MEETING THE DEMANDS AT PHOENIX SKY HARBOR INTERNATIONAL AIRPORT: THE REPLACEMENT OF RUNWAY 8-26 WITH PCC PAVEMENT

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ABSTRACT

Phoenix Sky Harbor International Airport (PHX), the world's fourth busiest airport, is owned and operated by the City of Phoenix. The City's Aviation Department decided to replace the bituminous concrete pavement on Runway 8-26 with Portland cement concrete (PCC) pavement. As PHX is the busiest three-runway airport in the world, the runway needed to remain operational during reconstruction.

The City chose Michael Baker Jr., Inc. to provide design services for the project. The project involved reconstructing the 11,000-foot long bituminous concrete runway and its exit taxiways with PCC pavement; the extension of the runway and its parallel taxiways; and the replacement of the drainage, electrical and NAVAID systems.

The project posed a number of operational and construction challenges for the design team. These challenges included such requirements as keeping the runway operational during construction, maintaining a minimum available runway length of 6,000 feet during construction, and satisfying all FAA safety area criteria when the runway is operational.

In order to minimize the operational impacts to the airfield, the City mandated an accelerated construction schedule. Soft subsurface conditions across the project site necessitated special attention to expedite the construction. In order to maintain the minimum runway length requirement of 6,000 feet, the center portion of the runway had to be constructed at night. The runway was shut down nightly and reopened each morning. Special material applications of Portland cement concrete were necessary to satisfy the FAA safety area criteria during construction of this center section.

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INTRODUCTION

The Phoenix Sky Harbor International Airport (PHX) is the world's fourth busiest airport, as well as the world's busiest three-runway airport. The Airport is located in the City of Phoenix, Maricopa County, Arizona, approximately four miles southeast of the City's central business district. The Airport site covers approximately 2,500 acres. The Airport is owned and operated by the City of Phoenix.

Two of the runways, Runway 8-26 and Runway 7L-25R, were originally constructed with a bituminous concrete surface. Runway 8-26 was 11,000 feet long and 150 feet wide. Runway 7L-25R is 10,300 feet long and 150 feet wide. The third runway, Runway 7R-25L, was constructed with Portland cement concrete (PCC) pavement. Runway 7R-25L is 7,800 feet long and 150 feet wide. It was completed just prior to the start of the reconstruction of Runway 8-26.

Each runway is served by a series of parallel taxiways and exit taxiways to facilitate efficient ground movements of aircraft. Taxiways T, S, and R are parallel to each other and connect the north and south sides of the airfield. The parallel taxiways serving Runway 8-26 are designated A and B. Taxiway A is constructed entirely of bituminous concrete pavement, while the majority of Taxiway B was previously reconstructed with PCC pavement. The remainder of Taxiway B and its holding aprons were constructed of bituminous concrete pavement.

PROJECT PURPOSE AND NEED

This project was undertaken to achieve two major objectives. The first objective was to extend Runway 8 by 900 feet to the west. Additional runway length was deemed necessary to help departing aircraft carry increased payloads (passengers, cargo, and fuel) on long domestic and international flights. The hot temperatures experienced in Phoenix serve to compound the need for additional runway length during the summer, when the average temperature exceeds 106 degrees Fahrenheit. The need for an extension to Runway 8 is discussed in the Airport's Master Plan.

The second objective of the project was to reconstruct existing Runway 8-26 with PCC pavement. The Airport had implemented a pavement management program to inventory and evaluate the condition of the existing airfield pavements. The resulting pavement management report recommended reconstructing the existing bituminous concrete airfield pavements with PCC pavement. The report further determined that the existing pavement on Runway 8-26 was in critical need of reconstruction.

The City selected a design team led by Michael Baker Jr., Inc., to provide design services for the project. The project was funded by the City of Phoenix and the Federal Aviation Administration (FAA).

PROJECT DESCRIPTION

The project involved extending Runway 8 and its parallel taxiways by 900 feet; reconstructing Runway 8-26 and its southern exit taxiways (Taxiway B connectors) with PCC pavement; and the replacement of the drainage, electrical and NAVAID systems. As a result of the Airport's future plans to construct a fourth parallel runway north of Runway 8-26, the ultimate locations of the northern exit taxiways are undefined. Since the locations of these taxiways were subject to change, the City did not want to reconstruct them with PCC pavement and possibly have to remove them in the future. Therefore, the pavement for the northern exit taxiways (Taxiway A connectors) was designated to remain as bituminous concrete.

