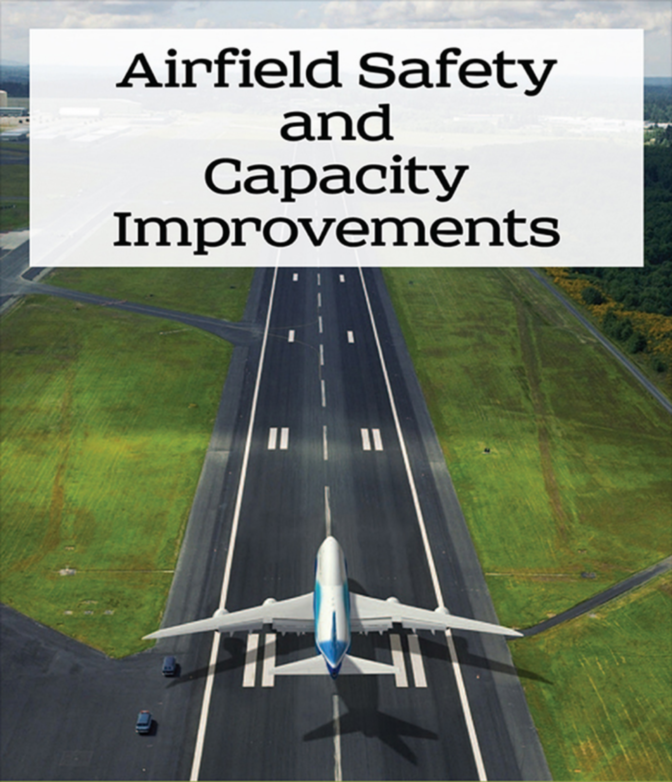
Airfield Safety and Capacity Improvements



Case Studies on Successful Projects

Edited by
Geoffrey S. Baskir
Edward L. Gervais, P.E.

ASCE
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AIRFIELD SAFETY AND CAPACITY IMPROVEMENTS

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Preface

Nothing is more crucial to the capacity of an airport than the addition of new runways. Most airport master planning exercises determine the need for facilities such as terminals, parking, roads, people movers and passenger amenities from the aircraft acceptance rate of the airport, and while efficiencies can be achieved in the administration of the airspace surrounding an airport, new runways provide the greatest increase in absolute capacity. A single runway can handle as many as 50 aircraft operations an hour, or in a dedicated situation, either 30 arrivals or 40 departures an hour.

A hub airport with 500,000 aircraft operations a year may need as many as four runways operating simultaneously to handle the volume of air traffic at a level of delay acceptable to the traveling public. And that demand level increases annually; in a healthy economy, the volume of passengers grows about 3% a year at the nation's airports (and decisions by the airlines on the expansion of service at their hubs can often cause sizeable increases at individual airports in any given year). A 3% annual gain is incrementally small, but it will boost an airport's level of activity by a third in a decade. It has now been more than three decades since the airlines were deregulated.

Beyond that, airports may find it necessary to expand their runways to handle larger or faster aircraft. At the same time, the service life of a typical runway is 20 years, at which time it needs to be rehabilitated or replaced. All three factors – addition, expansion and replacement – contribute to the need for new runway construction.

Development of a new runway or taxiway system is a process that often takes a decade or more, from conceptual planning through construction. It is a process influenced by the need to raise capital and complete environmental analyses. And it is a process that requires a robust database of information about the project site conditions and the working environment. Even in a situation where the runway or taxiway is simply being reconstructed, the replacement process often includes two years of design and engineering, and another two years of construction (although the construction of the new runway for IGI Airport in New Delhi, India, as described in one of the following articles, was executed in 18 months, about a half year ahead of schedule). Reconstruction brings with it the additional challenge of maintaining airfield operations while the work proceeds.

Each of the articles included herein is a narrative telling the story of how different project successes were achieved. Requirements, objectives, challenges, methodologies and lessons learned are outlined for each project. Different approaches have been taken to complete each project, and each offers a unique insight into how complex projects can be completed.

Above all, these projects represent in microcosm the kinds of infrastructure investments that airports will be making in the future to keep pace with growing demand. Two projects involve the rehabilitation of existing runways to support the next generation of traffic demand (and to accommodate a new generation of airplanes), one project is an entirely new runway to provide capacity at one of India's busiest airports as it is redeveloped into a 21st century hub, and one improved the operating efficiency of one of the busiest airports in the US as a new international terminal is completed.

The editors and authors of this monograph are indebted to the American Society of Civil Engineers Transportation and Development Institute under the leadership of Messrs. Terry Donovan, Ali Salim and Jonathan Esslinger for their support of this effort. The editors also acknowledge and thank Drs. Imad Al-Qadi and Ernie Heymsfield, and Messrs. Brian McKeehan, Jeffrey Gagnon, Frank Hermann and Rich Thuma for their review efforts. Finally, the editors wish to extend their most sincere thanks the authors of the articles collected herein; their tireless efforts to give of their time to create this monograph is deeply appreciated.

Abbreviations

ACC	Airport Access Controllers (airport operator's ground personnel)
AAI	Airports Authority of India
AC	Asphaltic Concrete
ACP	Asphaltic Concrete Pavement
AGL	Airfield Ground Lighting
ARFF	Aircraft Rescue and Fire Fighting
ARM	Area Resident Manager
ASDA	Accelerate Stop Distance Available
ATB	Asphalt Treated Base
ATC	Air Traffic Control
ATCT	Air Traffic Control Tower (FAA)
Baker Tanks	Large, mobile holding tanks for the temporary storage of storm water and storm water sediments
BC	Bituminous Concrete
CALM	Coordination and Logistics Management
CAT III B	Category III B Instrument Approach Procedures
CCR	Constant Current Regulator
CTA	Central Terminal Area
CTB	Cement Treated Base
CUP	Central Utility Plant
DBM	Dense Bituminous Macadam
DGCA CARs	Directorate General of Civil Aviation Civil Aviation Requirements
FAA	United States Federal Aviation Administration
FOD	Foreign Objects and Debris
GIS	Geographic Information Systems
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IGIA	Indira Gandhi International Airport
ILS	Instrument Landing System
LAWA	Los Angeles World Airport
LAX	3-Letter Code for Los Angeles International Airport
LDA	Landing Distance Available
LEG	Logistics Expeditor Group
M	Million
MCTOW	Maximum Certificated Take-Off Weight
MDP	Major Development Plan
MLW	Maximum Landing Weight
MPPA	Million Passengers Per Annum
NAVAID	Navigational Aids
NFPA	National Fire Protection Association
NOTAM	Notice(s) to Airmen
OMDA	Operation Management and Development Agreement

PCB	Polychlorinated Bi-phenyl
PCCP	Portland Cement Concrete pavement
PG	Performance Grade (a grade of bitumen)
PMB	Polymer Bituminous Macadam
PTB	Passenger Terminal Building
PQC	Pavement Quality Concrete
REDIM	Rapid Exit Design Interactive Model
RESA	Runway End Safety Area
RET	Rapid Exit Taxiway
RFF	Rescue and Fire Fighting
RM	Running Meters
ROT	Runway Occupancy Time
RWSL	FAA’s Runway Status Light program to prevent runway incursions
SAMI	Stress Absorbing Membrane Interlayer
SBS	Styrene-Butadiene-Rubber
STIA	Seattle-Tacoma International Airport
T3	Terminal 3
TBIT	Tom Bradley International Terminal at Los Angeles Intl Airport
TODA	Take-Off Distance Available
TORA	Take-Off Run Available
USCC	Utility Shutdown Control Center
USR	Utility Shutdown Request
WBS	Work Breakdown Structure

Chapter 1

New Delhi Indira Gandhi International Airport Runway Design and Construction

Arun Chandran[1] and Indana Prabhakara Rao[2]

ABSTRACT

The new airport pavement construction was part of a major modernization and upgrading plan which included renovation of existing terminals and construction of a new Terminal 3 (T3) and a new Runway System. This expansion work started in January 2006 and the project involved airfield development (construction of a new runway, new parallel taxiways, new taxiway system, new aircraft aprons and new satellite rescue and fire fighting (RFF) facilities), passenger terminal building (PTB) development works and landside development including construction of a new multi-level car park. This paper will detail the runway and its construction.

The expansion work was aimed at increasing the capacity of the airport from 17 million passengers per annum (mppa) to 34 mppa and was carried out alongside existing operating facilities of the airport.

The design and construction of a 4430m x 75m (14,530 feet x 246 feet) new third runway and over 16,000m (52,493 feet) of new taxiways was undertaken at the Indira Gandhi International Airport at New Delhi between February 2007 and August 2008. The airfield development work was completed in 18 months, more than 6 months ahead of its scheduled deadline. The new Code-F parallel runway opened for commercial operations on August 21, 2008 and was commissioned on September 25, 2008. It is one of the longest runways in India and features a CAT III B Instrument Landing System (ILS) and associated lighting systems at both ends, allowing compatible aircraft to land with the minimum runway visual range of 50m (164 feet). It is designed to handle new generation large aircraft such as the Airbus A380.

A number of innovations, design solutions and advanced construction techniques were adopted in the design and these features led to major benefits during the execution of the project. The scale of the project was huge as it required an enormous amount of work to be completed in the shortest possible time. The major challenges were continuous design as construction was in progress, mobilization of materials and

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resources, safety and security of the operational airport and completing the runway ahead of schedule in order to be ready for winter conditions in the year 2008.

INTRODUCTION

The Indira Gandhi International (IGI) Airport serves the city of Delhi and is located 16 km (10 miles) from the city centre. There were two existing runways (prior to the new runway being built) Runway 10/28 (3,810m – 12,500 feet) and an auxiliary Runway 09/27 (2,813m – 9,230 feet – in length). The main Runway 10/28 was one of the few runways in Asia that is equipped with a CAT III-B Instrument Landing System (ILS) on one end allowing landing visibility as low as 50m (164 feet).

This new Runway (11/29), parallel to the existing Runway 10/28, can accommodate the world's largest commercial aircraft and the associated taxiways and aprons were built at a cost of approximately USD $577 million (INR 26 billion). The developer of the IGIA project was the GMR group, Larsen & Toubro were the contractors and Parsons Brinckerhoff served as project management consultants for this project.

The airside works were completed successfully despite severe time constraints, a stringent Operation Management and Development Agreement (OMDA) containing the concessionaire requirements, and a lack of technically advanced contractors in India for the project construction. A number of design innovations were made based on numerous value engineering studies and obstacle planning exercises. The construction work was undertaken in rainy and humid conditions, varying temperatures with highs surpassing 40°C (104°F) and other changing environmental conditions. A controlled environment was required to ensure proper placement of asphaltic concrete and Portland Cement Concrete pavements. The challenges included plant and machinery procurement and setup within a short period, importing key equipment, drainage considerations and overall infrastructure planning.

All the challenges were met successfully through detailed planning, proper setup of infrastructure facilities, administration and management of over 10,000 workers on a monthly basis.

THE PROJECT: PHASING OF WORKS

The airfield pavements were to be constructed in two phases: Phase 1A and Phase 1B as per the runway plan shown in Figure 1-1. Phase 1A which included the main runway, was planned to be completed ahead of all the other works that included the terminal building and other airside works as described below.

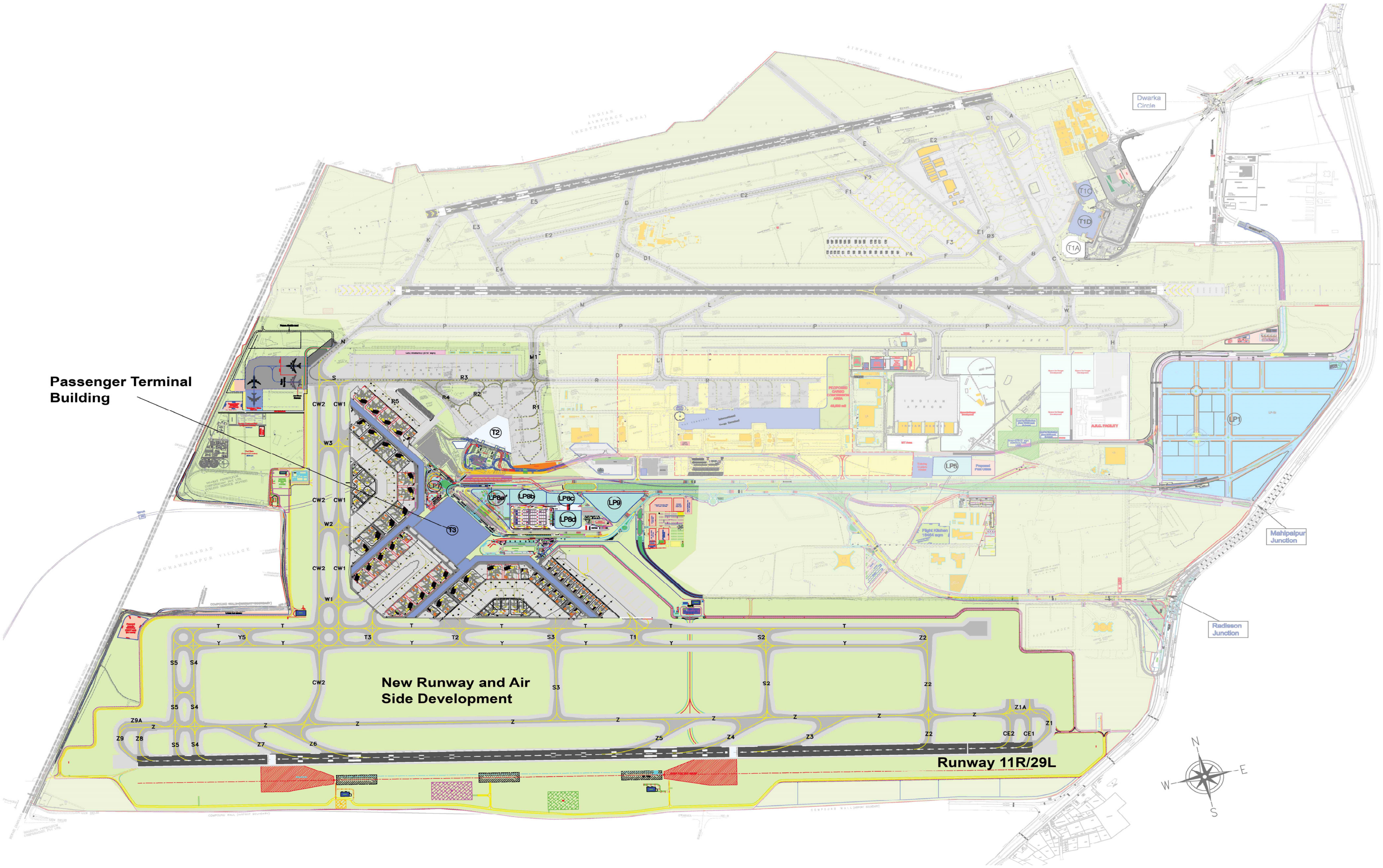

Figure 1-1. Airport master plan including new Runway (11/29)
Source: Delhi International Airport Limited (DIAL); reproduced with permission

Phase 1A (the plan of which is shown in Figure 1-2) included the following:

