 inches from the longitudinal joints. Cleanup of waste material shall be continuous during the grooving operation. Waste material shall be disposed of in an approved manner. Waste material shall not be allowed to enter the airport storm or sanitary sewer system.



**501-4.14 CURING.** Immediately after finishing operations are completed and marring of the concrete will not occur, the entire surface of the newly placed concrete shall be cured in accordance with the methods below. Failure to provide sufficient cover material, or lack of water to adequately take care of both curing and other requirements, shall be cause for immediate suspension of concreting operations. The concrete shall not be left exposed for more than 1/2 hour during the curing period.

a. **Impervious Membrane Method.** The entire surface of the pavement shall be sprayed uniformly with white pigmented curing compound immediately after the finishing of the surface and before the set of the concrete has taken place. The curing compound shall not be applied during rainfall. Curing compound shall be applied by mechanical sprayers under pressure at the rate of 1 gallon to not more than 150 square feet. The spraying equipment shall be of the fully atomizing type equipped with a tank agitator. At the time of use, the compound shall be in a thoroughly mixed condition with the pigment uniformly dispersed throughout the vehicle. During application the compound shall be stirred continuously by mechanical means. Hand spraying of odd widths or shapes and concrete surfaces exposed by the removal of forms will be permitted. The curing compound shall be of such character that the film will harden within 30 minutes after application. Should the film become damaged from any cause, including sawing operations, within the required curing period, the damaged portions shall be repaired immediately with additional compound or other approved means. Upon removal of side forms, the sides of the exposed slabs shall be protected immediately to provide a curing treatment equal to that provided for the surface.

b. **Curing in Cold Weather.** The concrete shall be maintained at a temperature of at least 50 degrees F for a period of 72 hours after placing and at a temperature above freezing for the remainder of the curing time. The Contractor shall be responsible for the quality and strength of the concrete placed during cold weather, and any concrete injured by frost action shall be removed and replaced at the Contractor's expense.

**501-4.15 REMOVING FORMS.** Not Used.

**501-4.16 SEALING JOINTS.** The joints in the pavement shall be sealed in accordance with Item P-605.

**501-4.17 PROTECTION OF PAVEMENT.** The Contractor shall protect the pavement and its appurtenances against both public traffic and traffic caused by the Contractor's employees and agents. This shall include watchmen to direct traffic and the erection and maintenance of warning signs, lights, pavement bridges, crossovers, and protection of unsealed joints from intrusion of foreign material, etc. Any damage to the pavement occurring prior to final acceptance shall be repaired or the pavement replaced at the Contractor's expense. The Contractor shall have available at all times, materials for the protection of the edges and surface of the unhardened concrete. Such protective materials shall consist of rolled polyethylene sheeting at least 4 mils thick of sufficient length and width to cover the plastic concrete slab and any edges. The sheeting may be mounted on either the paver or a separate movable bridge from which it can be unrolled without dragging over the plastic concrete surface. When rain appears imminent, all paving operations shall stop and all available personnel shall begin covering the surface of the unhardened concrete with the protective covering.

**501-4.18 OPENING TO TRAFFIC.** The pavement shall not be opened to traffic until test specimens molded and cured in accordance with ASTM C 31 have attained a flexural strength of 500 pounds per square inch when tested in accordance with ASTM C 78. Prior to opening to traffic, the pavement shall be cleaned and all joints shall either be sealed or protected from damage by installation of, as a minimum, backer rod or tape subject to approval by COTR.

**501.4.19 REPAIR, REMOVAL, REPLACEMENT OF SLABS.**

a. General. New pavement slabs that are broken or contain cracks shall be removed and replaced or repaired, as specified hereinafter at no cost to the owner. Spalls along joints shall be repaired as specified. Removal of partial slabs is permitted with COTR approval. Removal and replacement shall be full depth, shall be full width of the paving lane, and the limit of removal shall be normal to the paving lane and to the extent determined by the COTR. The COTR will determine whether cracks extend full depth of the pavement and may require cores to be drilled on the crack to determine depth of cracking. Such cores shall be 4-inch diameter, shall be drilled by the Contractor and shall be filled by the Contractor with a well consolidated concrete mixture bonded to the walls of the hole with epoxy resin, using approved procedures. Drilling of cores and refilling holes shall be at no expense to the Authority. All epoxy resin used in this work shall conform to ASTM C881, Type V.

Where cracks occur within an area 12 inches from another repair, the entire area around the cracks shall be removed and repaired as one. Where cracks occur within an area 12 inches from a joint, the area up to the joint shall be removed and repaired.

b. Slabs with Cracks through Interior Areas. Interior area is defined as that area more than 5 feet from either adjacent original transverse joint. Slabs with any cracks that extend into the interior area, regardless of direction, shall be replaced at no cost to the Authority.

c. Cracks Close To and Parallel To Transverse Joints. All cracks essentially parallel to original transverse joints and lying wholly within 5 feet either side of the joint shall be treated as specified hereinafter. Any crack extending more than 5 feet from the transverse joint shall be treated as specified above in subparagraph "Slabs With Cracks Through Interior Area."

(1) Cracks Present: Slab shall be saw cut full depth on all sides; 5 feet from and parallel to the original transverse joint, at the original transverse joint, and the two construction joints. The pavement shall be removed in a truly vertical fashion by suitable equipment and approved safe lifting devices or shall be broken up and removed using light, hand-held jackhammers, 30 lb. or less, or other approved similar equipment. Care shall be taken to prevent damage to concrete to remain in place. Dowels shall be epoxy grouted into holes drilled into the existing concrete at the original transverse joint location. Dowels shall be of the size and spacing specified for other joints. Tie bars of equivalent size and spacing as dowels shall be drilled and epoxied into the existing concrete face of the new transverse joint 5' parallel from the existing joint.



The exposed construction joints shall be reconstructed as originally shown on the plans. The surfaces of joint faces shall be cleaned of all loose material and contaminants. The sawed face of the new transverse joint shall be coated with epoxy grout immediately prior to placing the new concrete. The original transverse joint shall be coated with a double layer of membrane forming curing compound as a bond breaker. Protruding portions of dowels shall be greased. The new slab shall be reinforced with #4 bars spaced in both directions as shown on the detail for reinforced slab construction. Care shall be taken to prevent curing compound from contacting dowels or tie bars. The resulting joints shall be prepared and sealed as specified for original construction.

d. Slabs With Cracks Within 6 Inches of the Original Transverse Joint: If cracks occur within 6 inches of the original transverse joint, they shall be sawed in accordance with paragraph 501-4.10.m and sealed in accordance with Item P-605.