The major work items associated with the runway extension portion of this project included: the demolition of existing T-hangars to accommodate the extensions of Taxiways A and B; the construction of PCC pavement to extend Runway 8, Taxiway A, and Taxiway B; the construction of bituminous runway shoulders; the construction of associated drainage facilities; the extension of existing edge lighting systems for Runway 8-26 and Taxiways A and B; the installation of appropriate guidance signs for the proposed improvements; the construction of a 1,000' long and 520' wide RSA beyond the end of the runway, including paved blast pad; the relocation of airport navigational aids (NAVAIDs), including the localizer and Runway End Identifier Lights (REILs); the installation of a Category I Instrument Landing System (ILS) for the approach to Runway 8; the relocation of the existing perimeter fence and service road to accommodate the runway extension; the demolition and/or abandonment of existing 24th Street and its utilities within the Airport's secured area; and, the demolition of an existing parking facility within the proposed runway safety area.

The major work items associated with the runway reconstruction portion of this project included: the reconstruction of the existing bituminous Runway 8-26 and Taxiway B connector with PCC pavement; the reconstruction of existing bituminous Taxiways C12 and R with PCC pavement; the rehabilitation of all existing bituminous Taxiway A connectors within the runway safety area; the rehabilitation of the existing bituminous runway shoulders; the construction of additional connector taxiways to Taxiways A and B; the reconstruction of the existing bituminous Runway 26 aircraft hold pad at Taxiway B with PCC pavement; the construction of associated drainage facilities; the implementation of recommended elements of the Master Drainage Plan being prepared by others; the construction of a 1,000' long and 520' wide RSA beyond the end of Runway 26, including paved blast pad; the reconfiguration of the existing edge lighting circuitry on Runway 8-26, Taxiway A and Taxiway B; the replacement of all existing guidance signs on Runway 8-26, Taxiway A, Taxiway B and Taxiway C; and the relocation and/or installation of airport NAVAIDs, including the glide slope antenna, PAPIs and REILs on Runway 26.

PROJECT CHALLENGES

An airfield project of this magnitude presents a series of challenges to the project team. Obviously, reconstructing a runway on the world's fourth busiest airfield presents a host of operational impacts, especially when trying to keep the airport operating in a "business as usual" manner. The design of the project must consider these operational constraints as well as other factors in order to keep the airport operating as smoothly as possible during construction.

Operational Challenges

Prior to the start of this project, airport management conducted a series of informational meetings with the FAA and the primary air carriers to present several options for accomplishing the runway reconstruction. The options included a full runway closure to complete the runway reconstruction, the use of declared runway distances during construction, and the use of a reduced runway length during construction.