- Runway 11/29 (4430m x 60m) + 7.5m shoulder on either side – Code 4F
- Runway provided with ILS and CAT-IIIB lighting (compliant with ICAO)
- Five Rapid Exit Taxiways (RETS)
- Other 90° exit taxiways
- Full length parallel taxiway (taxiway 10) (4430 x 25m) 17.5m shoulder – Code F
- Twin parallel cross-field taxiways linking the new Runway 11/29 with the existing Runway 10/28 (taxiways 6 & 7)
- Various short length taxiways connecting parallel taxiways, and
- Aircraft parking stand apron pavements for cargo and international aircraft at Terminal 3

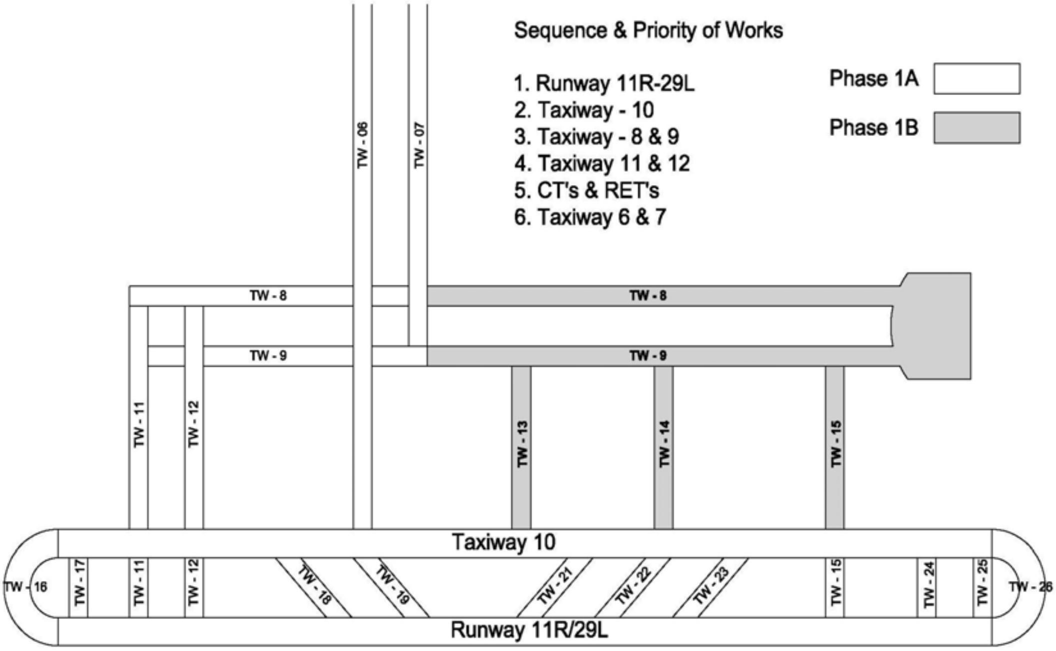

Figure 1-2. Phase 1A and 1B pavements
Source: authors

Phase 1B (also highlighted on Figure 1-2) included:

- Airside pavements (including twin parallel apron-edge taxiways running east-west (taxiways 8 & 9)
- Aircraft parking stand apron pavements for Terminal 3
- Apron taxi lanes
- Various cross field taxiways connecting taxiway 10 with taxiways 8 & 9
- Various short length taxiways connecting apron areas with adjacent taxiways and surrounding areas designed to enable the early handover of additional taxiways.

A future Runway 11L/29R is planned to be parallel to and 380m (1,250 feet) to the north of Runway 11/29. The existing Runway 10/28 in the northern airfield zone is planned to be retained as Runway 10R/28L, and a new Runway 10L/28R is planned to be constructed to the north of the existing runway. These planned runways are shown in Figure 1-3 below.

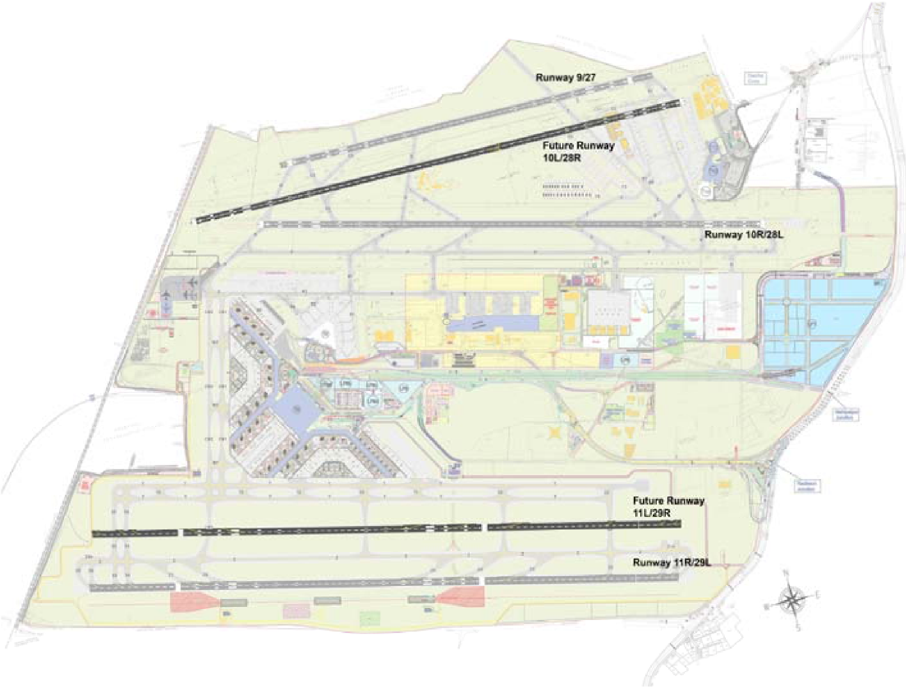

Figure 1-3. Planned runways
Source: Delhi International Airport Limited (DIAL); reproduced with permission

DESIGN CRITERIA

The criteria considered for the design of the runway, taxiways and aprons included:

- Director General Civil Aviation (DGCA) (India) Civil Aviation Requirements (CAR's), Section 4 Aerodrome Standards & Air Traffic Services, Series B, Part I – Aerodrome Design & Operations;
- International Civil Aviation Organization (ICAO), Annex 14 – Volume 1 Aerodrome Design and Operations (Standards and Recommendations);
- ICAO Aerodrome Design Manual – Part 1 Runways;
- ICAO Aerodrome Design Manual – Part 2 Taxiways, Aprons and Holding Bays;
- IATA Airport Development Reference Manual 8th & 9th Editions;
- National Fire Protection Association (NFPA) – 415 Standard on Airport Terminal Buildings, Fueling Ramp Drainage and Loading Walkways;
- Final Major Development Plan (MDP); and
- IGIA Master Plan.

DESIGN ENHANCEMENTS

Runway 11/29 End Positions

In general design practice, the runway ends line up with the edge of connecting taxiways, rather than the centreline, in order to have the runway end lights at the very end of the pavements and to prevent a situation where the pilots are required to taxi over a row of red runway end lights, which is not considered good practice as these lights appear similar to red stop bar lights. Originally the two runway end positions were to line up with the centrelines of cross taxiways 17 and 25. The connecting taxiways 17 and 25 were relocated by 12.5m (41 feet) to ensure that the runway ends line up with the edge of the taxiway pavement. In addition, the adjacent taxiways 16, 24 and 26 were relocated in order to maintain the taxiway separation requirements of 97.5m (320 feet).

Runway 11/29 Threshold Locations and Declared Distances

Displaced thresholds were required at both ends of Runway 11/29. Runway 11/29 has been designed with landing thresholds displaced 645m (2,116 feet) and 1460m (4,790 feet) for Runways 11 and 29 respectively, and with end of Take-off Run Available (TORA) displaced 320m (1,050 feet) and 150m (492 feet) for Runways 11 and 29 respectively. The Runway 11/29 threshold locations and runway declared distances are shown in Table 1-1

	TORA	**TODA**	**LDA**	**ASDA**
Runway 11	4,110m (13,484 ft)	4,110m (13,484 ft)	3,465m (11,368 ft)	4,430m (14,534 ft)
Runway 29	4,430m (14,534 ft)	4,430m (14,534 ft)	2,970m (9,744 ft)	4,430m (14,534 ft)

Table 1-1. Runway 11/29 declared distances
Source: Delhi International Airport Limited (DIAL); reproduced with permission

Landing Distance Requirements

The overall length of Runway 11/29 is 4,430m (14,534 feet). There is a significant obstruction which could not be relocated external to the eastern airport perimeter because of which the Runway 29 landing threshold is displaced 1,460m (4,790 feet) from the eastern end of the runway resulting in a Landing Distance Available (LDA) of 2,970m (9,744 feet). The displacement is less for Runway 11R resulting in an LDA of 3,465m (11,368 feet).

Safety Considerations

Given the unusually long displaced thresholds required for Runway 11/29, an analysis was undertaken to check the suitability of the proposed landing and take-off distances provided in Table 1-1 above. The analysis was conducted to assess the landing and take-off distances required for selected critical aircraft under the most difficult meteorological conditions experienced at Delhi airport which are as follows:

- Ambient temperature – 41 Degrees C (104 Degrees F)
- Runway elevation – 735 ft above sea level
- Barometric pressure – 1013hPa QNH
- Wet runway (monsoon) – 3mm (0.12 inches) of standing water
- Zero head wind
- Aircraft land at maximum landing weight(MLW)
- Aircraft take off at maximum certificated takeoff weight (MCTOW), and
- Aircraft have typical engines as defined by the aircraft type

The conclusions of the analysis were as follows:

- The Runway 29 LDA of 2,970m and the Runway 11 LDA of 3,465m are sufficient for all expected aircraft types when operating at the extreme conditions and MLW.
- The Runway 29 TORA of 4,430m and the Runway 11 TORA of 4,110m are sufficient for all expected aircraft except most B777 variants (B777-200LR, B777-300, B777-300ER) when operating at the extreme conditions and MCTOW. Depending on airline specific operating procedures, the B777 variants may be weight restricted when operating at the extreme conditions.

Runway Strip, Runway End Safety Area and Blast Pads

The runway was designed to extend 60m (197 feet) beyond the physical end of the runway and to span laterally to a distance of 150m (492 feet) on each side of the centreline. The graded portion of the runway strip was designed to extend 105m (344 feet) from the centreline. Although DGCA CAR’s allow the graded portion to be narrowed to a width of 75m (246 feet) from the centreline over the first 150m from the runway end and to taper from 75m to 105m over a further 150m, additional safety has been incorporated into the system by adopting the 105m width for the full length of Runway 11/29.

A Runway End Safety Area (RESA), extending 240m (787 feet) from the end of the runway strip and having a width of 75m on each side of the extended runway centerline, was provided at each end of the runway strip.

Blast pads (120m long and 75m wide) were provided at each end of the runway to prevent erosion of the surfaces adjacent to the ends of the runway due to jet blast or propeller wash.

Runway 11/29 Rapid Exit Taxiway (RET) Optimization

The angle of each RET is 30° to the runway, the curve leading onto each RET has an exit radius of 550m (1,800 feet) and each RET has a straight section 75m long after the curve to facilitate braking and stopping before the parallel taxiway. During the design stage, the designer used the computer program REDIM 2.1 (Rapid Exit Design Interactive Model), developed for the FAA, to determine the optimum locations of the Runway 11/29 RETs using a range of input parameters, including aircraft mix, landing weight, runway length, runway slope and ambient conditions.

Numerous combinations of number of RETs, RET location and exit speed were analyzed in order to determine the average Runway Occupancy Time (ROT) and the optimum RET locations. Exit speeds of 30, 45 and 50 knots were analyzed. A practical analysis followed the REDIM analysis to check how the REDIM recommendations fit with the overall airfield geometry. These analyses led to the following recommendations:

- Adoption of a design runway turnout speed (in wet conditions) of 45 knots.
- 3 x RETs for Runway 11 and 2 x RETs for Runway 29, with locations at optimum chainages determined by the REDIM analysis and inspection of the overall Runway 11/29 taxiway layout.
- The intersection of the main cross field taxiway (taxiway 06) and the parallel taxiway was recommended to be moved to the west, creating a “kink” in the taxiway 06 alignment in order to provide a sweeping exit from the RET to the cross field taxiway.

Changes to Taxiway Alignments

As has been mentioned earlier, taxiways 17 and 25 were relocated and so were the adjacent taxiways 16, 24 and 26 so that the required taxiway separation requirements were maintained.

The RET located at 1816m (5960 feet) measured from threshold 29, provides a connection to taxiway 6, and onwards to the T3 apron complex via the shortest route. This RET was positioned to cater for the majority of Code C traffic, which forms the majority of air traffic at IGIA. The usage of this RET was expected to be extremely high and therefore a functional connecting taxiway system was required.

As taxiway 6 is located at 2060m (6760 feet) measured from threshold 29, taxiway 6 was kinked between the future Runway 11L/29R centerline and the tangent to the 48.75m (160 feet) radius exit curve from the RET. Aircraft can therefore execute a simple turn in order to maneuver onto Taxiway 6.

As the construction was to be done in two phases, only Code E aircraft were allowed to operate on the eastern side of taxiway 07 and the northern side of taxiway 08 in order to maximize the construction area for the Phase 1B Stage 2 aprons. Code F aircraft required to operate on the southern airfield development prior to the opening of the Phase 1B Stage 2 aprons on Taxiways 06, 09 and 10.

The taxiway fillet geometry was designed to ensure that the aircraft track envelope is fully contained within the high strength pavement boundary. Typically, 90° intersections with a 48.75m (160 feet) turning radius were designed with a 93m (305 feet) long tapering section and inside pavement radius of 25m (82 feet).

Grading Plan

The development of a Master Grading Plan concept during any green field airport development is important to ensure that the initial phase infrastructure is positioned and graded to not only allow for future expansion, but to allow for the most optimal grading of that future expansion. A Master Grading Plan was developed for IGIA and includes all of the master planned southern airside development.

GENERAL LAYOUT

Pavement Types (Rigid versus Flexible)

Two options were considered for the pavement types for the runway and taxiway system namely rigid Portland Cement Concrete for the Pavement Quality Concrete (PQC) and flexible (semi-rigid) asphalt surfaced cement treated base (CTB). The asphalt surfaced CTB pavement type was chosen for the construction of the majority of airfield pavements because it was faster to construct and required less import of crushed aggregates as compared to a conventional unbound granular pavement type. Pavement quality concrete (PQC) pavement was chosen for the runway ends, the departure taxiways adjacent to the runway ends, the parallel taxiway ends to facilitate aircraft queuing, and at the aircraft parking aprons.

While taxiing for takeoff at the runway ends, aircraft typically move at a slow speed and in periods of high traffic they hold and move forward according to their turn for takeoff. Both of these actions increase the loading time of the pavement, causing asphalt rutting and premature pavement deformation especially at elevated temperatures. The departing aircraft often also carry high fuel loads in addition to payload, so maximum stress is applied onto the pavement structure. The turning movements from one taxiway to the other and on the runway can also place high shear stresses on the pavement and cause pavement “scuffing” and “rutting” if a flexible pavement is provided, particularly when the temperature is high. Therefore concrete taxiway pavements were constructed near the takeoff runway ends for the extent of likely taxiway queuing and holding.