e. Removal and Replacement of Full Slabs. Where it is necessary to remove full slabs, the slab edges shall be sawed full depth just beyond the end of the dowels or tie bars. All saw cuts shall be perpendicular to the slab surface. These joints shall then be carefully sawed full depth on the joint line. The main slab shall be further divided by sawing full depth, at appropriate locations, and each piece lifted out and removed. Suitable equipment shall be used to provide a truly vertical lift, and approved safe lifting devices used for attachment to the slabs. The narrow strips along doweled edges shall be carefully broken up and removed using light, hand-held jackhammers, 30 lb or less, or other approved similar equipment. Care shall be taken to prevent damage to the dowels, tie bars, or to concrete to remain in place. The joint face below dowels shall be suitably trimmed so that there is no abrupt offset in any direction greater than 1/2 inch and no gradual offset greater than 1 inch when tested in a horizontal direction with a 12-foot straightedge. No mechanical impact breakers, other than the above hand-held equipment shall be used for any removal of slabs. If underbreak between 1-1/2 and 4 inches deep occurs at any point along any edge, the area shall be repaired as directed before replacing the removed slab. Procedures will be directed before replacing the removed slab. Procedures directed will be similar to those specified for surface spalls, modified as necessary. If underbreak over 4 inches deep occurs, the entire slab containing the underbreak shall be removed and replaced. Dowels of the size and spacing as specified for other joints in similar pavement shall be installed by epoxy grouting them into holes drilled into the existing concrete using procedures as specified. Protruding portions of dowels shall be painted and lightly oiled. All four edges of the new slab shall thus contain dowels. Placement of concrete shall be as specified for original construction. Prior to placement of new concrete, the underlying material (unless it is stabilized) shall be recompact and shaped as specified in the appropriate Section of these specifications. The surfaces of all four joint faces shall be cleaned of all loose material and contaminants and coated with double application of membrane forming curing compound as bond breaker. Care shall be taken to prevent any curing compound from contacting dowels or tie bars. The resulting joints around the new slab shall be prepared and sealed as specified for original construction.

f. Repairing Spalls Along Joints. Where directed, spalls along joints of new slabs, and along parallel cracks used as replacement joints, shall be repaired as illustrated on the plans.

g. Repairing joint overcuts into existing pavements. Where proposed joints do not match existing joints, the contractor shall not saw-cut into existing pavement more than two inches horizontally. This

overcut shall be filled with a COTR approved epoxy material in accordance with the manufacturer's instructions. Where proposed joints match existing joints, the contractor shall minimize the damage to the existing joint sealing materials. Damaged joint seal material shall be removed and replaced to the satisfaction of the COTR and Item P-605.

**501-4.20 EXISTING CONCRETE PAVEMENT REMOVAL AND REPAIR.** All operations shall be carefully controlled to prevent damage to the concrete pavement and to the underlying material to remain in place. All saw cuts shall be made perpendicular to the slab surface.

a. Removal of Existing Pavement Slab. When it is necessary to remove existing concrete pavement and leave adjacent concrete in place, the removal shall be performed as illustrated on the drawings.

b. Edge Repair. The edge of existing concrete pavement against which new pavement abuts shall be protected from damage at all times. Areas which are damaged during construction shall be repaired at no cost to the Authority; repair of previously existing damage areas will be considered a subsidiary part of concrete pavement construction.

(1) Spall Repair. Spalls shall be repaired where directed by the COTR. Repair shall be performed as indicated on the drawings.

(2) Underbreak Repair. All underbreak shall be repaired. First, all delaminated and loose material shall be carefully removed. Next, the underlying material shall be recompact, without addition of any new material. Finally, the void shall be completely filled with paving concrete, thoroughly consolidated. Care shall be taken to produce an even joint face from top to bottom. Prior to placing concrete, the underlying material shall be thoroughly moistened. After placement, the exposed surface shall be heavily coated with curing compound.

(3) Underlying Material. The underlying material adjacent to the edge of and under the existing pavement which is to remain in place shall be protected from damage or disturbance during removal operations and until placement of new concrete, and shall be shaped as shown on the drawings or as directed. Sufficient underlying material shall be kept in place outside the joint line to completely prevent disturbance of material under the pavement which is to remain in place. Any material under the portion of the concrete pavement to remain in place which is disturbed or loses its compaction shall be carefully removed and replaced with concrete as specified in paragraph "Underbreak Repair." The underlying material outside the joint line shall be thoroughly compacted and shall be moist when new concrete is placed.

#### **MATERIAL ACCEPTANCE**

**501-5.1 ACCEPTANCE SAMPLING AND TESTING.** All acceptance sampling, making specimens, transportation of samples, initial and final curing, and coring for thickness determination necessary to determine conformance with the requirements specified in this section will be performed by the Contractor. All testing necessary to determine conformance with the requirements specified in this section will be performed by the COTR. Concrete shall be accepted for strength and thickness on a lot basis.

A lot shall consist of:

a day's production

Testing organizations performing these tests shall meet the requirements of ASTM C 1077. The Contractor shall bear the cost of sampling, making and transporting strength specimens to the COTR lab, for providing molds and sampling equipment, for providing curing facilities for the strength specimens, and for coring and filling operations.

a. Flexural Strength.

(1) Sampling. One (1) sample shall be taken by the Contractor for each lot from the plastic concrete delivered to the job site. Sampling locations shall be determined by the COTR in accordance with random sampling procedures contained in ASTM D 3665. The concrete shall be sampled in accordance with ASTM C 172.

(2) Making Specimens On-Site. Two (2) specimens shall be made by the Contractor on site, in the presence of the COTR, from each sample for testing at 6 hours and 28 days age plus two reserve beams (a total of 6 beams per sample). Specimens shall be made in accordance with ASTM C 31.

(3) Initial Curing, On-Site. The Contractor shall provide adequate facilities for the initial curing of beams on site. During the 24 hours after molding, the temperature immediately adjacent to the specimens must be maintained in the range of 60 to 80 degrees F, and loss of moisture from the specimens must be prevented. The Contractor shall store the specimens on site during the 24 hours after molding in tightly constructed wooden boxes, damp sand pits, temporary buildings at construction sites, under wet burlap in favorable weather or in heavyweight closed plastic bags, or use other suitable methods, provided the temperature and moisture loss requirements are met. Initial curing shall be performed in accordance with ASTM C31.

(4) Final Curing. After initial cure, the Contractor shall provide facilities for protecting, storing, and curing the beams until they are tested for flexural strength. The facilities shall be on site. The Contractor shall transport the specimens from the initial cure site to the final cure site, strip forms from the specimens, and label and place the specimens in the curing facilities. Storage conditions shall be in compliance with ASTM C31.

(5) Testing. The COTR shall test two specimens from each sample at 6 hours and 28 days from the date of molding. Testing will be done on a Rainhard recording beam tester, Model 416L, provided by the COTR. The Contractor may use the COTR's machine for the testing of his/her mix design specimens or correlation between the COTR's machine and the Contractor's machine used for CQC (Contractor Quality Control). The flexural strength of each specimen shall be determined in accordance with ASTM C78. The flexural strength for each subplot shall be computed by averaging the results of the two test specimens

representing that lot. The Contractor shall transport the test beams from the final curing facility to the COTR's testing machine. The COTR shall load the beams into the testing machine.

(6) Acceptance. Acceptance of pavement for flexural strength will be determined by the COTR in accordance with paragraph 501-5.2b.

b. Pavement Thickness. (Not Used)

c. Partial Lots. (Not Used)

d. Outliers. All individual flexural strength tests within a lot shall be checked for an outlier (test criterion) in accordance with ASTM E 178, at a significance level of 5 percent. Outliers shall be discarded, and the PWL shall be determined using the remaining test values.