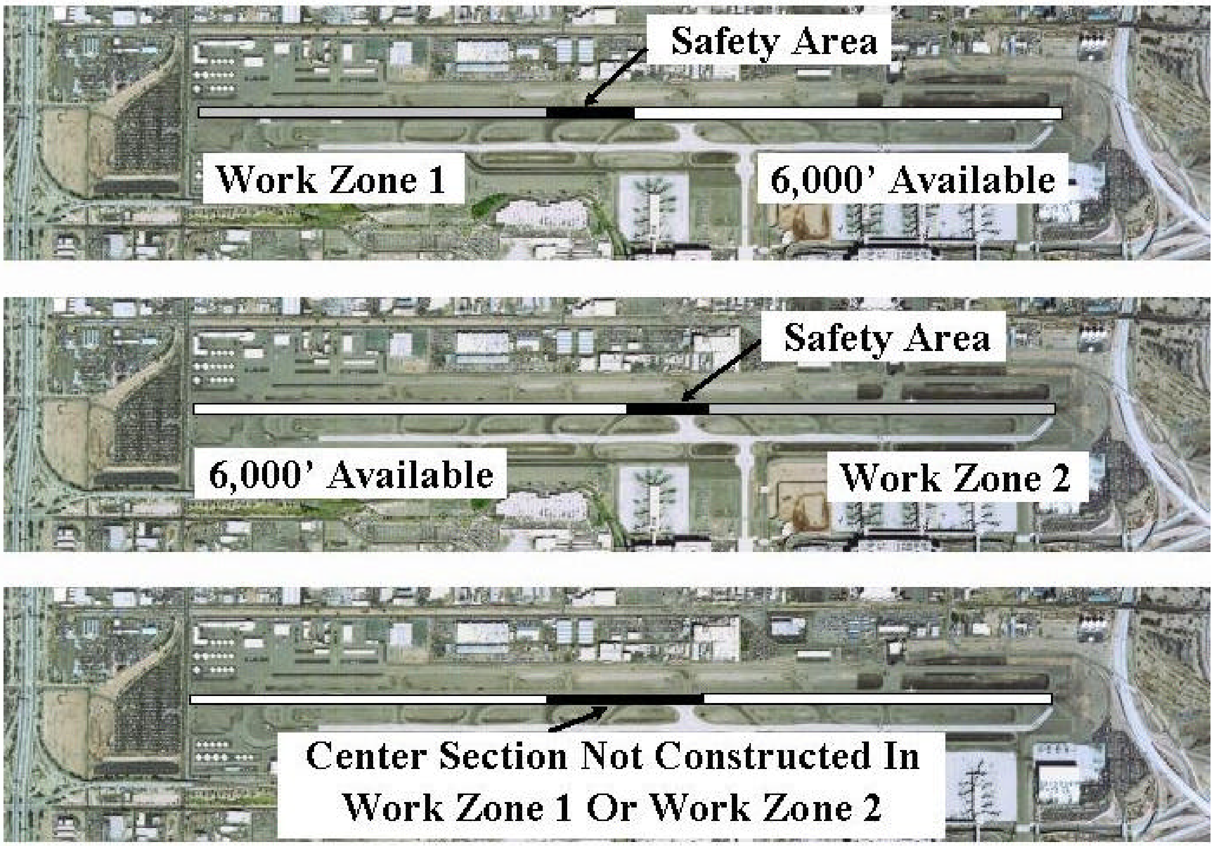
The full runway closure to complete the runway reconstruction was immediately eliminated from further consideration. Some of the factors that contributed to this decision included separation distance between the remaining runways, noise mitigation restrictions, and the large number of operations at PHX. According to the FAA Air Traffic Control Tower (ATCT), Air Transport Association (ATA), and the primary air carriers, an extended runway closure would effectively reduce PHX to one arrival runway and one departure runway. This would cause traffic congestion and substantial delays both on the ground and in the air. Because of these impacts to airport operations and the financial impacts to the users, extended runway closure periods were not deemed practical. Likewise, the FAA dismissed the use of declared runway distances during construction as a viable option.

The selected option was the use of a reduced runway length during construction. Because of the high temperatures between May 1 and September 30, reducing the runway length during this timeframe was not deemed acceptable. The primary air carriers and the ATA agreed that a minimum runway length of 6,000 feet would be required at all times between October 1 and April 30. The primary air carriers further stated that they would compensate for the 6,000-foot runway length by restricting the types of aircraft using the runway and by reducing their takeoff weights. Nightly runway closures for construction would be permitted.

As part of the preliminary design of this project, a general sequence for construction was determined using the parameters described above. The purpose of the general construction sequencing was to provide a basis for the development of an operational, cost-effective construction phasing plan to accomplish the extension and reconstruction of Runway 8-26. As discussed earlier, phasing concepts were considered that utilized declared runway distances or required the closure of the runway. In order to minimize this closure time, an accelerated construction schedule (around-the-clock work) would probably have been specified. Additionally, non-traditional paving materials and methods would have been necessary in order to minimize the runway closure time.

In order to accommodate the airlines' 6,000-foot minimum length requirement with nothing but nightly runway closures, the minimum length of runway pavement required would be 12,000 feet. The sequence is shown in Figure 1.

FIGURE 1
General Construction Sequencing



The challenge resulting from this general construction sequencing plan was to develop a means for constructing the runway center section while keeping the runway operational.