Based on the assessment of peak queuing requirements in the future, which indicated that up to six aircraft could be queued during busy periods, PQC pavement of length 437m (1,434 feet) has been provided on the runway, commencing at the Runway 11R end and finishing around 75m, or 246 feet (approximately one large aircraft length) past the tangent point of Taxiway 12.

The PQC on Taxiway 10 finishes at 4,087m (13,410 feet), which will enable a long queue of aircraft to hold on PQC pavements ready for departure on the dominant Runway 29.

Flexible pavement type 1 (Figure 1-4), flexible pavement type 2 (Figure 1-5) and rigid pavement type 1 (Figure 1-6) were the different types of pavement structures that were used at different locations on the Runway 11/29. The various layers of these pavement types have a different composition of materials such as asphaltic concrete (AC), dense bituminous macadam (DBM), polymer modified bitumen (PMB), 30/40 penetration grade bitumen, 60/70 penetration grade bitumen etc. as given in the diagrams below.

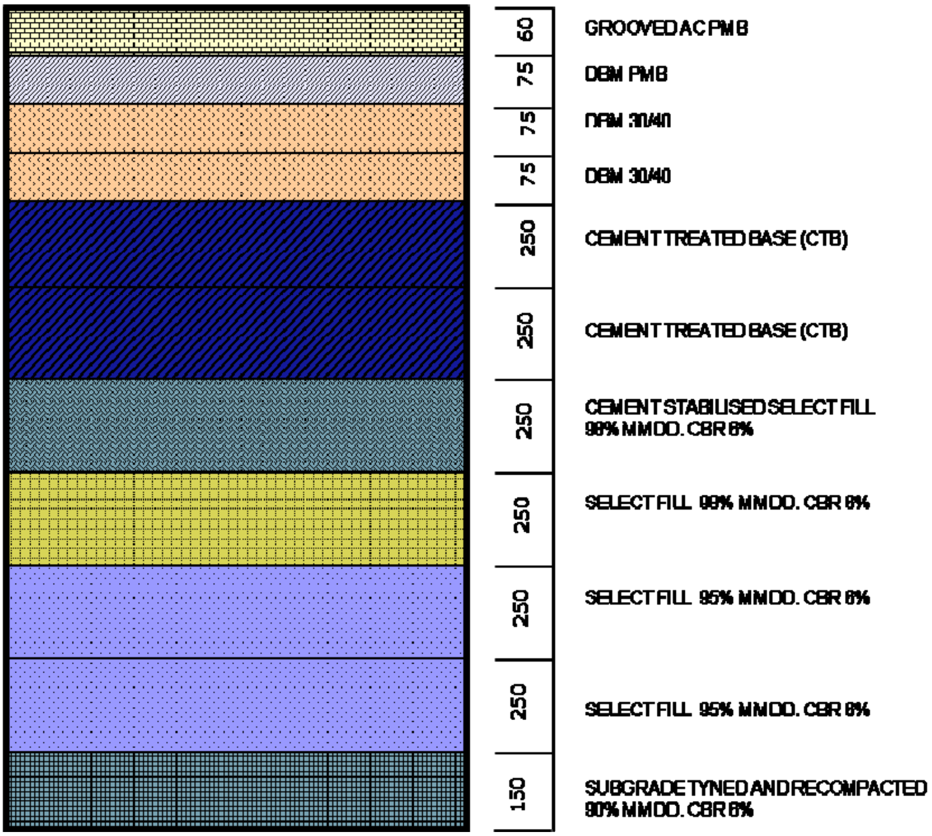

Figure 1-4. Flexible pavement type 1 used on the runway and at the RET entries *
Source: Delhi International Airport Limited (DIAL); reproduced with permission

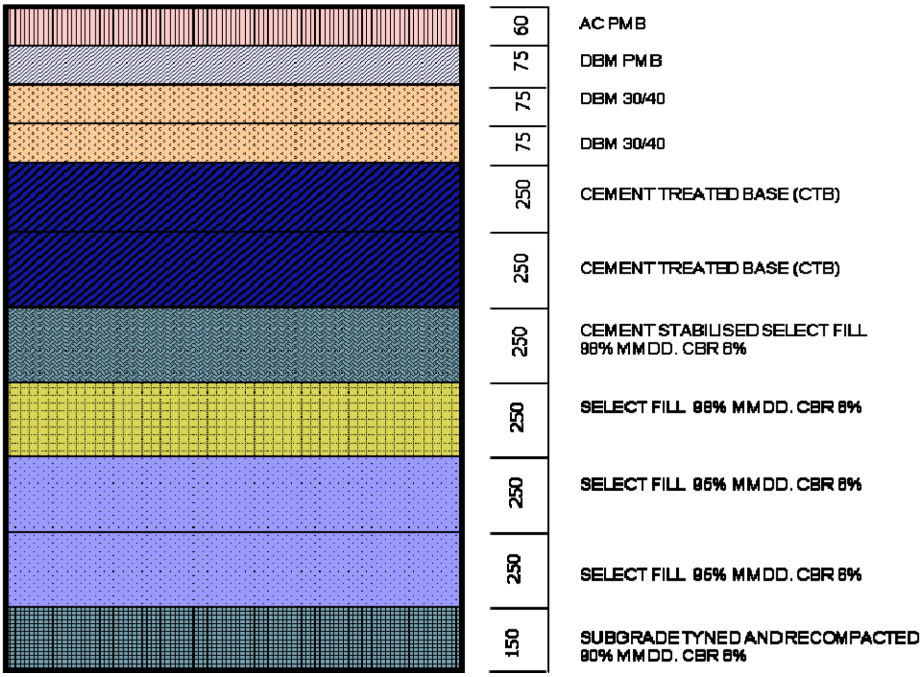

Figure 1-5. Flexible pavement type 2 used at the taxiways *
Source: Delhi International Airport Limited (DIAL); reproduced with permission
*A layer of Stress Absorbing Member Interlayer was laid over the first layer of DBM

Concrete Joint Detailing and Future Tie-ins

PQC panels were provided around the northern and eastern edges of Taxiways 24, 25, 26 and 10 to allow for future expansion of these taxiways. The future tie-in will be performed by dowelling into the existing panels, so that no edge thickening is required along these joints.

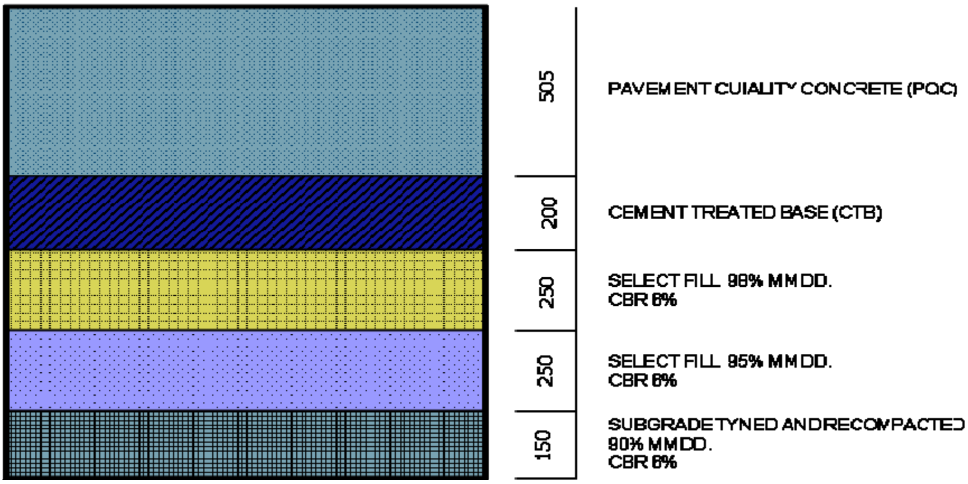

Figure 1-6. Rigid pavement type 1 used at the Runway ends, Taxiway 10, 11, 12 ends and Taxiways 16, 17, 24, 25 and 26
Source: Delhi International Airport Limited (DIAL); reproduced with permission

Structural concrete panels 0.7m (2.3 feet) wide were provided across the PQC to enable the installation of airfield ground lighting runway end lights and approach light threshold bars. This significantly reduced the risk of cracking of the panels in the vicinity of the closely spaced lights. An isolation joint has been provided along the edge of each threshold light bar.

Isolation joints were provided along the edge of the runway to separate the taxiway pavements, and these have been provided at other locations to separate uniform masses of concrete.

Dowelled construction joints were provided in the direction of paving, and un-dowelled sawn contraction joints were provided in the transverse direction. Sawn dowelled contraction joints were provided at strategic locations where joints may tend to open due to expansion, where floating slabs occur adjacent to isolation joints, or where a large mass of odd-shaped corner slabs will be placed in one placement.

Transition pavements were provided along the border between PQC and high strength flexible pavement as shown in Figure 1-7. The transition pavement is designed to transition both stiffness and depth, and to provide ease of construction adjacent to PQC pavements.

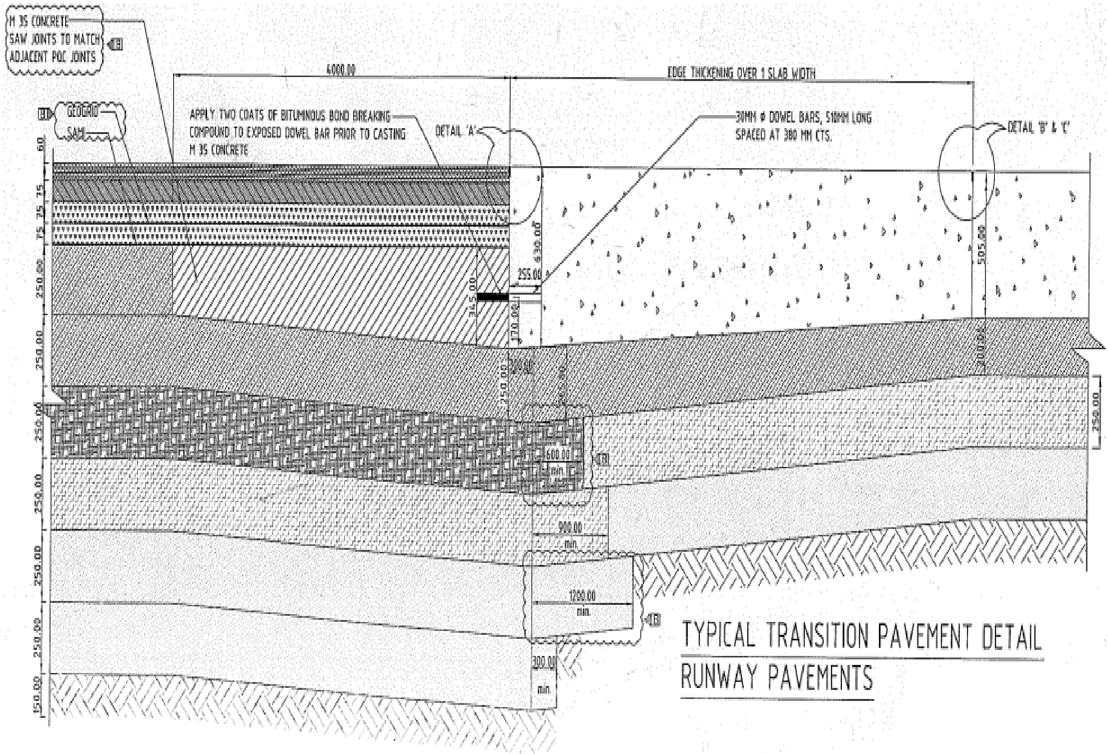

Figure 1-7. Transition pavement detail
Source: Delhi International Airport Limited (DIAL); reproduced with permission

ADDITIONAL DESIGN FEATURES

Pavement design was done such that the use of rock aggregate as compared to what is used in the conventional pavement design was minimized. An eco-friendly design for pavement material was designed to allow for the use of fly ash in concrete and other cement based material. Cement was used to stabilize the soil so the required design parameters of soil were consistent. Sophisticated state of the art machinery like the cement spreader, soil stabilizer and heavy capacity soil compactors were used for soil stabilization.

Specially designed cement treated aggregate base was used to reduce the consumption of rock aggregates. This was the first runway in India to use cement mixed aggregate base layer under the bituminous pavement layers. A specially designed stress absorbing membrane layer (polymer based glass grid of international standard) was used to prevent reflection of cracks on the pavement surface under aircraft loading. In order to make it more suitable for the local climatic conditions and for a superior pavement quality, polymer modified bitumen was used in the top layers of the bituminous pavement.

CONSTRUCTION WORK

The runway work started in February 2007 and was completed in a period of 18 months (including the monsoon period). There were demanding production targets for major items such as earthwork, cement stabilized subgrade, cement treated base (CTB), asphalt layers, pavement quality concrete (PQC), drainage works, line marking, airfield ground lighting (AGL) and turfing. Major works completed were:

- A 4,430 km runway (14,534 feet), 60 meters (197 feet) wide main pavement and 7.5 meters (25 feet) wide hard paved shoulders.
- More than 16 km (10 miles) of taxiways including a parallel taxiway with a length of 4,300 meters (14,107 feet), 5 Rapid Exit taxiways and 12 other taxiways.
- More than 350 Ha/ 5 million cubic meters (6.5 million cubic yards) of earthworks.
- More than 1.2 million square meters (1.4 million cubic yards) of area of cement treated/ stabilized subgrade material.
- 0.45 million cubic meters (590,000 cubic yards) of Cement Treated Base
- 0.59 million tonnes (0.65 million US tons) of asphalt works
- 0.17 million cubic meters (0.22 million cubic yards) of concrete
- More than 16 km of drainage works including open drains, pipe and box culverts
- 600 km of AGL conduits (all sizes)
- More than 2.15 million square meters of Turfing.
- 9.60 km of asphalt perimeter road.
- More than 9 km of concrete boundary wall.

Suitable plant, machinery and equipment were procured from various sources and locations and manufacturing units were setup on site to facilitate the production rates and the progress needed to complete the project in such a short time frame.

Earthworks

The earthworks involved excavation of more than 2.6 million cubic meters and filling quantity of 2.5 million cubic meters. Approximately 5,000 density checks were conducted. Nuclear density gauges were used to carry out the vast number of field density checks. More than 20 soil compactors/rollers, 100 trucks/tippers, 15 graders, 15 excavators and 20 water tankers were used along with other equipments like dozers, scrapers, tractors, etc.

Cement treated subgrade material was provided under the pavement strip to ensure consistent soil strength properties. 37.50 meters (123 feet) of lateral area beyond the hard paved shoulders of the runway was also strengthened with cement treated subgrade to withstand aircraft load as per the international requirements.