#### 501-5.2 ACCEPTANCE CRITERIA.

a. General. Acceptance will be based on the following characteristics of the completed pavement:

- (1) Flexural strength
- (2) Thickness (Not Used)
- (3) Smoothness
- (4) Grade
- (5) Edge slump (Not Used)
- (6) Dowel bar alignment

Acceptance for flexural strength will be based on the criteria contained in accordance with paragraph 501-5.2e(1). Acceptance for smoothness will be based on the criteria contained in paragraph 501-5.2e(3). Acceptance for grade will be based on the criteria contained in paragraph 501-5.2e(4).

The COTR may at any time, notwithstanding previous plant acceptance, reject and require the Contractor to dispose of any batch of concrete mixture which is rendered unfit for use due to contamination, segregation, or improper slump. Such rejection may be based on only visual inspection. In the event of such rejection, the Contractor may take a representative sample of the rejected material in the presence of the COTR, and if it can be demonstrated in the laboratory, in the presence of the COTR, that such material was erroneously rejected, payment will be made for the material at the contract unit price.

b. Flexural Strength. Acceptance of each lot of in-place pavement for flexural strength shall be based on the lot's average 28-day flexural strength.

c. Pavement Thickness. (Not Used)

d. Percentage of Material Within Limits (PWL). (Not Used)

e. Acceptance Criteria.

(1) Flexural Strength. If the 28-day flexural strength of the lot equals or exceeds the required 28-day strength, the lot shall be acceptable. Acceptance and payment for the lot shall be determined in accordance with paragraph 501-8.1.

(2) Thickness. (Not Used)

(3) Smoothness. As soon as the concrete has hardened sufficiently, the pavement surface shall be tested with a 16-foot straightedge or other specified device. Surface smoothness deviations shall not exceed 1/4 inch from a 16-foot straightedge placed in any direction, including placement along and spanning any pavement joint edge.

Areas in a slab showing high spots of more than 1/4 inch but not exceeding 1/2 inch in 16 feet shall be marked and immediately ground down with an approved grinding machine to an elevation that will fall within the tolerance of 1/4 inch or less. Where the departure from correct cross section exceeds 1/2 inch, the pavement shall be removed and replaced at the expense of the Contractor when so directed by the COTR.

(4) Grade. An evaluation of the surface grade shall be made by the COTR for compliance to the tolerances contained below.

Vertical Deviation. Vertical deviation from established grade shall not exceed plus or minus 0.04 foot at any point.

(5) Edge Slump. (Not Used)

(6) Dowel Bar Alignment. Dowel bars and assemblies shall be checked for position and alignment. The maximum permissible tolerance on dowel bar alignment in each plane, horizontal and vertical, shall not exceed 2 percent or 1/4 inch per foot of a dowel bar.

f. Removal and Replacement of Concrete. Any area or section of concrete that is removed and replaced shall be removed and replaced back to planned joints. The Contractor shall replace damaged dowels and the requirements for doweled longitudinal construction joints in paragraph 501-4.10 shall apply to all contraction joints exposed by concrete removal.

**CONTRACTOR QUALITY CONTROL**

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**501-6.1 QUALITY CONTROL PROGRAM.** The Contractor shall develop a Quality Control Program in accordance with Section 1400 of the General Provisions. The program shall address all elements which effect the quality of the pavement including, but not limited to:

- a. Mix Design
- b. Aggregate Gradation
- c. Quality of Materials
- d. Stockpile Management
- e. Proportioning
- f. Mixing and Transportation
- g. Placing and Consolidation
- h. Joints
- i. Dowel Placement and Alignment
- j. Flexural or Compressive Strength
- k. Finishing and Curing
- l. Surface Smoothness

**501-6.2 QUALITY CONTROL TESTING.** The Contractor shall perform all quality control tests necessary to control the production and construction processes applicable to this specification and as set forth in the Quality Control Program. The testing program shall include, but not necessarily be limited to, tests for aggregate gradation, aggregate moisture content, slump, and air content. A Quality Control Testing Plan shall be developed as part of the Quality Control Program.

- a. Fine Aggregate.

(1) Gradation. A sieve analysis shall be made at least twice daily in accordance with ASTM C 136 from randomly sampled material taken from the discharge gate of storage bins or from the conveyor belt.

(2) Moisture Content. If an electric moisture meter is used, at least two direct measurements of moisture content shall be made per week to check the calibration. If direct measurements are made in lieu of using an electric meter, two tests shall be made per day. Tests shall be made in accordance with ASTM C 70 or ASTM C 566.

b. Coarse Aggregate.

(1) Gradation. A sieve analysis shall be made at least twice daily for each size of aggregate. Tests shall be made in accordance with ASTM C 136 from randomly sampled material taken from the discharge gate of storage bins or from the conveyor belt.

(2) Moisture Content. If an electric moisture meter is used, at least two direct measurements of moisture content shall be made per week to check the calibration. If direct measurements are made in lieu of using an electric meter, two tests shall be made per day. Tests shall be made in accordance with ASTM C 566.

c. Slump. Four slump tests shall be performed for each lot of material produced in accordance with the lot size defined in Section 501-5.1. One test shall be made for each subplot. Slump tests shall be performed in accordance with ASTM C 143 from material randomly sampled from material discharged from trucks at the paving site. Material samples shall be taken in accordance with ASTM C 172.

d. Air Content. Four air content tests, shall be performed for each lot of material produced in accordance with the lot size defined in Section 501-5.1. One test shall be made for each subplot. Air content tests shall be performed in accordance with ASTM C 231 for gravel and stone coarse aggregate and ASTM C 173 for slag or other porous coarse aggregate, from material randomly sampled from trucks at the plant site. Material samples shall be taken in accordance with ASTM C 172.

**501-6.3 CONTROL CHARTS.** The Contractor shall maintain linear control charts for fine and course aggregate gradation, slump, and air content.

Control charts shall be posted in a location satisfactory to the COTR and shall be kept up to date at all times. As a minimum, the control charts shall identify the project number, the contract item number, the test number, each test parameter, the Action and suspension Limits, or Specification limits, applicable to each test parameter, and the Contractor's test results. The Contractor shall use the control charts as part of a process control system for identifying potential problems and assignable causes before they occur. If the Contractor's projected data during production indicates a potential problem and the Contractor is not taking satisfactory corrective action, the COTR may halt production or acceptance of the material.

a. Fine and Coarse Aggregate Gradation. The Contractor shall record the running average of the last five gradation tests for each control sieve on linear control charts. Specification limits contained in Tables 1 and 2 shall be superimposed on the Control Chart for job control.

b. Slump and Air Content. The Contractor shall maintain linear control charts both for individual measurements and range (i.e. difference between highest and lowest measurements) for slump and air content in accordance with the following Action and Suspension Limits.

CONTROL CHART LIMITS  
Based on Sample Size n=4

Control	Individual Measurements		
Parameter	Action Limit	Suspension Limit	Range Suspension Limit
Slump	+/- 1 inch	+/- 1.5 inch	+/- 2.4 inch
Air Content	+/- 1.2%	+/- 1.8%	+/- 2.8%

The individual measurement control charts shall use the mix design target values as indicators of central tendency.