Constructibility Challenges

The initial step in developing a means for reconstructing the runway was to evaluate the various materials and methods available for constructing the center section. Among the materials considered were full depth bituminous pavement, permanent pre-cast post-tensioned concrete slabs, and rapid set concrete pavement. Since the rehabilitation method recommended in the pavement management report was to reconstruct the runway with PCC pavement, the City quickly rejected the use of full depth bituminous pavement. The City also dismissed permanent pre-cast post-tensioned concrete slabs because of the limited historical data available to support the use of this method. The City had concerns with the use of rapid set concrete pavement as well. These concerns revolved around the use of rapid set concrete materials in an arid climate and how they may adversely impact the performance and subsequent maintenance of the pavement structure.

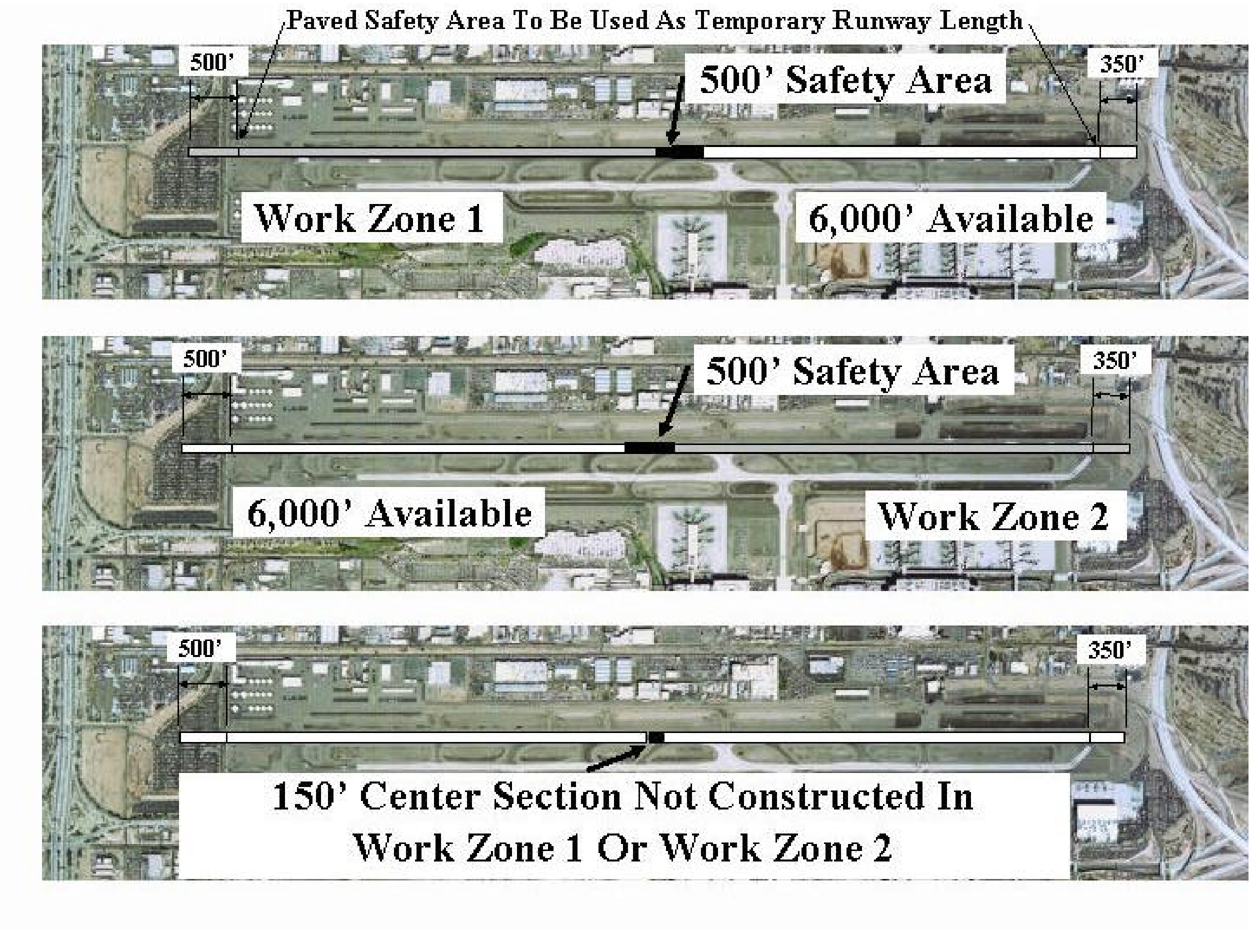
At the time, a project was underway at Los Angeles International Airport (LAX) that was using rapid set concrete for construction of pavements in the Runway Safety Area (RSA). Arrangements were made for the project team to visit the Southside Taxiway WG, WF and T Project at LAX. Because of its location, the construction of rapid set concrete pavement was done under severe operational constraints, during periods of night construction only. Although the constraints imposed on the contractor significantly diminished the efficiency of the construction, the field view convinced the City and the design team that some form of rapid set concrete was a viable option at PHX. As a result, the City opted to use rapid set concrete to construct the center section of the runway.