Equipment and Machinery

Five cement spreaders and four soil stabilizers/ recyclers imported from Germany were mobilized to construct the cement stabilization work. For the subgrade and base layers, eight 18 tonne vibratory soil compactors were used. Six, 27-tonne, 8-wheeled pneumatic tire rollers and more than 20 8-tonne, tandem vibratory rollers with maximum working weight of 10.4 tonnes were used primarily for asphalt works. Three specially designed tractors were used for placing glass grids on the asphalt layer. A custom made aggregate spreader was used for uniform and speedy distribution of aggregates over the glass grids and PMB. A power sweeper was used for cleaning the paved surface and a truck mounted sprayer with temperature control, heating arrangements and pressure control was used to uniformly distribute polymer modified bitumen over the glass grid layer (Figure 1-8) prior to spreading of aggregates.

Figure 1-8. Imported glass grid
Source: Delhi International Airport Limited (DIAL); reproduced with permission

Figure 1-9. Batching plant
Source: Delhi International Airport Limited (DIAL); reproduced with permission

Ten sensor operated pavers were imported from Germany for use in paving operations. Two batching plants of capacity 240 cubic meters/hr each were installed to produce PQC and CTB respectively. Three more batching plants (Figure 1-9) of capacity 110 cubic meters, 20 cubic meters and 30 cubic meters were erected to produce concrete for drainage works and the boundary wall.

Asphalt Works

The various types of bituminous mixes used in the project were Dense Bituminous Macadem (DBM) layer using 30/40 grade bitumen, 60/70 grade bitumen and polymer modified bitumen. The asphaltic concrete layer was also produced using 30/40, 60/70 as well as polymer modified bitumen. The 30/40 and 60/70 grade bitumen was procured from Mumbai. Polymer was imported from Holland and processed at OOMS plant, Mathura in India to produce polymer modified bitumen.

A comparison of the performance grades used for the IGI Runway 11/29 with those used at the Runway 12L/30R at the Dubai International Airport, Dubai is given in Table 1-2 below.

Airport Pavement Thickness Design				
	Layer Thickness		**Material**	
Description	**Dubai**	**Delhi**	**Dubai International Airport (Runway 12L/30R)**	**Delhi (IGI) International Airport (Runway 11R/29L)**
Wearing	55	60	BC20 PG76 Cariphalte Fuelsafe - Two Gradings (Coarse and Fine)	AC13.2 PG80 Polymer Modified Bitumen
Intermediate	65	75	BC20 PG76 SBS Modified Binder	AC20 PG80 Polymer Modified Bitumen
Intermediate	65	75	BC20 PG76 SBS Modified Binder	DBM 20 Dense Bitumen Macadam
Base course	70	75	BC32 60/70 Bitumen	DBM 20 Dense Bitumen Macadam 30/40
Base course	70	250	BC32 60/70 Bitumen	CTB (Cement Treated Base) below the SAMI (Stress Absorbing Membrane Interlayer
Base course	70	250	BC32 60/70 Bitumen	CTB (Cement Treated Base)
Sub base	200	250	Cement Treated Fine Crushed Rock	Cement Treated Subgrade

Table 1-2. Comparative performance grades

Note: Asphalt is a sub-product of Bitumen and the two of these can be used as a substitute for each other

Source: Dubai data from Stephen Emery and Ivan Mihaljevic, 2008, "Accelerated Load Testing of Asphalt Mix Designs for Heavy Duty Pavements in Hot Climates" *23rd ARRB Conference – Research Partnering with Practitioners, Adelaide, Australia, 2008.*

Three aggregate crushing units were specifically established around the Delhi area to cater to this project. More than 30,000 metric tonnes of bitumen was used including polymer modified bitumen. Two types of cement from 15 recognized brands were used to cater to the huge demand and their total consumption was more than 0.17 million metric tonnes. Almost 2000 trial mix designs were conducted in the project laboratory to arrive at the most suitable concrete and asphalt mixes.

An average of 3-5 electronically operated sensor pavers, 18-24 rollers (including pneumatic tire rollers), 18-35 tippers were used simultaneously during the peak production period.

A hot mix asphalt material transfer vehicle was imported and used for the first time on Indian airports to maintain a uniform temperature and produce a consistent mix of asphalt even under extreme cold conditions. The latest technology involving use of modern equipments such as pavesets, balancing beams was used to produce a uniform leveled surface. The paveset grade control system connects to existing controls on asphalt paving machines and controls the paving operations with computerized inputs for items like thickness, direction of operation, etc. The balancing beam attaches to the paver and moves with it and is used to maintain a transverse profile of the top layer of asphalt with consecutive lanes.

Three hot mix plants having a total capacity that exceeded 600 metric tonnes were erected (these were imported from Italy and Germany and approval of the Supreme Court of India was required for their installation in view of the environmental regulations in and around the city of Delhi) to produce the different types of asphalt mixes.

Multilevel quality control and quality assurance checks were performed under a Quality Management System to ensure the required product was delivered. Temperature checks (Figure 1-10) were conducted and density meters were used as an initial compaction check (Figure 1-11) during the placement of the asphalt layer.

Figure 1-10. Temperature check
Source: Delhi International Airport Limited (DIAL); reproduced with permission

Figure 1-11. Density meter check
Source: Delhi International Airport Limited (DIAL); reproduced with permission

As the work was completed in stages, the rolling straight edge check (Figure 1-12) was conducted to check surface irregularity and confirm surface smoothness.

A Stress Absorbing Membrane Interlayer (SAMI) was laid over the first layer of DBM to prevent the reflective cracking of succeeding layers. More than 0.6 million square meters of runway and taxiway areas was covered with SAMI.

Figure 1-12. Rolling straight edge check
Source: Delhi International Airport Limited (DIAL); reproduced with permission

Pavement Quality Concrete

Three Slip Form concrete pavers (two of these were of Wirtgen make shown in Figure 1-13) were used to meet the project production requirements. These were used in tandem at different locations on phase 1A airside works.

Figure 1-13. Wirtgen slip form paver
Source: Delhi International Airport Limited (DIAL); reproduced with permission

The third paver (Figure 1-14), which was a bigger arrangement, was preferred for long runs of PQC. More than 1000 running meters of steel formwork was fabricated to support the placement of PQC.

Figure 1-14. Paver for PQC
Source: Delhi International Airport Limited (DIAL); reproduced with permission

An additional silo was provided in the batching plant for storage and constant feeding of flyash. The silo was insulated and halogen lamps were also provided to avoid moisture and hence blockage of flyash. Manual teams with screed and nozzle vibrators were also mobilized for concrete placement in areas where paver placement was not possible.

Drainage Works

For drainage works, both cast in place (cast in situ), precast drains and a combination of both were adopted to save time. More than 2.8 km of storm sewer was constructed cast in situ while more than 10,000m of pipe was laid using precast elements. A combination of precast and cast in situ concrete work was also used for some portion of the drainage work.

A manufacturing unit was established for producing precast drain panels so that the drainage works could be expedited. Two gantry with capacity 25 tonnes each and five casting beds with the capacity of casting 15 panels each were established in this unit. More than 4,000 panels consuming more than 8,000 cubic meters of concrete were fabricated in this yard and more than 300 men along with 3 hydras (6, 8 and 12-tonne special cranes known to provide consistent performance even in harsh working conditions), one 60-metric tonne crane and 6 trailers were mobilized for this during peak period.

Five boom placers/pump trucks (Figure 1-15) with capacity of 105 cubic meters/hr were mobilized to facilitate pouring of concrete. Their use was shared with PTB and Pier works but at least one was in constant use for airside drainage works.

A fully automated steel service center was established for cutting and bending of reinforcement steel. Though catering mainly to the PTB and Piers, it provided reinforcement steel for drainage works and precast concrete units.

Both pipe culverts and box culverts were used. More than 3500 pipes were used in the construction of pipe culverts.

Figure 1-15. Boom placer
Source: Delhi International Airport Limited (DIAL); reproduced with permission

A concrete pipe manufacturing unit was established on site as the market supply was not sufficient to meet the project demand rate. A vertical casting unit with major parts imported from USA, was erected and its peak production rate was 40 pipes per day. Two horizontal casting units were also erected and their peak production rates reached 15 pipes per day. Curing of these pipes was done using sprinklers (Figure 1-16) and water tanks.

Figure 1-16. Curing of pipes by sprinklers
Source: Delhi International Airport Limited (DIAL); reproduced with permission

Figure 1-17. Box culvert construction
Source: Delhi International Airport Limited (DIAL); reproduced with permission

More than 1080 meters of 2 cell, 3 cell and 5 cell box culverts were constructed. The top covers of box culverts (Figure 1-17) were pre cast to expedite the work.

Line Marking

The paint used for the runway line marking was pre-mixed water based conforming to grade 2 of IS 164-1981 in white, yellow, black and red colors. Glass beads imported from Thailand were also used with the paints. Three line marking machines (GRACO Line laser, model 3900/5900 fitted with glass beads dispenser) were used.

Airfield Ground Lighting (AGL)

Thorn airfield light fittings imported from Honeywell, Germany were used in the runway and taxiways. Photometric tests were carried out before each light fitting was passed for installation on site. 179 deep base cans were imported from the US for light installation in the apron area. 4387 shallow base cans were imported from Germany for installing inset light fittings on the runway and taxiways. Shielded AGL cables were used for the entire installation. The fiber optic cable (along with a redundant line) was connected to the Air Traffic Control tower (ATC) managed by the Airport Authority of India (AAI). .

A total of 200 movement area guidance signs (imported from Germany) and 4 wind cones were installed in Phase 1A. There are 4 AGL substations to provide power supply to the AGL system. These substations house an 11 kv switchgear and a diesel generator set. Constant current regulator (CCR) panels (90 in number) were installed in each of the substations in Phase 1A. Each lighting circuit in the airfield has a separate regulator which maintains the output current throughout at its rated output value depending on the load. All these regulators are equipped with 6 step brightness controls which adjust the brightness of the lamps in the lighting system to compensate for low visibility conditions.

Navigational Aids

The site requirements for navigation aids required for Runway 11/29 were coordinated with the AAI. Weekly meetings were held with AAI to discuss, amongst other issues the location of navigation aids, the dimensions and grading requirements of the navigation aids in critical and sensitive areas and all other power supply and other interface requirements.

Night time work was carried out (Figure 1-18) so that the aggressive deadlines could be met. Figure 1-19 shows the completed Runway 11/29.

Figure 1-18. Night time work
Source: Delhi International Airport Limited (DIAL); reproduced with permission

Figure 1-19. Runway 11/29
Source: Delhi International Airport Limited (DIAL); reproduced with permission

Production Rates, Progress and Resourcing

The daily asphalt production peak rates exceeded 5000 metric tons thus achieving one of the highest production rates in the construction industry. The average daily supply of aggregates during peak period was more than 500 trucks per day and overall more than 2 million tonnes of aggregates was used from various sources. Sample production rates achieved in some activities are given in Table 1-3.

Major items	Quantity	Start Date	Finish Date	Production Rate Achieved (average)
Earthworks (incl. excavation and fill)	5 million m^3	Feb 2007	June 2008	9800 cubic meters/day
Cement stabilized subgrade	0.35 million $meters^3$	Jul, 2007	June, 2008	900 cubic meters/day
Cement treated base	0.45 million cubic meters	Aug, 2007	June, 2008	1250 cubic meters/day
Asphalt layers (excl. perimeter road)	0.59 million metric tones	Oct, 2007	July 2008	1950 metric tonnes/day
SAMI	6,00,000 m^2	Dec, 2007	June, 2008	2850 square meters/day
PQC	94,000 m^2	Dec, 2007	May, 2008	520 cubic meters/day
Line marking	36,000 m^2	Jun, 2008	August, 2008	400 square meters/day
Drains and culverts	3,500 pipes, 10 km precast, 2.8 km cast in situ, 25 km slope lining	Nov, 2008	July, 2008	12 pipes/day, 37 m pre cast drains/day. 10 m cast in situ drains/day. 92 m concrete lining/day.

Table 1-3. Sample production rates achieved
Source: Delhi International Airport Limited (DIAL); reproduced with permission

With the progress of time, activities got more critical as there was less time to complete the works. The quarterly progress had to be ramped up. Table 1-4 gives an idea of the quarterly progress achieved.

Months	**Progress (%)**	**Cumulative Progress**	**Months**	**Progress (%)**	**Cumulative Progress**
Feb-Apr, 07	11.10	11.10	Nov 07-Jan, 08	26.02	78.96
May-Jul, 07	14.29	25.39	Feb-Apr, 08	17.26	96.22
Aug-Oct, 07	27.55	52.94	May-Jul, 08	3.77	99.90

Table 1-4. Quarterly progress details
Source: Delhi International Airport Limited (DIAL); reproduced with permission

A total of 971,142 man days of work was performed and the month-wise Man Days is shown in Table 1-5 below.

Month	Month-wise Man Days	Cumulative Man Days
Feb, 2007	12515	12515
Mar, 2007	13848	26363
Apr, 2007	15948	42311
May, 2007	16235	58546
Jun, 2007	18312	76858
Jul, 2007	19292	96150
Aug, 2007	24607	120757
Sep, 2007	33996	154753
Oct, 2007	39244	193997

Month	Month-wise Man Days	Cumulative Man Days
Nov, 2007	45177	239174
Dec, 2007	74748	313922
Jan, 2008	82120	396042
Feb, 2008	80147	476189
Mar, 2008	93611	569800
Apr, 2008	98276	668076
May, 2008	90853	758929
Jun, 2008	105602	864531
Jul, 2008	106611	971142

Table 1-5. Month-wise and cumulative man days
Source: Delhi International Airport Limited (DIAL); reproduced with permission

Stakeholder Coordination and Collaborative Working Environment

A runway porta-cabin office was set up in the vicinity of the work area to maximize the communication between all the parties and facilitate efficient decision making and problem resolution. The decision-making process was developed early in the project to enable smooth transfer of instructions to the contractor. This was further enhanced by regular monthly coordination meetings that were held.

CONCLUSION

The success of the project was possible only due to thorough planning, an innovative approach both in the design and construction phase, expert project management and excellent teamwork of the various stakeholders – the contractors, consultants, designers, workers and the client. The coordination between these stakeholders was crucial and it was possible because all of them were aligned towards and committed to achieving target timelines and the best outcome.

A clear understanding of the client requirements and the real project drivers was critical for all the parties involved in the design and execution of the project. Tremendous effort was put in to develop innovative solutions and interaction between stakeholders was facilitated to achieve their buy-in. A project of this scale could not have been completed within the aggressive timelines without successful risk management. Actual project risks were identified through in-depth analysis and strategies were developed jointly by all the parties involved.

The project was completed in 18 months and met all quality and safety requirements. The runway was commissioned in September 2008 more than 6 months ahead of the scheduled deadline.

Chapter 2

Reconstruction of Runway 16L-34R at Seattle–Tacoma International Airport

Michelle Moshner[1]; Denise Almojuela[2]; Chris Sherwood[3];
Ray Rawe[4]; and Ralph Wessels[5]

ABSTRACT

Runway 16L-34R has served as the primary runway for air operations at Seattle-Tacoma International Airport (STIA) since 1942. In order to provide adequate allowances for changing aircraft characteristics and greater operational capacity during inclement weather and low visibility in the Seattle area, the runway over the years has been lengthened from the original 1,860 m (6,100 ft) to its current 3,865 m (12,680 ft). The reconstruction of this runway in 2009 with a fast track, 6-month shutdown was a result of prior planning and made possible by construction of a new and shorter third runway in 2008 which allowed the maximum amount of shut down time for this project while still maintaining aircraft operations.