**501-6.4 CORRECTIVE ACTION.** The Quality Control Plan shall indicate that appropriate action shall be taken when the process is believed to be out of control. The Quality Control Plan shall detail what action will be taken to bring the process into control and shall contain sets of rules to gauge when a process is out of control. As a minimum, a process shall be deemed out of control and corrective action taken if any one of the following conditions exists.

a. Fine and Coarse Aggregate Gradation. When two consecutive averages of five tests are outside of the Tables 1 or 2 specification limits, immediate steps, including a halt to production, shall be taken to correct the grading.

b. Fine and Coarse Aggregate Moisture Content. Whenever the moisture content of the fine or coarse aggregate changes by more than 0.5 percent, the scale settings for the aggregate batcher(s) and water batcher shall be adjusted.

c. Slump. The Contractor shall halt production and make appropriate adjustments whenever:

- (1) one point falls outside the Suspension Limit line for individual measurements or range; or
- (2) two points in a row fall outside the Action Limit line for individual measurements.

d. Air Content. The Contractor shall halt production and adjust the amount of air-entraining admixture whenever:

- (1) one point falls outside the Suspension Limit line for individual measurements or range; or
- (2) two points in a row fall outside the Action Limit line for individual measurements.

Whenever a point falls outside the Action Limits line, the air-entraining admixture dispenser shall be calibrated to ensure that it is operating correctly and with good reproducibility.

**METHOD OF MEASUREMENT**

PORTLAND CEMENT CONCRETE PAVEMENT  
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501-7.1 Portland cement concrete pavement shall be measured by the number of square yards of either plain or reinforced pavement as specified in-place, completed and accepted.

#### BASIS OF PAYMENT

#### 501-8.1 PAYMENT.

Payment for an accepted lot of concrete pavement shall be made at the contract unit price per square yard and adjusted in accordance with paragraph 501-8.1a. Payment shall be full compensation for all labor, materials, tools equipment, and incidentals required to complete the work as specified herein and on the drawings. This item shall also include joint sealing associated with panel replacements and as described by Item P-605 and shall include materials, labor, equipment, tools and incidentals necessary to seal the joints. The patching items shall also include partial depth pavement removal as illustrated on plans and/or as described by Item P-101.

TABLE 3. PRICE ADJUSTMENT SCHEDULE

Flexural Strength of Lot	Lot Pay Factor (Percent of Contract Unit Price)
725 and higher	100%
700-724	95%
675-699	85%
650-674	70%
Below 650	Reject <sup>1</sup>

<sup>1</sup> The lot shall be removed and replaced. However, the COTR may decide to allow the rejected lot to remain. In that case, if the COTR and Contractor agree in writing that the lot shall not be removed, it shall be paid for at 50 percent of the contract unit price.

For each lot accepted, the adjusted contract unit price shall be the product of the lot pay factor for the lot and the contract unit price.

b. Payment. Payment will be made under.

P-501-5.1 Airfield PCC Pavement, 15" Thickness -- per square yard  
P-501-5.2 Airfield PCC Pavement, 18" Thickness -- per square yard

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P-501-5.3	Corner Spall Patching, 4" Thickness -- per square foot
P-501-5.4	Joint Spall Patching, 4" Thickness -- per square foot
P-501-5.5	Full-Depth PCC Repair Patching -- per square foot
P-501-5.6	Partial-Depth Patch Repair -- per square foot

#### TESTING REQUIREMENTS

ASTM C 31	Making and Curing Concrete Test Specimens in the Field
ASTM C 39	Compressive Strength of Cylindrical Concrete Specimens
ASTM C 70	Surface Moisture in Fine Aggregate
ASTM C 78	Test for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
ASTM C 131	Test for Resistance to Abrasion of Small Size Coarse Aggregate by Use of the Los Angeles Machine
ASTM C 136	Sieve Analysis of Fine and Coarse Aggregates
ASTM C 138	Test for Unit Weight, Yield, and Air Content (Gravimetric) of Concrete
ASTM C 143	Test for Slump of Portland Cement Concrete
ASTM C 172	Sampling Freshly Mixed Concrete
ASTM C 173	Test for Air Content of Freshly Mixed Concrete by the Volumetric Method
ASTM C 174	Measuring Length of Drilled Concrete Cores
ASTM C 227	Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)
ASTM C 231	Test for Air Content of Freshly Mixed Concrete by the Pressure Method
ASTM C 289	Potential Reactivity of Aggregates (Chemical Method)
ASTM C 295	Petrographic Examination of Aggregates for Concrete
ASTM C 311	Sampling and Testing Fly Ash for Use as an Admixture in Portland Cement Concrete
ASTM C 535	Test for Resistance to Abrasion of Large Size Coarse Aggregate by Use of the Los Angeles Machine

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ASTM C 566	Total Moisture Content of Aggregates by Drying
ASTM C 1077	Standard Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation
ASTM D 3665	Random Sampling of Construction Materials
ASTM D 4791	Test Method for Flat or Elongated Particles in Coarse Aggregate
AASHTO T 26	Quality of Water to be Used in Concrete

**MATERIAL REQUIREMENTS**

ASTM A 184	Specification for Fabricated Deformed Steel Bar Mats for Concrete Reinforcement
ASTM A 185	Specification for Welded Steel Wire Fabric for Concrete Reinforcement
ASTM A 497	Specification for Welded Deformed Steel Wire Fabric for Concrete Pavement
ASTM A 615	Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement
ASTM A 616	Specification for Rail-Steel Deformed and Plain Bars for Concrete Reinforcement
ASTM A 617	Specification for Axle-Steel Deformed and Plain Bars for Concrete Reinforcement
ASTM A 704	Specification for Welded Steel Plain Bar or Rod Mats for Concrete Reinforcement
ASTM A 714	Specification for High-Strength Low-Alloy Welded and Seamless Steel Pipe
ASTM C 33	Specification for Concrete Aggregates
ASTM C 94	Specification for Ready-Mixed Concrete
ASTM C 150	Specification for Portland Cement
ASTM C 171	Specification for Sheet Materials for Curing Concrete
ASTM C 260	Specification for Air-Entraining Admixtures for Concrete
ASTM C 309	Specification for Liquid Membrane-Forming Compounds
ASTM C 494	Specification for Chemical Admixtures for Concrete

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ASTM C 595	Specification for Blended Hydraulic Cements
ASTM C 618	Specification for Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete
ASTM C 881	Specification for Epoxy-Resin-Base Bonding System for Concrete
ASTM C 989	Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars
ASTM D 1751	Specification for Preformed Expansion Joint Fillers for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types)
ASTM D 1752	Specification for Preformed Sponge Rubber and Cork Expansion Joint Fillers for Concrete Paving and Structural Construction
AASHTO M 254	Specification for Coated Dowel Bars
ACI 305R	Hot Weather Concreting
ACI 306R	Cold Weather Concreting.
TT-P-644 D)	Federal Specification for Primer Coating, Alkyd, Corrosion-Inhibiting, Lead and (Rev. Chromate Free, VOC-Compliant

END OF ITEM P-501

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## **William P. Hobby/Houston Airport Reconstruction of Intersection of Runway 12R-30L and Runway 4-22**

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### **General Information**

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Airport: William P. Hobby/Houston Airport

Owner: City of Houston, Houston Airport System

Airport Classification: Medium Hub

Climatic Region: Dry/No Freeze

FAA Region: Southwest

Facility: Intersection of Runways 4-22 and 12R-30L

Description of project: Reconstruction of runway intersection; removal and replacement of failed, very high-early strength concrete placed in 1994 within 19-day closure

Dates of construction: October 2001

Engineer/Designer: Brown & Root, Inc.