Even though the City had decided to use the rapid set concrete, its inherent construction inefficiencies made it incumbent upon the design team to minimize the length of the runway's center section. The most obvious method of reducing the length of the center section was to decrease the RSA length beyond the ends of the shortened runway. The City and the design team approached the FAA with a request to allow the use of safety area lengths of five hundred feet (500'), instead of the one thousand feet (1,000') required by Advisory Circular AC 150/5300-13. As depicted in Figure 2, the use of shortened safety area lengths could reduce the length of the center section to as little as one hundred fifty feet (150'). In light of its increased attention to safety area criteria, the FAA would not agree to safety area lengths less than the required one thousand feet (1,000').

As discussed earlier, the overall length of pavement required to maintain a 6,000-foot operational runway is 12,000 feet. The actual pavement length available at the completion of construction would be 11,900 feet. In order to provide the required length, an additional 100 feet of structural pavement was constructed on the runway's west end. With the 1,000-foot RSA length required by the FAA, the length of the center section was two thousand feet (2,000'). In order to meet the established operational parameters, the runway's center section had to be constructed during nightly runway closures.

The final step in developing a means for reconstructing the runway was to minimize the time that the runway would be reduced to 6,000 feet. As stated earlier, the airlines agreed to the 6,000-foot runway length between October 1 and April 30. During a series of project coordination meetings with the City, the airlines, the FAA, and the ATA, concerns were expressed that temperatures in October and April can still be relatively high in Phoenix. As a result, it was determined that a minimum runway length of 10,000 feet would be needed during the months of October and April to reduce the payload impacts to the airlines. As the design developed, the airlines continued to assess the financial impacts of reducing their takeoff payloads. These analyses prompted the airlines to ask the City to try to reduce the construction duration for the 6,000-foot runway. As a result, the City requested that the design team compress this construction time as much as possible.

FIGURE 2
Effects of Reduced Safety Area Lengths on Center Section



One of the major factors to be considered in trying to minimize the construction time was the variable subgrade material encountered throughout the project site. Variable subsurface conditions had been an ongoing problem during previous projects at the airport. Consequently, the design team undertook a very extensive subsurface investigation to identify any potential problem areas.

In accordance with the City's and the airlines' earlier requests, the maximum length of time that the runway could be reduced to 6,000 feet had effectively been reduced to the period between November 1 and March 31. This construction window meant that the majority of the work would be performed during what are typically the wettest months in Phoenix. This only served to compound the potential subgrade problems on a fast track construction project.

Once again, the design team identified another construction project that provided insights into how other airports were meeting the challenges of continually compressed project schedules. The City of Atlanta was reconstructing Runway 9R-27L at Hartsfield Atlanta International Airport on a fast-track schedule. The project consisted of PCC pavement removal and replacement with new PCC pavement on the existing cement treated base course (CTBC). The reconstruction of the runway was scheduled to be completed in thirty-five and one-half (35.5) days. Despite the fact that the project had experienced eight days of rain, the project manager expected the runway would be reopened no more than one day late. Placement on the CTBC was considered the key issue in being able to complete the project in such a short time frame.

In addition to keeping the runway operational as stated earlier, the design team had to consider a means for constructing the runway while minimizing the overall duration of the reduced runway length. The factors contributing to the fast track constructibility challenge included runway length restrictions; variable subgrade materials; development of a rapid set concrete specification; and protection of the subbase during construction.