An analysis of Runway 16L-34R rehabilitation options concluded that replacement of the total runway airfield pavement would provide the best opportunity to ensure optimum flexibility throughout construction and provide 50 years of service.

As a result of these decisions, a construction phasing plan was developed with contract documents; an investigation and evaluation of material options was performed; and a constructability review was performed. This resulted in the use of a multi-phased construction plan sequenced to provide on-going air operations.

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The Port of Seattle is the owner / operator of Seattle-Tacoma International Airport, Seaport and Real Estate Holdings

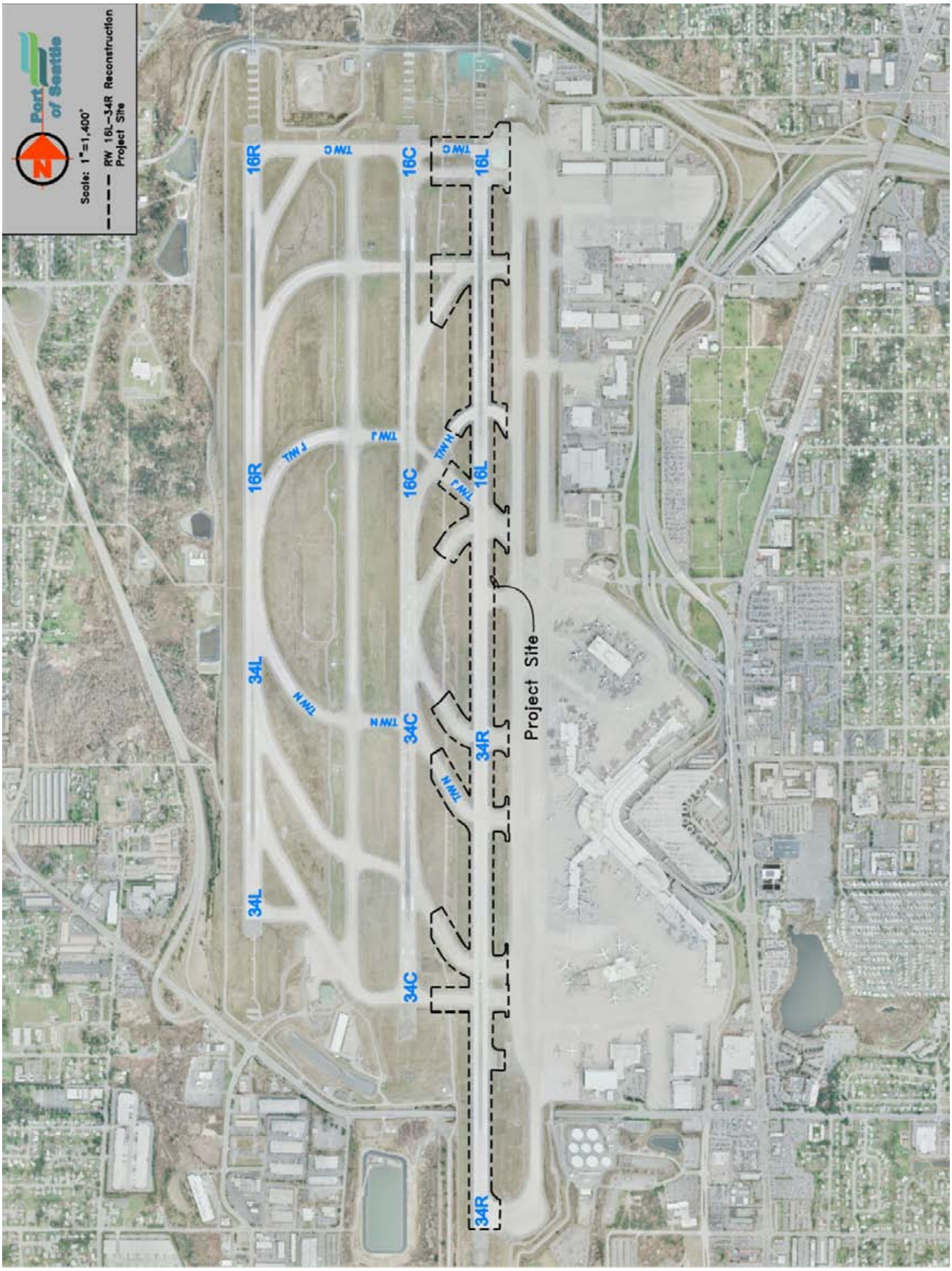


Figure 2-1. Aerial Photo of Seattle-Tacoma International Airport
Source: Port of Seattle; reproduced with permission.

RUNWAY BACKGROUND

The original 16L-34R (Runway 16 Left – 34 Right) was constructed in 1942 and was 1,860 m (6,100 ft) in length. Refer to Figure 2-1. It was constructed of Portland cement concrete pavement (PCCP) 150 mm (6 in.) thick. Over the ensuing years, several additions to the length of the runway were made. In 1950, 430 m (1,400 ft) of pavement were added to the north. This pavement was 200 mm (8 in.) thick PCCP. In 1955, an additional 300 m (1,000 ft) were added to the north which was followed in 1957 with the addition of yet another 520 m (1,700 ft) to the north. These additions were 305 mm (12 in.) thick PCCP. The final lengthening of the runway happened in 1961 when 760 m (2,480 ft) were added to the south which also consisted of 305 mm (12 in.) thick PCCP.

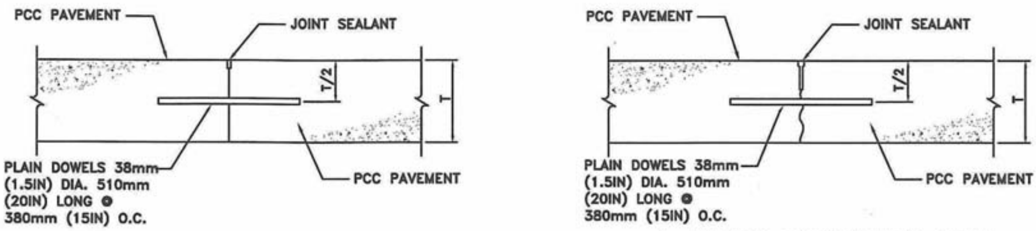
Numerous asphalt overlays and repairs were done in addition to the lengthening described above. These were completed in 1952, 1957, 1963 and at various times between 1972 and 2002.

Runway 16L-34R and its infrastructure were completely reconstructed in 2009. The runway was reconstructed with the crown moved 8 m (25 ft) east of the previous centerline to the centerline of the new runway. The lateral safety areas, east and west of the runway, were completely re-graded to meet current FAA standards where possible. In some cases, the FAA requested that re-grading not be performed so as to avoid impacting NAVAID surfaces and equipment.

The runway width before reconstruction was 46 m (150 ft) of ACP (asphaltic concrete pavement) overlay on PCCP with 12-15 m (40-50 ft) wide ACP shoulders. The reconstructed runway width was 46 m (150 ft) of PCCP with 11 m (35 ft) wide ACP shoulders. The completed runway length was 3,860 m (12,680 ft). Portions of Taxiways C, H and J were reconstructed within the lateral safety area of 16L-34R as part of this project.

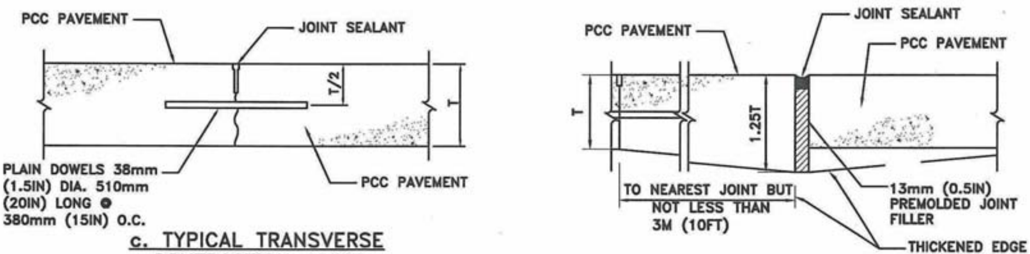
The PCCP was placed utilizing a slipform paver. The slipform paving was completed in four lanes that were 11 m (37.5 ft) wide with a contraction joint cut at the center (5.7 m or 18.75 ft). The transverse contraction joints are typically located at 6 m (20 ft) spacing. The transverse isolation joints (formerly known as expansion joints) are located along the edges of all connecting taxiways. Refer to Figure 2-2.

All longitudinal and transverse joints (construction and contraction) are dowelled.



a. TYPICAL CONSTRUCTION JOINT
(DOWELED)
SCALE: NTS

b. TYPICAL CONTRACTION JOINT
(DOWELED)
SCALE: NTS



c. TYPICAL TRANSVERSE CONTRACTION JOINT
(DOWELED)
SCALE: NTS

d. TYPICAL ISOLATION JOINT
SCALE: NTS

Figure 2-2. Typical PCC Pavement Joints

AIRPORT OPERATIONAL AND SAFETY CONSIDERATIONS

The new third runway, 16R-34L, opened November 2008. The Air Traffic Control Tower (ATCT) personnel were just getting proficient having all three runways operational after extensive planning, training and 5 months of use when runway 16L-34R was closed, dropping back to two operational runways. This impacted ATCT schedule changes, runway operation changes, and midfield monitoring. In the course of constructing runway 16L-34R in the summer of 2009, valuable lessons were learned about safely integrating aircraft operations with major construction activities.

The primary construction site is between the two active runways on the west side and all commercial aircraft parking areas on the east side. Refer to Figure 2-1. This meant that approximately 1,000 aircraft taxied through the construction site every day!

Another impact was the reduction of available runway length. This was a loss of nearly 760 m (2,500 ft), during the busy passenger summer travel and cruise ship season, cherry season for cargo operations, and the unanticipated diversions from the Mt. Redoubt eruptions near Anchorage, AK (267 Heavy aircraft were diverted to Seattle instead of Anchorage).

Crossing and intersecting taxiways had to be maintained for aircraft use and Aircraft Rescue and Fire Fighting (ARFF) routes. Restrictions were established in the plans identifying certain taxiways which could NOT be closed.

There were times when aircraft had a complicated taxi route to obtain the full length of Runways 16C or 34C, as well as taxiing through the construction site. Not only were NOTAMS issued, there were published bulletins, including maps and restrictions, and these bulletins were sent to station managers and chief pilots anytime there was a change. Airport Operations continually briefed Station Managers, Flight Crews, and others with initial briefings prior to closure; phased briefings for taxiway closures and openings; and bulletins to post in the airline crew rooms.

Since the runway closure was scheduled for 6 months, it was decided to remove or cover all signage or references. Thus, taxi markings associated to holding or entering the runway were blacked out. All closed runway signs and taxiway signs were covered.

AIRPORT OPERATIONAL AND SAFETY LESSONS LEARNED

- A lesson learned from this project revealed that operations had not taken into account having at least one of our main ARFF routes, Taxiways N or J, always open for ARFF access. When the contractor published their schedule, there was a time period with both taxiways closed. The Port was able to negotiate, allowing them Taxiway M for the duration (with ATCT consent) if they would change the timing of the Taxiway J closure.

- Another lesson learned was that even if a taxiway was closed, operations should NOT cover the signs. Flight crews would still reference the closed taxiways as they exited, for example, when they were assigned to exit Runway 16C at Taxiway N, they knew Taxiway N was right after Taxiway M, if there was not an exit sign to Taxiway M, sometimes they missed Taxiway N and rolled to Taxiway P. Since it was in the plans to cover the taxiway sign, the covering of the taxiway signs still took place occasionally. As a result, operations would find the signs covered, remove the covering, and find the signs covered again a few days later.

- A third lesson learned dealt with communications between airfield operations and contractor operations. On other projects, operations had been successful using red and green lights to cross construction vehicles at open taxiways. This project had primarily day time work hours; unfortunately, these lights were often difficult and sometimes impossible to see when the sun was out. When operations switched to hand signals, the problem of “airport” hand signals (how the access controllers marshal vehicles) vs. “highway” hand signals (which the contractor’s truck drivers knew and were expecting to see) arose. Operations quickly realized it would be much easier to train the access controllers to flag using highway signals. The Airport operations and the contractor jointly held mandatory training classes for all access controllers. Additionally, the contractor provided brightly colored gloves. As an added safety measure, all vehicle drivers were told to look both directions before crossing, even when being waved through… just in case!

- There were a few instances when there was a lineup of aircraft, that the pilots would try to wave the truck drivers to cross in front of them, especially when the aircraft knew they would be holding for several minutes. The control tower also tried to help by making an opening between the lined up aircraft for vehicles to cross. Operations had to say thanks, but no thanks to both. This was because of the need to keep the policy that the vehicles would always yield to aircraft and only cross an active taxiway when instructed to by the access controllers.

- There were occasions when aircraft ground flow caused some taxiways not to be used and were closed, freeing up escort/flagger personnel for other duties. These were called “SOFT” closures. With our soft closures, we were able to get ATCT to agree to give us as much notice as possible when aircraft flow changed or when there needed to be an immediate flow change. This still required barricade removal and sweeping before inspecting and opening a taxiway. Soft closure taxiways were identified by the green “taxiway closed” sign. If there was no sign, the vehicles were not to cross without direction from an access controller/flagger. With these signs, the contractors could cross taxiways without stopping.

- In some instances of the phasing plan, operations added the lighted “X’s” at both ends of the runway as well as the fabric “X’s” that were on the blast pads for additional safety considerations.

- Another lesson learned that contributed to the success with this project was the every morning briefings. Airport operations, construction management, project management, the contractor, and any other interested parties would meet every morning. Primary discussion topics would be the current weather, forecasted weather (looking for potential wind, rain, temperature issues), potential for aircraft flow changes, contractor haul route requests for the day, specific access gates to be staffed, construction activity for that day, requested soft closures, and NOTAMS to be issued. This included discussions about any operations that were different from the previous day. The meetings lasted approximately 10 to 20 minutes.

- One last lesson learned was Airport Operations assigning an experienced liaison early-on during the design phase and continued this through construction. This was highly beneficial to the project.

RUNWAY RECONSTRUCTION DESIGN AND MATERIALS

The reconstructed runway pavement section is comprised of 510 mm (20 in.) thick PCCP placed on 100 mm (4 in.) of ATB (Asphalt Treated Base) material with 305 mm (12 in.) of subbase. The reconstructed connecting taxiway pavement section is comprised of 460 mm (18 in.) thick PCCP placed on 100 mm (4 in.) of ATB with 200 mm (8 in.) of subbase. The pavement cross section was based upon the earlier design of the third runway constructed in 2008. This included additional recycling considerations for the existing materials removed. Refer to Figure 2-3.