Project Manager/Construction Manager: DMJM Aviation/Houston Airport System

Prime Contractor: Champagne-Webber Inc

### **Project Overview**

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Houston's second largest airport, William P. Hobby (HOU), has served the city for over 60 years, since it was acquired by the City of Houston in 1937 as its first airport. It is operated and maintained by the City of Houston Airport System, and it is the 45<sup>th</sup> busiest airport in the U.S. for total passengers. The airport is served by seven scheduled passenger airlines, has more than 250,000 operations per year, and is a hub for Southwest Airlines. It has two ILS Category I runways, Runways 4-22 and 12R-30L, both 7,600 ft long, as well as two shorter general aviation runways. The airport diagram is shown in figure 1.

The intersection of Runways 4-22 and 12R-30L at Houston Hobby airport is heavily used and closures for repairs of this area must be limited because of the impact on commercial operations: the intersection carries 95 percent of the total aircraft traffic at the airport. When the intersection is closed, Hobby has only one VFR runway that can handle air carrier operations, and even short periods of rain or fog shut down the airport.

The intersection was repaired in 16 days in 1994 using very high early strength concrete (Project 485). The original 6-inch thick runway pavement at the time of this repair was more than 50 years old and had been overlaid several times to increase the section by 18 inches.

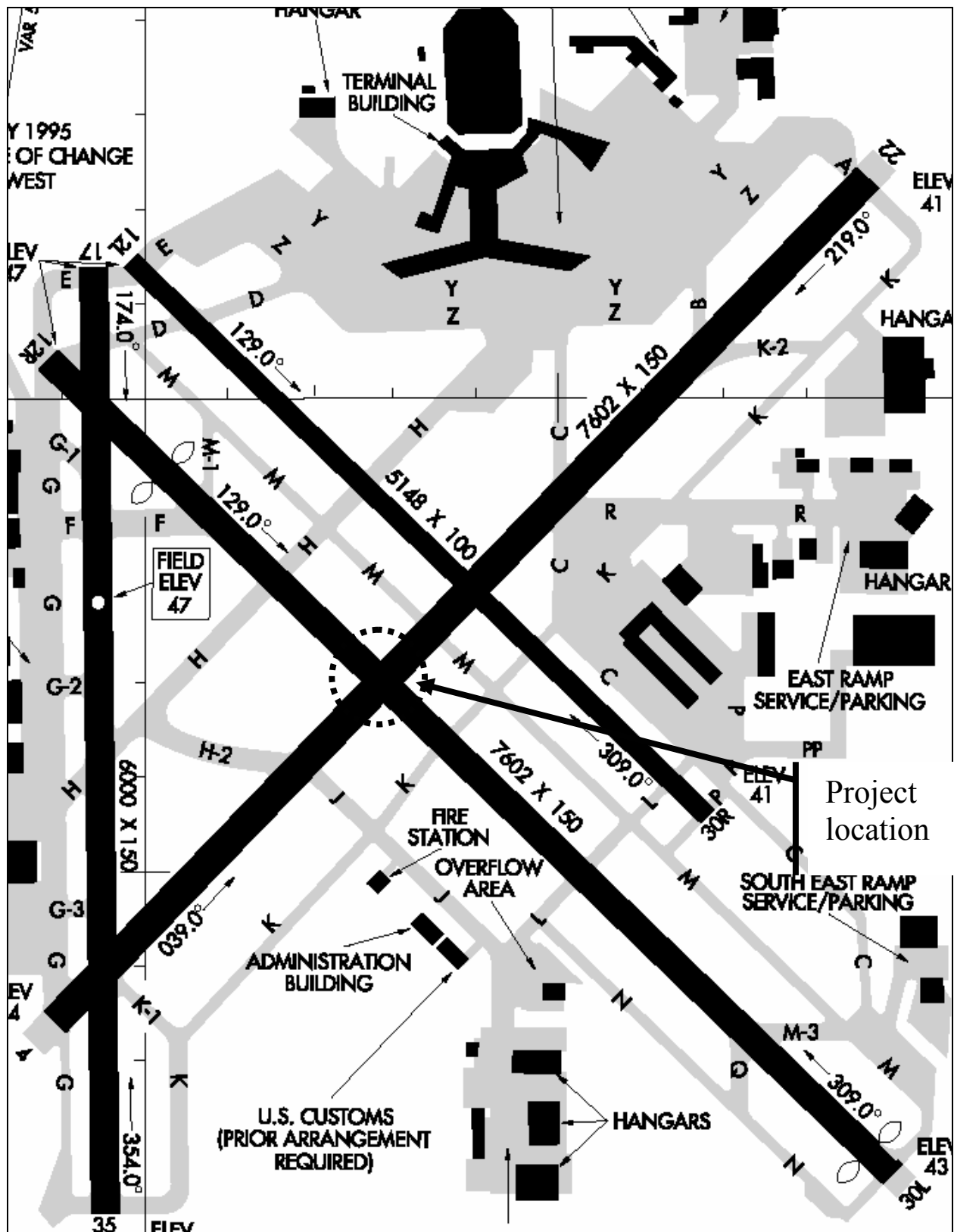


Figure 1: Airport Diagram (from [http://www.naco.faa.gov/ap\\_diagrams.asp](http://www.naco.faa.gov/ap_diagrams.asp))

The new pavement cross section consisted of 17 inches of high performance concrete, over a 1.5-inch asphalt bond breaker, over the original 6-inch concrete pavement. Project specifications allowed either Type III cement or one of two proprietary high early strength cements. The project concrete consisted of 705 pounds of Type III cement and 140 pounds of fly ash per cubic yard, with a superplasticizer and an accelerating admixture. The specified flexural strengths were 750 psi at 24 hours and 850 psi at 28 days. Because the original amount of accelerator used was too great and the concrete lost workability before finishing could be completed, the amount of accelerator was reduced, leading to decreased 24-hour strengths. The actual 24-hour strengths ranged from 600 to 685 psi, and the 28-day strengths ranged from 840 to 960 psi. All of the concrete exceed 750 psi before opening to aircraft.

The existing 12-inch concrete panels were lifted out using cranes and eye bolts. New lights also had to be installed, and the contractor was allowed less than 3 full days for their installation. The work was scheduled in October to minimize the chance for weather disruptions.

By the late 1990s, this repaired area had experienced significant deterioration, resulting in operational warnings to pilots and emergency closures for repairs. The problem was initially identified through pilot complaints about rideability problems on Runway 12R-30L. Although the center line profile was smooth, the wheel track profiles for the main gear had an abrupt transition to 1 percent slopes. Observed distresses included surface cracking, differential joint movement, concrete expansion and shoving, and full depth and lateral cracking. A forensic investigation found that the concrete used in the project had produced delayed ettringite crystal formations, which expanded the volume of the concrete pavement. This movement was so great that several light bases in the intersection were damaged by shearing forces as the pavement expanded and slid relative to the base. Asphalt adjacent to the intersection was cracked and shoved due to the pressure of the expanding concrete.