MEETING THE CHALLENGE

The challenge of developing the pavement section needed to consider the variable subgrade characteristics and the protection of this material during construction.

As was the key to the fast track schedule in Atlanta, a stabilized subbase was recommended by the design team to serve as a paving platform for the PCC pavement. The primary purpose of the paving platform was to protect the subgrade from unfavorable weather conditions. The scheduled timeframe for construction during the winter months only magnified the need for such a platform.

According to the requirements of Paragraph 328 in AC 150/5320-6D, “Stabilized subbase is required for all new rigid pavements designed to accommodate aircraft weighing 100,000 pounds or more.” Pavements serving similar functions at PHX have historically been constructed using aggregate base courses (ABC). AC 150/5320-6D includes an exception to the policy requiring stabilized bases and subbases if superior materials are available, “such as 100 percent crushed, hard closely graded stone. These materials should exhibit a remolded soaked CBR minimum of 100 for base and 35 for subbase.” The City’s materials laboratory has indicated that aggregates native to the Phoenix area routinely meet these requirements. As a result, the City’s preference has been the use of P-209 ABC for economic reasons. Additionally, they have experienced longer pavement lives with the use of ABC, as compared to stabilized bases. However, after having witnessed the benefits of a stabilized subbase in Atlanta, the City agreed that the paving platform was an important component in achieving this fast track construction schedule. Consequently, the City approved the use of a four-inch (4”) thick bituminous concrete base course as a paving platform for the proposed eighteen-inch (18”) PCC pavement.

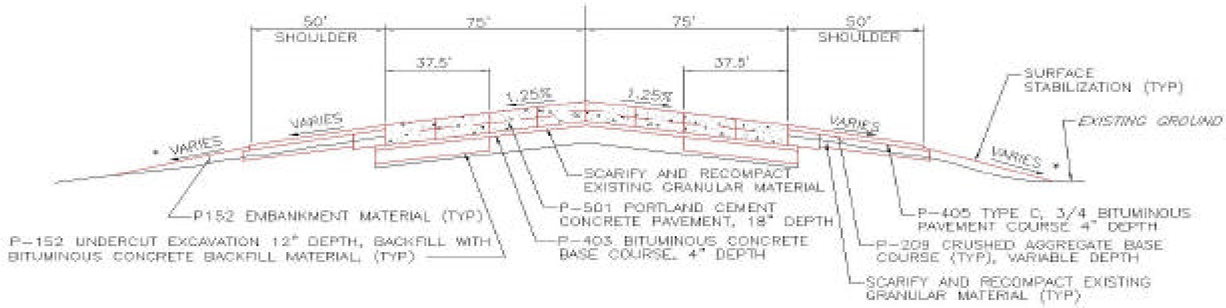
Like the trip to Hartsfield Atlanta International Airport, the design team’s extensive subsurface exploration also proved invaluable in helping to develop the appropriate pavement section. A typical geotechnical analysis usually is limited to investigating areas near the runway centerline. In addition to the centerline, the analysis undertaken for this project also examined the outer edges of the runway. Such an extensive investigation allowed the design team to locate and isolate poor quality subgrade conditions.

The subsurface exploration revealed a keel section that was much thicker than the outer edges of the runway pavement. Of the various components making up the existing runway pavement section, the ABC exhibited the widest variation in thickness. A relatively thick layer of ABC existed beneath the bituminous pavement within the runway's keel section. The geotechnical investigation found this ABC layer to be in good condition, with a CBR value in excess of 35. Given its thickness and condition, the ABC could be used as part of the structural pavement section, thereby saving substantial construction time. After the removal of the existing bituminous pavement, the ABC layer needed to be protected prior to the placement of the paving platform. To achieve grade and to prevent damage from heavy construction equipment, the project specifications required the use of auto trimming equipment to remove the final six inches (6").

Unlike the keel section, the quality and thickness of the aggregate base course material in the outer (non-critical) edges of the runway pavement varied widely. The design team was concerned about the suitability of this material to serve as a base course. Historically, undercuts as deep as seven feet (7') have been performed when unsuitable material was encountered on airfield projects at PHX. Removal and replacement of such a substantial amount of unsuitable material could seriously impact the fast track construction schedule. In order to facilitate the fast track construction schedule, the project specifications required unsuitable areas to be undercut by only one foot (1'). These undercut areas were backfilled in three lifts with bituminous pavement in order to provide a bearing strength similar to the keel section.