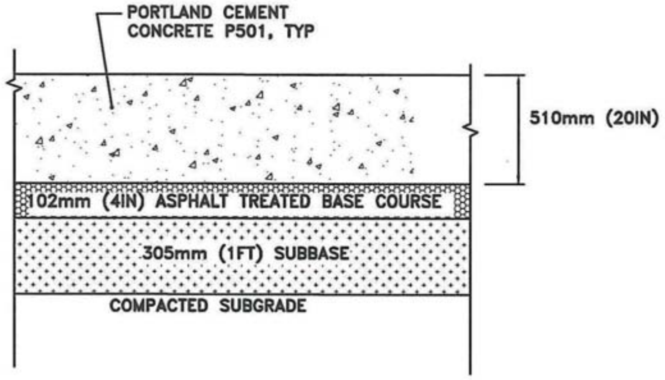


Figure 2-3. Typical Pavement Cross Section (Not to Scale)

In order to be environmentally responsible and control costs, the existing PCCP was removed, crushed, and utilized in the subbase layer. Onsite crushing operations took concrete rubble and processed it into minus 1-1/4 inch (32 mm) subbase material meeting the specification requirements.

ATB was selected through analysis to be the base material of choice. Compared to a crushed aggregate base course, ATB took less time to obtain good compaction. Another attribute was ATB density does not rely on obtaining and maintaining the optimal moisture content. The asphalt was placed via standard hot mix asphalt placement methods and rolled to a density not less than 80 percent.

The specified PCCP concrete strength was 4.8 MPa (700 psi) of flexural strength at 56 days. The actual average flexural strength was 5.8 MPa (835 psi). The Pacific Northwest is well known for its quality aggregate material. The hard aggregate materials provide for a high quality and durable concrete.

All acceptance testing was performed by an independent third party testing laboratory.

The runway has in-pavement runway centerline lighting, taxiway centerline lighting, and touchdown zone lighting at each end of the runway. In addition, new FAA runway status lights were installed.

The runway and connecting taxiways have a subdrain system on east and west edges of the PCCP, which discharge into the existing infield drainage system and off site treatment facilities.

RUNWAY RECONSTRUCTION DESIGN AND MATERIALS LESSONS LEARNED

- The high quality aggregate material did make it difficult for saw cutting and runway surface grooving. The pavement grooving subcontractor expended a lot of effort to find suitable cutting blades that would efficiently cut through the hard aggregate and provide a clean finish without raveling the edges.

- Another lesson learned was that even extensive utility research prior to starting work on a runway did not uncover all utility conflicts and problems. Among those conflicts were three unexplained large diameter deep holes below the existing pavement structure. The formed holes were believed to have been in place during the initial construction in 1942.

- It is valuable to have the engineer of record on site and dedicated to the project to provide design guidance and input on problems encountered during construction.

BIDDING

The airport contracting and procurement processes are governed by the State and Federal laws and procedures. Thus, the runway reconstruction project was procured through an open bidding/lowest cost bid procedure. The lowest responsible and responsive bidder was awarded the construction contract.

During the time this project was advertised for bid, the bidding environment was competitive throughout the region. Many of the contractors who worked on the previous year's new runway project were bidding on this reconstruction project. In total, 4 firms provided bids ranging from $51.6M - $68.4M (US Dollars). The Engineer's Estimate was $56.3M (US Dollars).

Prior to bidding, consideration was given to including incentives for early completion and liquidated damages for late completion by the contractor. The Port's project team decided to use only liquidated damages. The liquidated damages were calculated at $4,000 (US Dollars) per day which was a minimal amount. Previous experiences with monetary incentives had not been successful. The contractor finished ahead of schedule and no liquidated damages were assessed.

BIDDING LESSONS LEARNED

- In order to mitigate risks, the project utilized numerous unit prices for items usually paid via lump sum. For example, storm water storage tanks were paid by the month. This gave the Airport a method for dealing with site rain water by adding additional storm water tanks that could be rented on a monthly basis. By making them a bid item, we allowed the contractors to competitively bid and arrive at a competitive unit price. This was true for the majority of the material and labor activities in the contract.

CONSTRUCTION AND PHASING

The construction contract included removal of the existing pavement section; removal of lighting; placing approximately 95,600 cubic meters (125,000 cubic yards) of PCCP; 44,000 metric tons (49,000 tons) of asphalt treated base; installing an additional 8,380 lineal meters (27,500 lineal feet) of drainage pipe and 14,300 lineal meters (47,000 lineal feet) of electrical ductbank; and applying 389,000 square meters (465,000 square yards) of bonded fiber matrix hydroseeding.

Given the typically wet weather of the Pacific Northwest, a major factor in the development of the construction schedule was the accommodation of the short paving season and managing any rainfall on the construction site. Therefore, construction was planned to occur over the summer months and the runway was scheduled to close for 180 consecutive days to accomplish the entire project. The runway had to be ready for the FAA flight check by September 30th due to anticipated low visibility operations after that date.

Onsite work started on March 26th and involved a series of phased work areas each lasting from 45 or 50 calendar days. A major obstacle in phasing Runway 16L was its location relative to the terminal, with it being the closest of the three runways. Therefore, every aircraft arrival and departure had to taxi across the project site. Phasing was developed so that each end of the runway had open taxiways for accessing the terminal or the other two runways. Airport access controllers (AAC) staffed each active taxiway crossing and provided a traffic movement system that controlled contractor traffic.

Initial work started with installation of 5 storm water holding tanks (Baker tanks) that would be used to help manage any rainwater on-site. Temporary drainage systems were installed to move rainwater to these tanks. Pump trucks would then transfer stormwater from the tanks to the disposal/treatment facilities.

The existing runway was made up of a myriad of asphalt and PCCP, placed in various layers throughout the years. Runway demolition included the milling up to 760 mm (2.5 ft) thick of ACP with several passes. The asphalt spoils were piled at the south end of the runway and hauled out at night to avoid congested daytime traffic. The material was hauled to a local pavement recycling site. The contractor utilized a mobile guillotine manufactured by Badger State Highway Equipment, Inc. which moved along in 610 mm (2 ft) increments to fracture existing PCCP into pieces small enough to manage. In the middle of the runway, a crushing operation was set up to receive the fractured PCCP and crush it for reuse as part of the subbase. For that portion of the material not needed in this project, the material was hauled to a local recycling plant.

In the runway infield areas a new storm drain system was installed. The system moved stormwater to either the north or south end of the runway. Concurrently, a series of new electrical ductbanks were constructed. The project also installed the infrastructure for the FAA’s new Runway Status Light (RWSL) program. Installation of in-pavement lighting was meticulously surveyed and laid out by Airport survey crews. Light can bases and reinforcement cages were placed in 21 MPa (3000 psi) concrete to ensure precise alignment. Setting the light can bases in concrete also helped ensure that the head of concrete from the PCCP slipform operation didn’t impact or move the light cans out of alignment. Installation of the storm drain and electrical systems also followed the general phasing for the project. Therefore, installation could not cross active taxiways and runway sections until those work areas were open according to the phasing plan.

The PCCP was batched at a mobile batch plant that was set up just outside of the airport’s north perimeter fence. This area was also used by the contractor as a staging area for materials such as reinforcement, light cans, and other equipment thus providing ready access to the project site. The majority of the PCCP was placed via a GOMACO GP-4000 slipform paver. Paving started on April 30th and progressed almost daily until September 3rd. The contractor was able to average approximately 1,550 square meters (1,850 square yards) of PCCP each paving day.

Once the infield work areas were graded, topsoil was delivered and spread. Seeding started as soon as possible, so that a sufficient stand of grass grew in time to help control stormwater turbidity and eliminate erosion. In the late summer, the contractor utilized water trucks with long range nozzles to water the young grass to prevent it from dehydrating.

Approximately $49M (US Dollars) worth of work was completed within the specified 180-calendar days. The runway was opened for flight check on September 25th, five days ahead of schedule.

CONSTRUCTION AND PHASING LESSONS LEARNED

- The project utilized a highway interchange previously installed as part of the RW 16R-34L project. This interchange was for construction use only and allowed the contractor to efficiently get from the airfield to the highway system. A staffed gate was controlled by ACC at the end of the interchange where badges and credentials were verified prior to allowing access onto the airfield.

- In order to help manage vehicle track-out of FOD, the project used a wheel wash system previously installed as part of the RW 16R-34L project. The wheel wash system was custom built to handle heavy use from truck and trailer vehicles.

- The project was the first Port of Seattle project to participate in the Helmets to Hardhats Program. The program places military veterans in construction type positions where the skillset is similar. The contractors place the employees on the crews where they will thrive and gain skills to help them acclimate back into the civilian work force.

- Just prior to starting the project, the Port's environmental group learned another regional airport discovered PCB contaminated joint sealant in the old concrete joints. Not knowing if STIA's vintage concrete had the same joint material, the contractor was directed to expose the joints as soon as the runway was closed and made available. The team elected to mill down through the existing asphalt sections of runway and uncover several locations of the old concrete joints. Samples were then taken and shipped for a quick analysis. The samples came back negative for regulated materials; had the samples tested positive, the team would have been forced to scramble to find a quick and reliable method for removal. Depending on the quantity of joint material, it could have easily derailed the project's schedule and phasing plans.

- During initial start-up, the FAA became concerned that the amount of equipment used on the project might cause interference with their navigational equipment. Large pieces of metal construction equipment could have caused reflections and shadows with their guidance systems. Prior to starting the work, the Airport mobilized as much of their snow removal and maintenance equipment as possible to mimic the construction equipment. The FAA monitored their systems and determined there was no risk present.
- There were no problems or issues with dust control related to the milling or crushing operations.

CONCLUSION

The great success of this project can be attributed to the significant amount of coordination that took place with all of the stakeholders. During the programming/planning phase of the project, a number of stakeholders key to completing such a complex job in a constrained time frame were identified. Refer to Figure 2-4.

This same group of internal and external stakeholders continued to work as a team throughout the design phase and the construction phase. Having this consistency throughout the duration of the project ensured minimal disruption to operations while maintaining the same level of safety. The transparency of sharing information meant no surprises during construction.

Paramount was the ever present acknowledgement that safety was critical and attention to details and active communications provided the most flexibility in developing solutions to unforeseen problems. It also helped that all of the members had the same goals of completing the work on schedule and without any incidents.

ACKNOWLEDGMENTS

Prime Contractor, ICON Materials

Paving Contractor, Gary Merlino Construction Company

Underground Utilities Contractor, SCI Infrastructure

Electrical Contractor, Elcon Corporation

Port of Seattle Construction Management Consultants: CH2MHill, Shen Consulting & KWAME NW

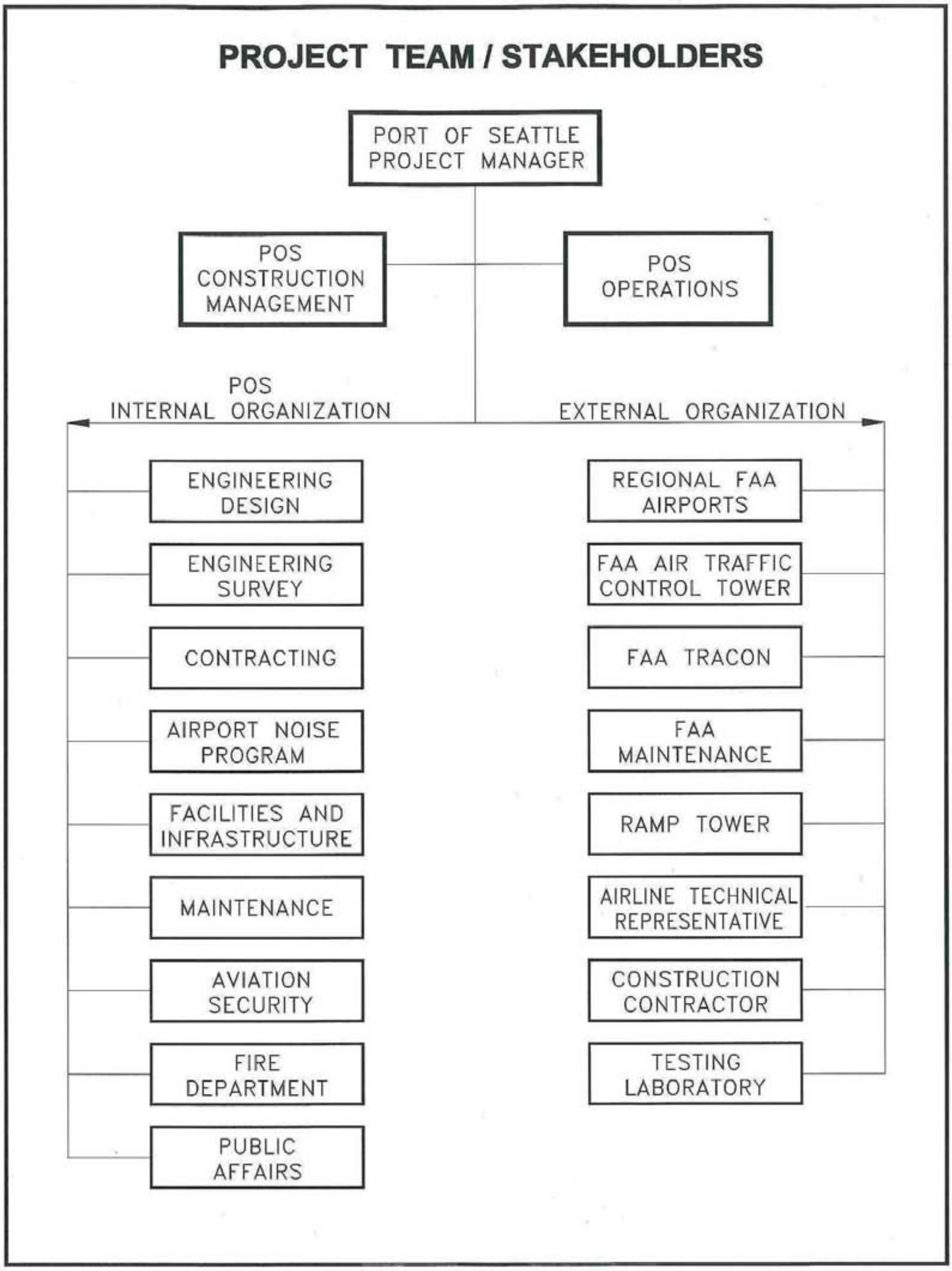


Figure 2-4. Project Stakeholders

Chapter 3

Rehabilitation of Runway 09-27 at George Bush Intercontinental Airport

Justin P. Jones, P.E.[1]; William G. Stamper, P.E.[2]; and Adil Godiwalla, P.E.[3]

ABSTRACT

Runway 9-27 (shown on Figure 3-1) is one of five existing runways at George Bush Intercontinental Airport. The runway and the associated taxiway system, located south of the terminal complex, are collectively referred to as the "south complex." Runway 9-27 was originally constructed in 1987 as part of the south complex. The 10,000 foot (3,048 meter) runway was constructed with 300 foot (91 meter) PCC pavement at each end, and asphalt pavement in the center with a lime / cement / fly-ash (LCF) base. The asphalt portion of the runway (9,400 ft., or 2,865 meters in length) received an asphalt overlay in 1998 and portions of the taxiways have been reconstructed and repaired since the original construction.

A pavement condition investigation of the south complex was conducted in 2005 on Runway 9-27 and indicated that rehabilitation of the pavement on Runway 9-27 would be required in the near future. In addition, visible defects to the runway were recorded with tearing and shoving evident at the landing areas and high-speed exits. As a result, the Houston Airport System (HAS) contracted with Atkins in June 2006 to develop the rehabilitation design.