Three options were considered for repair. These were:

- Sealing of fine cracks using a low viscosity polymer grout injection.
- Providing new expansion joints on each side of the concrete intersection to allow an additional 5 inches for further expansion.
- Repairing light bases only by coring new holes through the pavement

In late February 2001, it was determined that none of these repairs was likely to be satisfactory in the long term, and it was necessary to remove and replace the entire intersection. The intersection project that emerged from this planning included 600 feet of each runway, for a total of 11,000 ft<sup>2</sup> of pavement. As a result, a new reconstruction plan, designated Project 566A, was developed.

The design team initially estimated 30 days would be required for construction. However, after detailed analysis of the construction activities and development of design requirements and a detailed construction sequence plan, the design team was able to demonstrate that construction could be completed in 21 days.

## **Key Project Components**

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The project was accelerated in that it had to be constructed as quickly as possible. The key fast track components of this project are noted below:

- 19-day closure window for critical runway – 17 days for construction with a 2-day buffer. The entire project was allotted 26 days for substantial completion.
- Scheduling and coordination – the proposed strategy was developed in detail to assure the owner and other stakeholders that the total reconstruction could be accomplished within the tight closure window.
- Use of a high early strength concrete meeting the FAA's P-501 specification, attaining 550 psi flexural strength in 3 days and avoiding the problems of the 1994 construction.
- Paving in 37.5-ft wide lanes to minimize the number of paving passes.
- Elimination of the 1.5-inch bond breaker layer.
- Reuse of existing subbase and subgrade layers.
- Using adjustable light bases and extensions for the in-pavement lighting.
- Prior to starting work, the contractor was required to obtain approval for all construction materials, to receive all construction materials, and to be mobilized on site.

## **Planning**

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The project team first evaluated a wide range of design options for the intersection. After destructive testing and analysis of the pavement layers, the existing pavement was found to not be strong enough for rehabilitation. Therefore, a complete reconstruction of the intersection was necessary. Because of the negative experience from the 1994 intersection replacement, the Houston Airport System and the other stakeholders required proven design technologies that would ensure the long-term durability of the pavement.

Next, the project team prepared a construction design and phasing plan to minimize service interruptions. Air carrier operations were switched to Runway 17-35 for the duration of the intersection replacement. This required load limitations on departing aircraft, and left the airport without all-weather capability. However, scheduling the intersection replacement during the drier and cooler weather of October helped reduce the effect of these limitations.

A detailed work plan and schedule were presented to the airlines, users, FAA, and airport operations staff 6 months in advance of the closure, based on known production rates for removal of existing pavement and placement of new pavement. The detailed plan was presented to all of the stakeholders to build confidence that the 19-day closure would be sufficient for complete reconstruction. Options were developed by the affected parties, including schedule revisions, weight limitations, and potential use of alternate airports.



## Design

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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 550 psi flexural strength in 3 days.
- Paving 37.5-ft wide lanes rather than 25 ft.
- Elimination of the 1.5-inch bond breaker layer.
- Reuse of existing base and subgrade layers.
- Use of adjustable light bases and extensions for the in-pavement lighting.

Eliminating the 1.5-inch bond breaker layer had two advantages. First, it allowed for faster construction. Second, it allowed the replacement concrete pavement thickness to be increased by the same amount. In place of the 1.5-inch bond breaker, a thin layer of asphalt prime coat was applied to the underlying pavement. This technique had been used successfully in previous construction at Bush Intercontinental Airport, also owned by the Houston Airport System. The asphalt prime coat can be applied more quickly than the hot mix asphalt layer, and is less susceptible to damage from inclement weather.

Widening the paving lane to 37.5 ft allowed the intersection to be paved in four passes rather than six, which also saved some time. The concrete was delivered on both sides of the paving lane, to further speed the paving operation. An intermediate longitudinal contraction joint was constructed in the middle of each pass, resulting in a final slab dimension of 18.75 ft by 20 ft.

Specifying PCC opening at 550 psi flexural strength was intended to allow the contractor to operate construction equipment on the pavement. To achieve this, the contractor only submitted one concrete mix design. It was a proven mix design that had been successfully used by this contractor on other work that they were performing at the Airport. The Contractor had an on-site batch plant and recent documentation on the performance of the mix, which was a conventional mix design that did not rely on accelerators to obtain early strength. The required strengths were 3,750 psi (compressive) at 3 days and 5,250 psi (compressive) at 28 days. As allowed in the specification, the design team opted to use compressive strengths as the strength criteria. A 3-day strength, in lieu of a 7-day strength, was specified to address the accelerated construction of the pavement. In addition, the P-501 specification stipulated that the large aggregate would be crushed granite.

The underlying, World War II vintage, 6-inch thick concrete was in good shape and provided an excellent base and working platform for the reconstruction. While that original pavement was retained, the materials placed in 1994 were completely removed.

Using adjustable light bases and extensions eliminated the 4 to 6 weeks typically required after paving to fabricate and deliver spacers. Fixtures could be installed within 3 days of pavement construction.

The pavement reconstruction section was designed for a 20-year life, based on traffic projections through 2020. The design assumed that the airport would reach capacity in 2012. The pavement design was based on FAA AC 150/5320-6D, using the FAA computer programs R805FAA and F806FAA. Forty soil borings and fifteen field California Bearing Ratio (CBR) tests were performed to provide inputs to the design.

Based on a CBR of 5, an average modulus of subgrade reaction (k-value) of 100 psi/in was used for the subgrade. Other design parameters included a new concrete strength of 715 psi and a slab length of 20 ft. The required pavement thickness was 18.5 inches, with light reinforcement and 1.5-inch diameter dowels spaced 18 inches apart.

## **Construction**

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Reconstruction of the intersection required seven major construction tasks:

- Pavement demolition.
- Runway pavement construction.
- Airfield lighting and circuitry.
- Shoulder pavement construction.
- Pavement grooving.
- Pavement marking.
- Pavement joint sealing.

Lanes with centerline and TDZ lights were paved first, to provide more time to complete the electrical work. Runway 12R-30L was completed before Runway 4-22, allowing that runway to resume operations.

Demolition of the 1994-vintage pavement had to be performed carefully to prevent damage to the underlying base materials and the contractor used two different methods to accomplish this. On Runway 4-22, a continuously reinforced pavement, four hoe-rams (excavator with the bucket replaced with a hydraulic jack hammer) were placed shoulder to shoulder and “walked” together down the runway. This technique was used on that part of the project because of the amount of steel reinforcement. The end of the jack hammer had a painted line to mark the depth of the concrete pavement and prevent penetration into the underlying cement-stabilized base material. Along Runway 12R-30L a guillotine breaker was used to break up the concrete pavement. This pavement was constructed over an asphalt bond breaker and only contained a nominal amount of reinforcing steel. As such, it was easier to break up and the guillotine breaker proved to be adequate.