The typical pavement section developed to accommodate the variable subgrade characteristics discussed above is shown in Figure 3.

FIGURE 3
Typical Runway Reconstruction Section



The challenge of developing the rapid set concrete specification was to specify a material that would meet the FAA's runway safety area criteria related to both strength and grade.

The 2,000-foot center section of the runway served to provide the 1,000-foot temporary runway safety areas for the 6,000-foot runways. The runway was to be closed each night, allowing for construction within the center section, and the runway would have to be reopened each morning with a fully functional safety area.

In order to provide a fully functional safety area, all criteria as described in AC 150/5300-13 and AC 150/5370-2 had to be met each morning prior to re-opening the runway. This criteria includes the following:

- The area shall be cleared and graded and have no potentially hazardous ruts, humps, depressions, or other surface variations.
- The area shall be free of objects, except for objects fixed by function.
- Longitudinal grades for the first 200 feet of the RSA beyond the end of the runway shall be between 0 and 3 percent, with any slope being downward from the end. For the remainder of the RSA, the maximum longitudinal grade shall be 5 percent provided no part of the RSA beyond the end of the runway penetrates the approach surface or clearway plane.
- The maximum transverse grades are 1.5 % to 3 %.
- The maximum drop off at a pavement edge is 3 inches.

In addition to the above criteria, the safety area surface shall be capable of supporting maintenance equipment, aircraft rescue and firefighting (ARFF) equipment, and the occasional passage of aircraft without causing structural damage to the aircraft.

In order to meet the safety area criteria, a rapid set concrete material was needed to allow reopening the runway each morning. Since the temporary safety area would ultimately serve as runway pavement, the concrete was also required to achieve the same 28-day flexural strength (650 psi) as the rest of the runway. Because of its similar operational constraints the Southside Taxiway Project at LAX posed comparable challenges. The LAX project was night construction only with 8-hour work shifts within the RSA. The RSA had to be restored each morning prior to reopening the runway. A high early strength (HES) PCC pavement specification (Item P-503) had been developed for this project. The flexural strength at the time established for reopening the runway was 350 psi. The concrete placement method was restricted to sideform only.

Given the City's initial concerns regarding rapid set concrete and some of the difficulties witnessed at LAX, a lower strength P-503 concrete was specified for this project. Using the anticipated aircraft fleet mix provided by the signatory airlines, the necessary flexural strength to meet the safety area criteria was determined to be 250 psi. Though this pavement strength was determined to be adequate to meet the safety area criteria, any slab subject to such early loading could be expected to experience potential structural damage. Therefore, a provision was included in the specification stating that any load induced damage to P-503 pavement, which might occur prior to final acceptance, and which was beyond the Contractor's control, would be removed and replaced. The lower strength P-503 requirement also provided an additional benefit, in that it permitted the concrete to be placed using either sideform or slipform methods.

The resulting rapid set concrete specification (P-503) included strength requirements for both daily reopening of the runway and for 28-day design strength. Payment reduction factors were imposed for failure to meet either of these requirements.

The challenge to minimizing the construction duration of the reduced runway length was to develop a construction schedule that was aggressive but achievable. The reduced undercut depth, the paving platform, and the P-503 specification all contributed significantly to minimizing the construction duration. Obviously, reducing the depth of the undercut created a substantial time savings. The use of the paving platform reduced the risk of extended weather-related delays. The primary purpose of the P-503 specification was to allow reconstruction of the runway's center section while keeping the runway operational during the day. However, in order to meet the time constraints imposed for the 6,000-foot runway, the duration for the construction of the center section was limited as well. As discussed earlier, the lower opening strength HES concrete allowed the contractor the option of slipforming in lieu of sideform placement, thereby helping to complete the construction in the minimum time frame possible.

The schedule developed for this project provided the contractor with 285 calendar days to complete the entire construction. However, the 6,000-foot runway length was limited to ninety (90) calendar days. With some minor phasing modifications, the contractor was able to successfully complete this portion of the work in eighty (80) calendar days.

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