In partnership with HAS, the design team undertook an extensive and rigorous investigation of the existing runway to determine the potential cause of the evident distress and to develop a cost-effective, site-specific design to accommodate the anticipated loading for the next 20 years.

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Figure 3-1. Runway 9-27 Complex

A new paradigm was used for the analysis and design, involving "LEDFAA" (an FAA layered elastic design program) and the finite element computer program "ISLAB 2000" to determine the thickness, edge stresses and strains, thermal stresses and strains, and deflections in the pavement layers. A host of other analyses including non-destructive testing, computer-aided tomography, and electronic image scanning was also performed for the forensic analysis. The finite element analysis included deteriorating load transfer efficiency of the concrete panels for a 20- year design.

EVALUATION OF EXISTING CONDITIONS

A pavement condition investigation was conducted by Eckrose-Green in 2005 on Runway 9-27 and the taxiway system as part of the Houston Airport System's (HAS's) Pavement Management Program. The pavement study indicated that rehabilitation of the pavement on Runway 9-27 would be required in the near future and HAS contracted with the Atkins Team in June 2006 to develop the design. As part of the preliminary engineering phase of the project, Atkins, assisted by Applied Research Associates (ARA) and CMS Engineering Group (CMS), undertook an extensive and rigorous investigation of the existing runway to determine the potential cause of the evident distress (Figure 3-2 and 3-3) and provide data to develop a cost-effective, site-specific rehabilitation design.

The investigation of the existing pavement included a topographic survey, geotechnical investigation, forensic study of cores, and finite element analysis of the existing pavement structure.

Figure 3-2. Shoving of Wearing Course on Runway 9-27

Figure 3-3. Longitudinal Fatigue Cracking of Wearing Course on Runway 9-27

A review of record drawings provided the team with an understanding of the construction of the existing pavement, which revealed the center 9,400-foot (2,865 meter) portion of the runway consisted of a 7-inch (18 cm) asphalt surface course including a ½-inch (1.3 cm) stress absorbing membrane interlayer (SAMI) Layer on a 28-inch (71 cm) LCF base course and a 30-inch (76 cm) stabilized subbase course. The first 300 feet (91.4 meters) on each end of the runway consisted of 14-inch (35.6 cm) Portland Cement Concrete (PCC) and a 3-inch (7.6 cm) asphalt concrete (AC) separation layer on a 14-inch (35.6 cm) LCF base course and a 30-inch (76.2 cm) stabilized subbase course.

The deflection data from the heavy weight deflectometer (HWD), along with thicknesses from the geotechnical investigation, were used with the back-calculation software, Deflexus, to determine the modulus of the pavement layers and the subgrade. Figures 3-4 and 3-5 graphically show the back-calculated moduli for the AC and LCF layers. Upper and lower limits were set in Deflexus for the AC, LCF, and subbase layers, which served as maximum and minimum allowable moduli for each layer. The limits are necessary to control the range of the outputs.

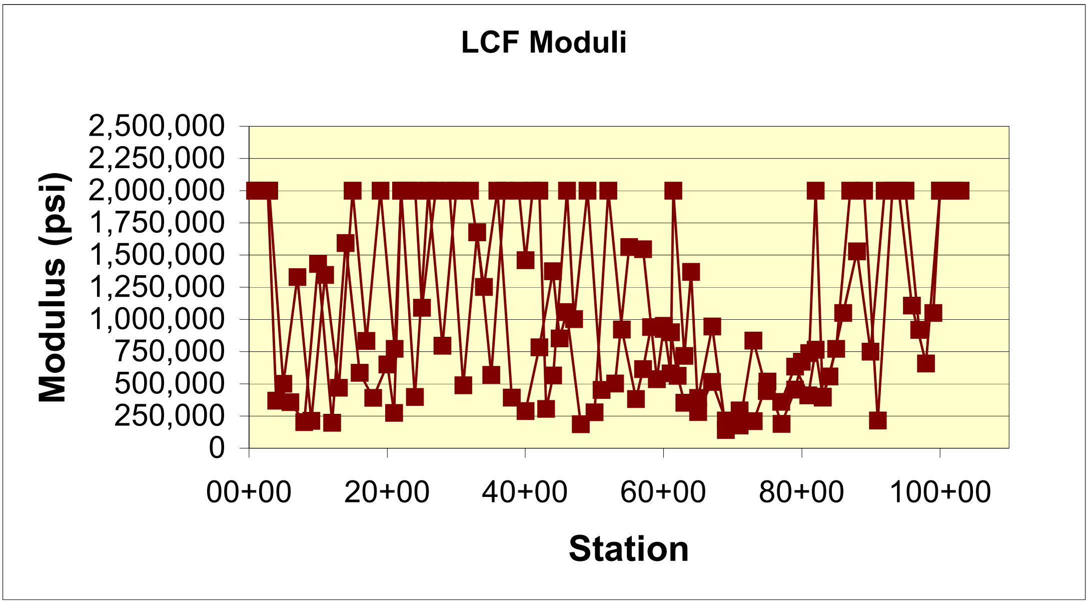

Figure 3-4. Elastic Modulus of Asphaltic Concrete

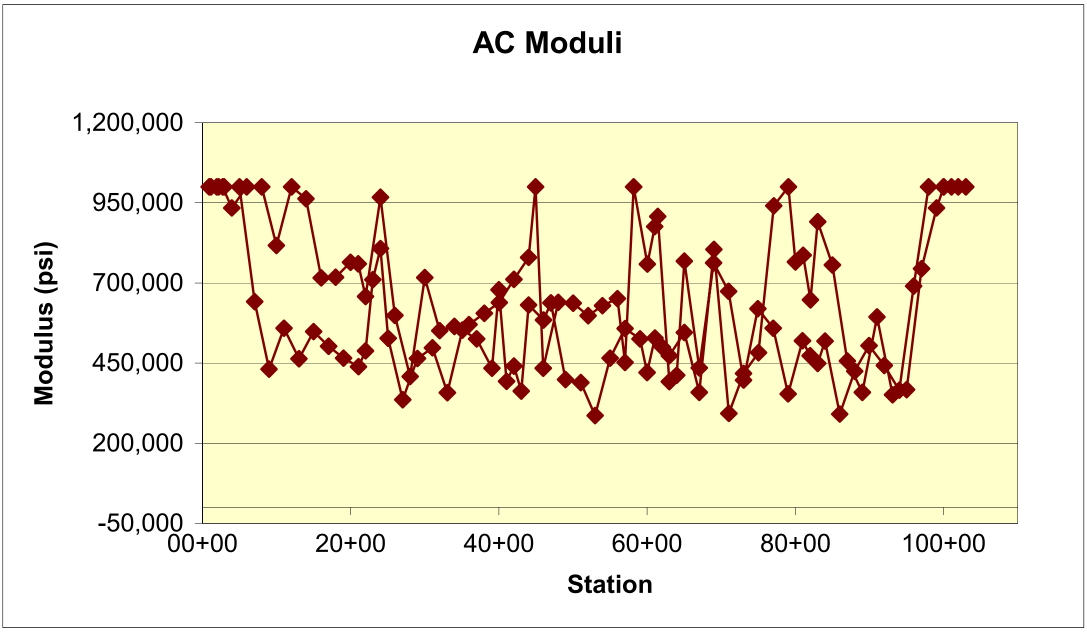

Figure 3-5. LCF for Runway 9/27

Forensic Evaluation

The forensic evaluation focused on the relationship between the air void and crack distributions in the cores and the distresses observed in different locations in RW 9-27. In this analysis, weak interlayers are defined as either poorly tacked interfaces between pavement layers or the presence of a SAMI that is either too thick or too near the surface.

X-ray CT Analysis of Air Void Distribution

X-ray Computed Tomography (CT) was used to evaluate the internal air void distribution in cores C1, F10A, F10B, F10C, and F14.

Results from Core F14, provide an indication of the data developed from this analysis: Core F14 exhibited low air voids except in the location of the SAMI layer (Figure 3-6). The low void content is an indication of mix instability or shoving, which was observed in this location during the site visit. This location has three characteristics that make it different than all other sections. First, the SAMI layer in this core is thicker than in all the other cores. Second, the SAMI layer is at a depth of about three inches from the surface, which is the smallest depth to SAMI among all cores. The third characteristic is that the aggregate source, which is a darker aggregate, appears to be different than the aggregates used in the rest of RW 9-27. Figure 3-7 includes images captured at different depths within the core, and Figure 3-8 shows the three dimensional distribution of air voids in F14. These images show the percent of air voids within the SAMI layer is much higher than in the rest of the core.

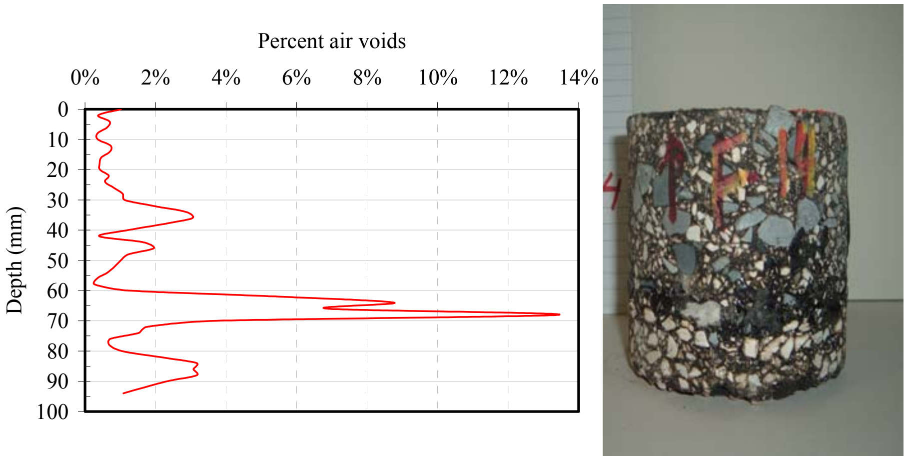

Figure 3-6. Air Void Distribution in Core F14

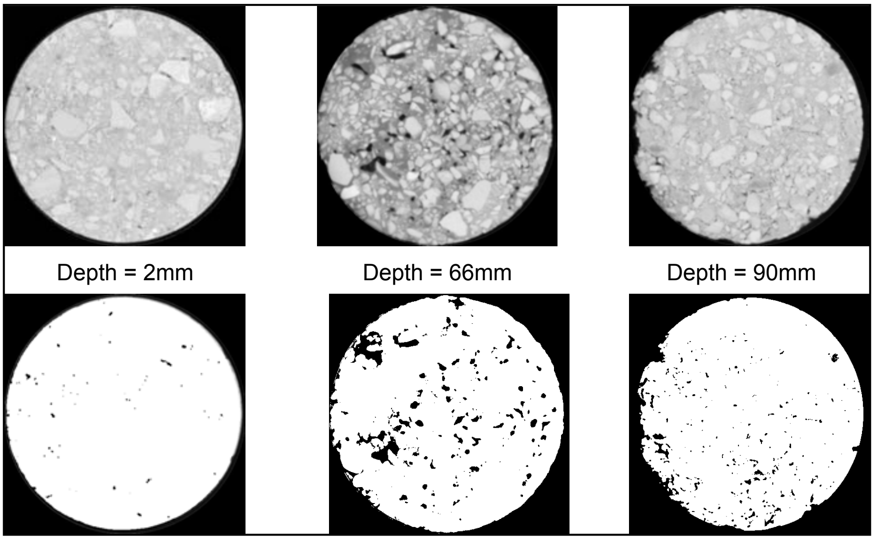

Figure 3-7. Images Taken at Different Depths within the F14 Core

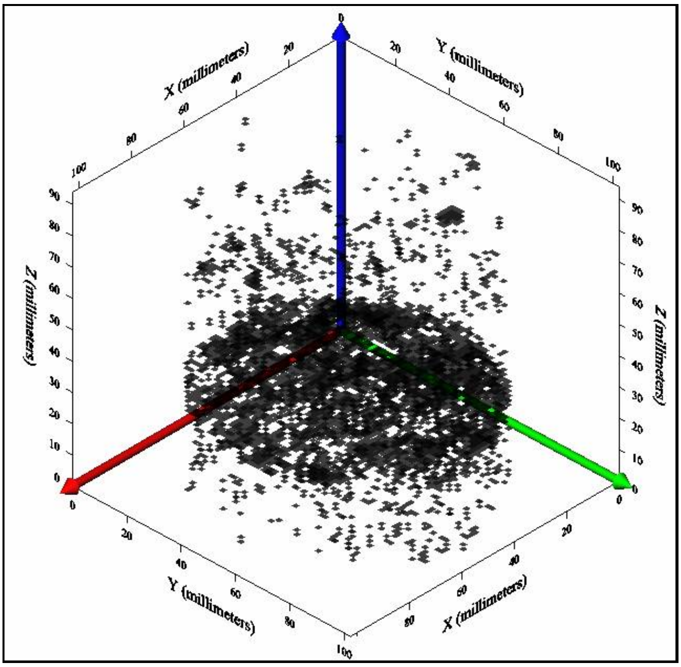

Figure 3-8. Three-Dimensional Air Void Distribution in F14

Finite Element Analysis of the Influence of Weak Interlayers

An elasto-visco-plastic finite element model was used to analyze the permanent deformation of an airfield pavement section. The objective of this simulation is not to model the RW 9-27 structure and material properties because that requires extensive material testing, but to demonstrate the influence of the location of a SAMI layer on shear stresses and permanent deformation.

The analysis was conducted using an axisymmetric finite element model (Dessouky et al. 2006). The asphalt mix material properties were selected to represent the properties of a typical asphalt mix that was recently evaluated at Texas A&M University at a high temperature of 58^{o} C (136^{o} F). The applied load was that of a B-737-300 aircraft, as shown in Table 3-1. Illustration of the axisymmetric finite element model with the applied forces is shown in Figure 3-9. The asphalt layer thickness is 6 inches (15 cm) and the width is 120 inches (3.05 meters). The SAMI was modeled as a one-inch (2.5 cm) layer with an elastic modulus equal to 40% of that of the surrounding hot mix asphalt layers. However, the viscoplastic model parameters were maintained at the same level for both the SAMI and asphalt mixture. Figure 3-10 shows the maximum permanent deformation in the three sections. It is important to note that as the SAMI layer is moved closer to the surface, the shear stresses within the hot mix asphalt surface are increased (Figure 3-10). This could lead to near surface distortion, and could possibly contribute to groove closure or distortion of the groove pattern. The system with a SAMI layer at 4 inches (10 cm) below the surface induces a favorable combination of low permanent deformation and low surface shear stresses. The system with no SAMI layer gives the least permanent deformation but the highest surface shear stresses.