Parts of the existing base and subgrade were examined during a repair in February 2001 and determined to be sound, although there were some cracks. The rest of the base and subgrade were assumed to be in similar condition. In fact, during the reconstruction, a few sections of the base concrete were found to be badly cracked and were replaced.

There were no difficulties with achieving the appropriate concrete strength. The test data showed that the concrete developed an average range of 4,150 to 4,260 psi (compressive) at 3-days and 6,710 to 7,740 psi (compressive) at 28-days.

## **Other Issues**

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Service was resumed on Runway 12R-30L 17 days after closure of the intersection. A 2-day buffer was provided for weather and other unforeseen conditions, but it was not needed in the end. After this runway was re-opened, the remainder of Runway 4-22 was constructed at night to minimize disruptions. An additional 7 days were allowed for completion of Runway 4-22 following the critical 19-day closure, for a total maximum project duration of 26 days.

One unusual step that was taken on this project was a petrographic analysis of the concrete following placement. This study determined that there were no potential durability problems with the in-place concrete.

## **Summary**

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The strategy discussed above had a number of benefits:

- Used proven and reliable construction materials.
- Construction techniques were familiar to the industry.
- Produced a smoother surface profile.
- Allowed existing pavement to be removed rapidly.
- Reduced construction costs.
- Allowed operations to resume on Runway 12R-30L before completion of Runway 4-22.

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. As a result, the Houston Airport System believes that the construction costs were reduced. 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 1994 repair.

The project engineer believes that there were several important factors that led to the success of the Project:

Planning – Every aspect of the project was projected, planned, and coordinated with the actual parties that would be involved. This included HAS personnel, Hobby Airport personnel, the engineers, contractors, suppliers, and others.

Execution – A detailed execution plan was developed for the project.

Commitment – Everyone on the project was committed to the successful completion of the Project. Once the runways were closed and the demolition was started, all issues would have to be addressed and resolved quickly.

Courage and Conviction – The Houston Airport System and Hobby Airport had to address a difficult situation and make a courageous decision. They were faced with a serious problem, and a range of solutions. The alternatives were to choose a quick fix that might only provide an interim solution; or to choose a long-term solution that would have a big impact on airport operations. They made that decision, seeking the advice of their staff and engineers, and once that decision was made, the Client provided the engineers, contractors, and construction managers with the resources that they said they needed to get the job done. The project was finished ahead of schedule, and after 3 years pavement performance has been excellent.

Along the way, the Airport learned the following lessons:

1. You cannot plan enough.
2. Having the engineer of record on site is an asset. The engineer spent 15 to 18 hours a day on the job during every day of construction.
3. Sometimes good old hard work and conventional methods are the best solution

Based on the negative experience with the 1994 repair, the Houston Airport System has worked since this project to develop durable concrete that is compatible with fast track construction. They have recently adopted a ternary blend concrete (50 % Type I portland cement, 25 % fly ash, and 25 % slag) for a new runway construction project at George Bush Intercontinental Airport, with a predicted service life of about 120 years. Most of the locally available coarse and fine aggregates are susceptible to ASR, which may be avoided through the use of ternary blend concrete.

## **Available Sources of Information**

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Interviews with several key individuals involved in this project were held by telephone and e-mail. The project team would like to acknowledge the input and contributions of the following individuals for providing much of the information presented in this case study document:

- Adil Godiwalla, City of Houston, Houston Airport System
- John Bush, DMJM Aviation

The following documents also provided valuable information used in this summary:

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**APPENDIX B – IDENTIFIED AIRPORT CONCRETE PAVEMENT  
CONSTRUCTION PROJECT DATABASE**

Table B-1. Identified airport concrete pavement construction projects.

<b>Airport/Project</b>	<b>Classification</b>	<b>Facility Type</b>	<b>FAA Region</b>	<b>Accelerated Aspect</b>	<b>Construction Method</b>
Airborne Airpark (OH) (DHL Facility); Runway Reconstruction	Cargo	Runway/ Taxiway	Great Lakes	Planning/Design/ Construction	New/Reconstruction/ Overlay
Alpena County Regional (MI); Runway Rehabilitation	Small Hub	Runway/ Taxiway	Great Lakes	N/A	New/Reconstruction/ Overlay
Charleston International; Runways 15-33 and 3-21 Intersection Reconstruction	Small Hub	Intersection	Southern	Planning/Design/ Construction/Other	New/Reconstruction/ Overlay
Charlotte-Douglas International; Runway 18R-36L Slab Replacement	Large Hub	Runway/ Taxiway	Southern	Planning/Design/ Construction/Other	New/Reconstruction/ Overlay
Cincinnati/North Kentucky International; Taxiway M Reconstruction	Large Hub	Runway/ Taxiway	Great Lakes	Planning/Design/Other	New/Reconstruction/ Overlay
Cleveland-Hopkins International; Runway 6L-24R	Medium Hub	Runway/ Taxiway	Great Lakes	Planning/Design	New/Reconstruction/ Overlay
Colorado Springs; Runway/Taxiway Patching	Small Hub	Runway/ Taxiway	Northwest Mountain	Planning/Design/ Construction/Other	Major Repair
Colorado Springs; Taxiways H and C	Small Hub	Runway/ Taxiway	Northwest Mountain	Planning/Construction	New/Reconstruction/ Overlay
Columbia Regional Airport (MO); Runway 2-20 Repair	Small Hub	Runway/ Taxiway	Central	Planning/Design/Other	New/Reconstruction/ Overlay
Dallas/Fort Worth International; Runway 17L-35R	Large Hub	Runway/ Taxiway	Southwest	Planning/Construction/ Other	New/Reconstruction/ Overlay
Dallas/Fort Worth International; Runway 17L Extension	Large Hub	Runway/ Taxiway	Southwest	Planning/Construction/ Other	New/Reconstruction/ Overlay
Dallas/Fort Worth International; Runway 17R Extension	Large Hub	Runway/ Taxiway	Southwest	Planning/Construction/ Other	New/Reconstruction/ Overlay

Table B-1 (continued). Identified airport concrete pavement construction projects.

<b>Airport/Project</b>	<b>Classification</b>	<b>Facility Type</b>	<b>FAA Region</b>	<b>Accelerated Aspect</b>	<b>Construction Method</b>
Dallas/Fort Worth International; Runway 17C Extension	Large Hub	Runway/Taxiway	Southwest	Planning/Construction/Other	New/Reconstruction/Overlay
Dayton International; Taxiway and Connectors	Primary	Runway/Taxiway	Great Lakes	Waiting for additional information.	New/Reconstruction/Overlay
Denver International; Runway 16R-34L	Large Hub	Runway/Taxiway	Northwest Mountain	Planning/Construction/Other	New/Reconstruction/Overlay
Detroit Metropolitan Wayne County; Deicing Apron	Large Hub	Apron	Great Lakes	Planning/Design/Other	New/Reconstruction/Overlay
Detroit Metropolitan Wayne County; Runway 4L-22R	Large Hub	Runway/Taxiway	Great Lakes	Planning	New/Reconstruction/Overlay
Ellington Field (TX); Runway 17R-35L	Small Hub	Runway/Taxiway	Southwest	N/A	New/Reconstruction/Overlay
George Bush Intercontinental; Taxiway	Large Hub	Runway/Taxiway	Southwest	N/A	New/Reconstruction/Overlay
Hartsfield-Jackson Atlanta International; Taxiway M	Large Hub	Runway/Taxiway	Southern	Planning/Design	New/Reconstruction/Overlay
Hartsfield-Jackson Atlanta International; Runway 9R-27L	Large Hub	Runway/Taxiway	Southern	Planning/Design/Construction/Other	New/Reconstruction/Overlay
Hartsfield-Jackson Atlanta International; Runway 9L-27R/Taxiway M Slab Replacement	Large Hub	Runway/Taxiway	Southern	Planning/Design	Major Repair
Hartsfield-Jackson Atlanta International; Taxiway Extension	Large Hub	Runway/Taxiway	Southern	Planning/Design	New/Reconstruction/Overlay
Hartsfield-Jackson Atlanta International; Taxiway F & L	Large Hub	Runway/Taxiway	Southern	Planning/Design/Construction	New/Reconstruction/Overlay



Table B-1 (continued). Identified airport concrete pavement construction projects.

<b>Airport/Project</b>	<b>Classification</b>	<b>Facility Type</b>	<b>FAA Region</b>	<b>Accelerated Aspect</b>	<b>Construction Method</b>
Hartsfield-Jackson Atlanta International; Ramp	Large Hub	Apron	Southern	Planning/Design	New/Reconstruction/Overlay
Indianapolis International; FedEx Ramp	Medium Hub	Apron	Great Lakes	Planning/Design	Major Repair
John F. Kennedy International; Taxiway L-A	Large Hub	Runway/Taxiway	Eastern	Planning/Design/Construction/Other	New/Reconstruction/Overlay
Kansas City International; Runway 19R-37L	Medium Hub	Runway/Taxiway	Central	N/A	New/Reconstruction/Overlay
Kansas City International; Apron	Medium Hub	Apron	Central	N/A	New/Reconstruction/Overlay
LaGuardia Airport; Taxiway	Large Hub	Runway/Taxiway	Eastern	N/A	New/Reconstruction/Overlay
Lambert-St. Louis International Airport; Runway 12L-30R	Large Hub	Runway/Taxiway	Central	Planning/Design/Other	New/Reconstruction/Overlay
Las Vegas-McCarran International; Apron Reconstruction	Large Hub	Apron	Western Pacific	N/A	New/Reconstruction/Overlay
Los Angeles International; Patching/Repair	Large Hub	Runway/Taxiway	Western Pacific	Design/Construction	Major Repair
Louis Armstrong New Orleans International; Runway 1-19	Medium Hub	Runway/Taxiway	Southwest	Planning/Design/Construction/Other	New/Reconstruction/Overlay
Manhattan Regional (KS); Taxiway A	Non-hub (Primary)	Runway/Taxiway	Central	N/A	New/Reconstruction/Overlay
Memphis International; Runway 18R-36L	Medium Hub	Runway/Taxiway	Southern	Planning/Design/Construction/Other	New/Reconstruction/Overlay

Table B-1 (continued). Identified airport concrete pavement construction projects.

<b>Airport/Project</b>	<b>Classification</b>	<b>Facility Type</b>	<b>FAA Region</b>	<b>Accelerated Aspect</b>	<b>Construction Method</b>
Memphis International; Runway 18C-36C	Medium Hub	Runway/ Taxiway	Southern	Planning/Design/ Construction/Other	New/Reconstruction/ Overlay
Miami International; Runway 8-26	Large Hub	Runway/ Taxiway	Southern	Planning/Design/ Construction/Other	New/Reconstruction/ Overlay
Minneapolis-St. Paul International; Runway 12R-30L	Large Hub	Runway/ Taxiway	Great Lakes	Planning/Other	New/Reconstruction/ Overlay
Norman Y. Mineta San Jose International; Runway 12L-30R Extension	Medium Hub	Runway/ Taxiway	Western Pacific	Planning/Design/ Construction/Other	New/Reconstruction/ Overlay
Norman Y. Mineta San Jose International; Runway 12L-30R Overlay	Medium Hub	Runway/ Taxiway	Western Pacific	N/A	New/Reconstruction/ Overlay
Okmulgee Municipal (OK); Runway 17-35	GA	Runway/ Taxiway	Southwest	N/A	
Ontario International (CA); Taxiway	Medium Hub	Runway/ Taxiway	Western Pacific	Planning/Design/Other	New/Reconstruction/ Overlay
Phoenix Sky Harbor International; Runway 8-26	Large Hub	Runway/ Taxiway	Western Pacific	Planning/Design/ Construction/Other	New/Reconstruction/ Overlay
Pittsburgh International; Deicing Apron	Large Hub	Apron	Eastern	Planning/Other	New/Reconstruction/ Overlay
Port Columbus International; Apron	Medium Hub	Apron	Great Lakes	N/A	New/Reconstruction/ Overlay
Rapid City Regional; Runway 14-32	Non-hub (Primary)	Runway/ Taxiway	Great Lakes	Waiting for additional information.	New/Reconstruction/ Overlay
Sacramento International; Apron	Medium Hub	Apron	Western Pacific	N/A	Major Repair

Table B-1 (continued). Identified airport concrete pavement construction projects.

<b>Airport/Project</b>	<b>Classification</b>	<b>Facility Type</b>	<b>FAA Region</b>	<b>Accelerated Aspect</b>	<b>Construction Method</b>
Salt Lake City International; Apron	Large Hub	Apron	Northwest Mountain	N/A	Major Repair
San Diego International; Apron	Large Hub	Apron	Western Pacific	N/A	Major Repair
Savannah/Hilton Head International; Runways 9-27 and 18-36 Intersection	Small Hub	Intersection	Southern	Planning/Design/Construction/Other	New/Reconstruction/Overlay
Seattle-Tacoma International; Runway 16R-34L	Large Hub	Runway/Taxiway	Northwest Mountain	Planning/Design/Construction	Major Repair
Seattle-Tacoma International; Apron	Large Hub	Apron	Northwest Mountain	N/A	Major Repair
Vance Airforce Base; Runway and Taxiway A	Military	Runway/Taxiway	Southwest	N/A	Major Repair
Washington Dulles International; Taxilane	Large Hub	Runway/Taxiway	Eastern	N/A	Major Repair
Washington Dulles International; Taxiway	Large Hub	Runway/Taxiway	Eastern	N/A	Major Repair
Washington Dulles International; Runway 12-30	Large Hub	Runway/Taxiway	Eastern	Planning/Design/Construction/Other	Major Repair
William P. Hobby Airport; Runways 12R-30L and 4-22 Intersection (1995)	Medium Hub	Intersection	Southwest	Design/Construction	New/Reconstruction/Overlay
William P. Hobby Airport; Runways 12R-30L and 4-22 Intersection (2002)	Medium Hub	Intersection	Southwest	Design/Construction	New/Reconstruction/Overlay
Williams Gateway Airport	Cargo (Reliever)	Apron	Western Pacific	N/A	New/Reconstruction/Overlay

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