Gross Weight lbs (tons)	140,000 (63.503)
Tire pressure psi (kPa)	201 (1386)
Percent Gross Weight on Gear	47.5 %
Dual Spacing in (mm)	30.5 (774.7)
Tire Contact Width in (mm)	11.47 (291.4)
Tire Contact Length in (mm)	18.36 (466.3)

Table 3-1. The B-737-300 Loads Used in the Finite Element Model

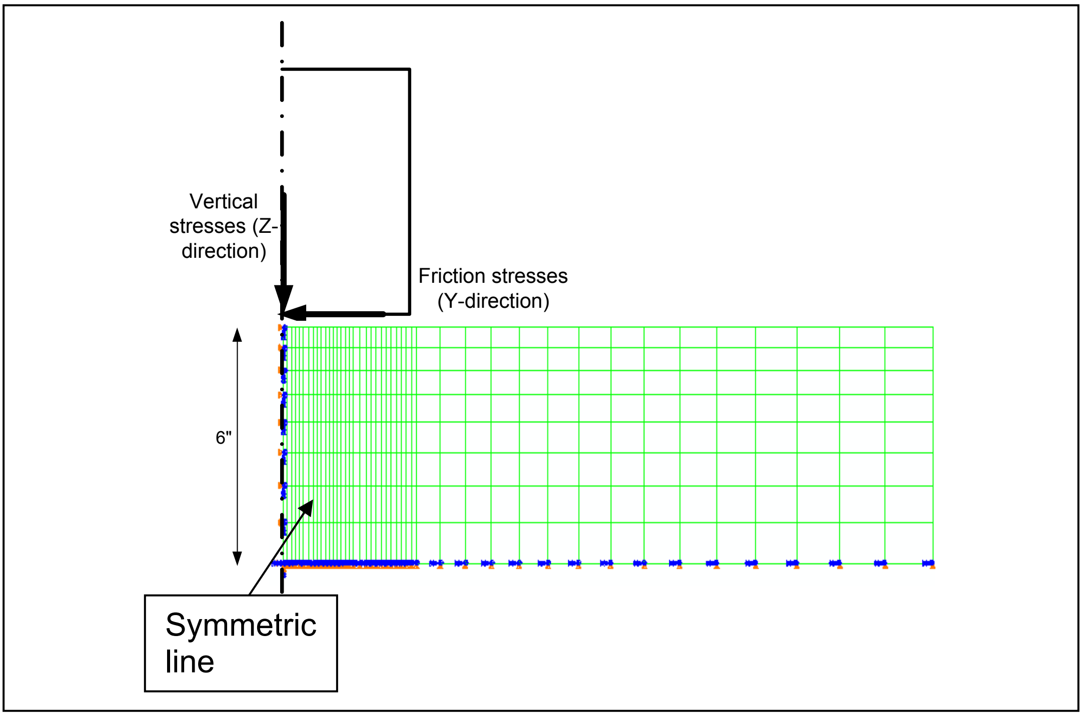

Figure 3-9. Illustration of the Applied Loads in the Finite Element Model

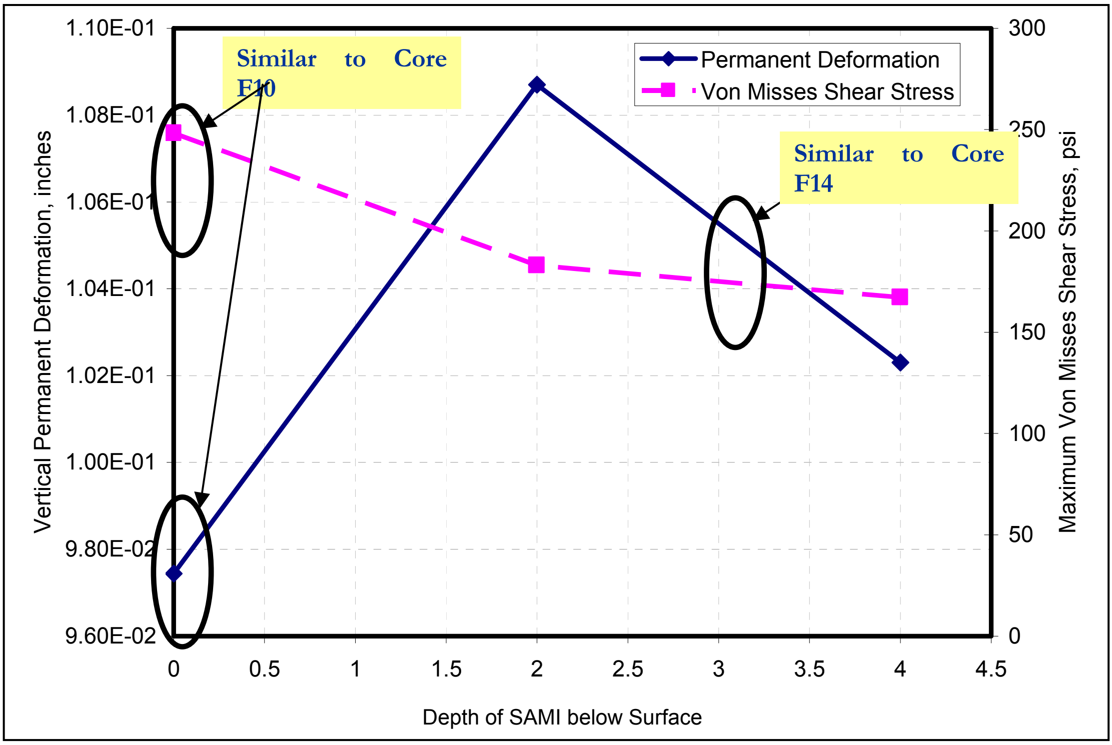

Figure 3-10. Permanent Deformation and Shear Stresses in Asphalt Layer Due to Different SAMI Layer Depth

Reconciliation

In addition to analyzing the influence of weak layers, the parallel forensic evaluation undertaken by CMS tested intact LCF cores in the laboratory, which yielded elastic moduli of around 4,000,000 psi (27,580 mPa), was significantly higher than that resulting from the back-calculation analysis completed by ARA. However, it is estimated that while this high result may be true of an intact specimen, cracking in the LCF layer and poor bonding among the multiple LCF layers yielded a composite layer with a much smaller modulus matching that resulting from the back-calculation.

The team took a three-phase approach to reconcile the differences between laboratory measured compressive strengths, resilient moduli, and field back-calculated values. The hypothesis of the analysis was that both the laboratory-measured compressive strength and modulus values and the back-calculated values from HWD testing were probably correct and could be reconciled.

The conclusion from that work is that the residual HMA surface can be reasonably modeled in the ISLAB analysis as a Totski interface with a interlayer constant of 0.75 x 10^6 psi/in., the LCF layer can be modeled as a 28-inch (71 cm) thick layer with an effective modulus of 500,000 psi (3,450 mPa), and the composite subbase-subgrade interlayer can be modeled with a composite k-value of between 200 and 300 pci (5.5

to 8.3 kg/m^3), a result which is comparative to that established through back calculation of HWD data.

FORENSIC ANAYLSIS AND REHABILITATION DESIGN

A LEDFAA analysis was performed to prepare paving alternatives using the material properties for specific pavement areas, with results for a PCC overlay ranging from 8.5 to 14.5 inches (21.6 to 36.8 cm)\. Following the LEDFAA analysis, the finite element based ISLAB computer model was used to further evaluate the PCC overlay thicknesses predicted by LEDFAA.

This analysis demonstrated an unusual trend as the bending stresses actually decreased when the PCC overlay thickness is less than about 10 inches (25.4 cm). However, an overlay thickness below 12 inches (30.5 cm) induced high bending stresses at the bottom of the LCF layer, which may be a potential for excessive damage in that layer. However, curling stresses were conservatively considered in the analysis, and although the analysis demonstrates the high bending stresses that can occur in the LCF, the acceptable performance of this layer over more than 20 years of service tempers that assessment. Furthermore, traditional transfer functions, such as the one used in the fatigue consumption analysis, are highly sensitive to the stress ratio. Increasing the PCC rupture modulus from 650 psi to 750 psi (4.48 to 5.17 mPa) increases the performance life to 20 years or more.

The result of this analysis demonstrates that a PCC thickness between approximately 10 and 15 inches (25.4 to 38 cm) has little impact on critical PCC stresses. However, the thickness of the PCC significantly impacts critical stresses in the LCF, particularly when a Totski interface is not considered (Figure 3-12). Subsequently, the design thickness was developed with two goals in mind: the first to limit the stress in the PCC and the second to minimize the stress in the LCF layer. Based on the results of this analysis detailed in Figures 3-11 and 3-12, it is apparent that the optimum thickness is approximately 14 inches (35.6 cm), which would provide adequate support to protect the PCC as well as the bottom LCF layer. A thickness of 10 inches (25.4 cm) would likely provide the needed support for the PCC layer, but degradation would likely occur in the LCF layer over time.

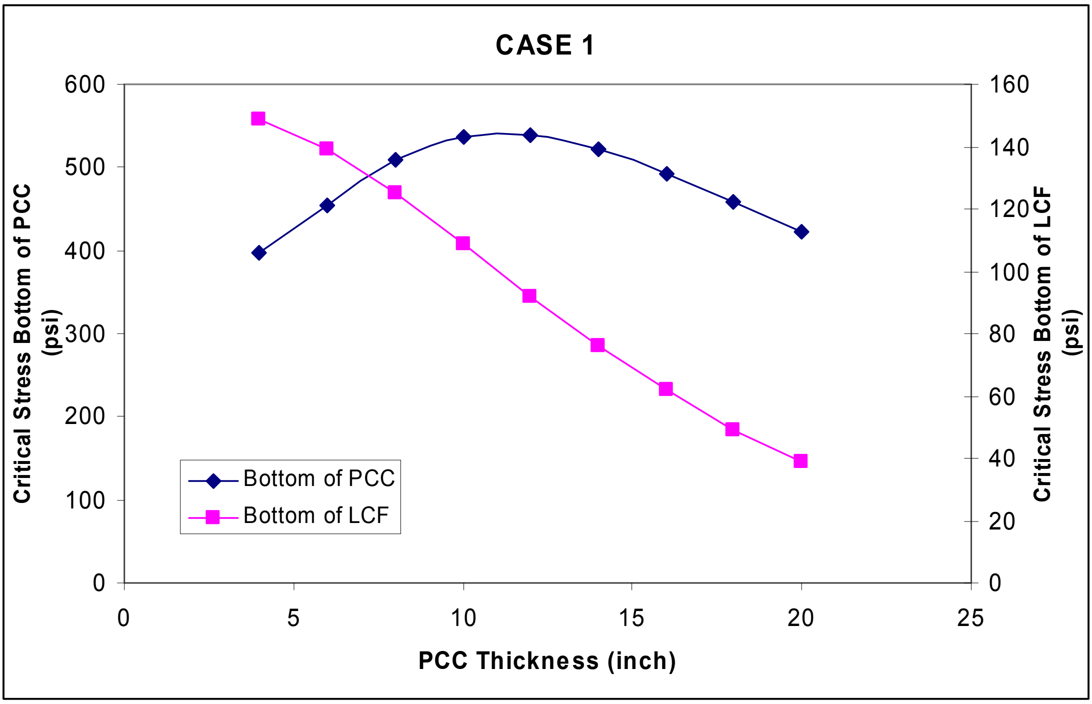

Figure 3-11. Case 1 - HMA as Totski Interface (with Temperature Gradient)

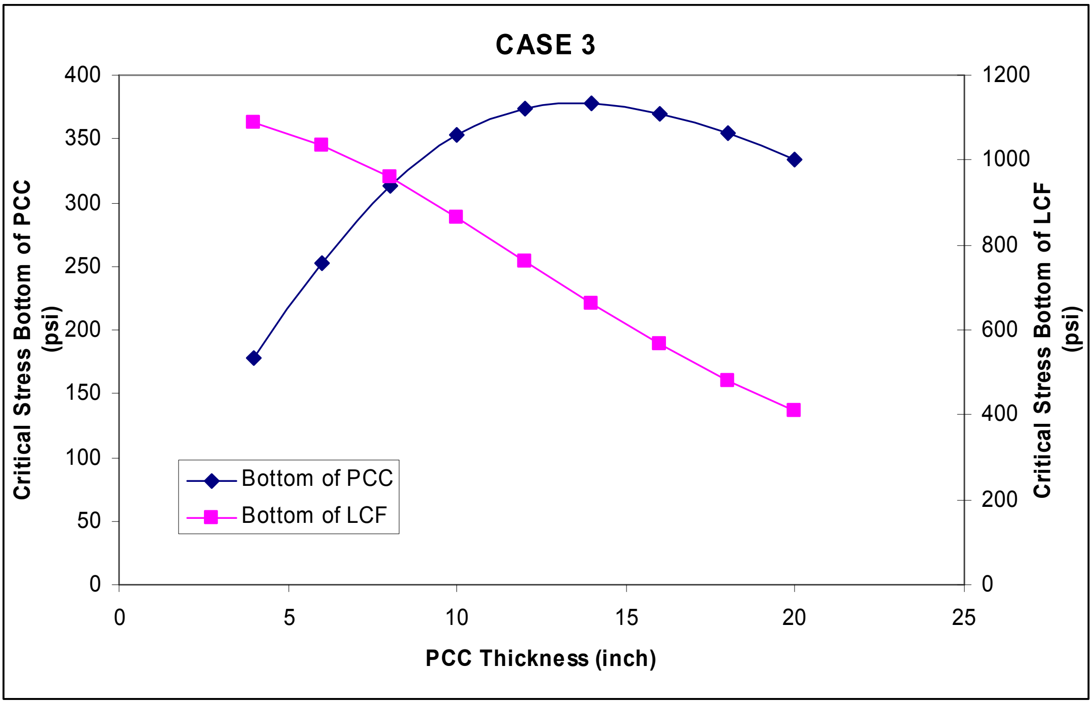

Figure 3-12. Case 3 HMA and LCF as Composite Layer (with no Temperature Gradient)

Conclusions of Forensic Evaluation / Lessons Learned

In addition to finalizing the material properties, the forensic evaluation also determined that the current distress is likely due to high shear stresses resulting from the braking and cornering action of aircraft and due to the nature of the asphalt layer placed. The asphalt binder used was very stiff. The synergistic effects of a very stiff, polyethylene binder; oxidative aging in the top inch of the pavement; and the high, near surface shear stresses resulted in shoving and crazing (closely spaced top-down cracking). Initial assumptions that the SAMI layer was a major contributor to the distress were, therefore, proved unfounded.

The analysis also identified the benefits of maintaining a section of the existing AC in the final overlay design. This layer, approximately 2 or 3 inches (5 to 75 cm) after milling, provides at least two favorable functions: (a) it acts as a cushioning effect for the PCC overlay that will reduce corner stresses imposed by loading and temperature-induced curling, (b) it acts as a bond-breaker between the PCC overlay and the LCF structural layer that allows the PCC overlay and the LCF to function as two separate layers, thereby, reducing the bending stresses within the LCF. The analysis also enabled the team to develop a model for use during the design of the overlay solution.

This investigation went beyond the normal limits of project development and included a forensic evaluation of the existing pavement. This rigorous approach enabled the team to develop an efficient site-specific solution, balancing initial cost, longevity, and construction schedule to best meet the challenges. The cost of this additional investigation was less than 0.3 percent of the final construction cost, yet the savings achieved as a result were far greater by factors of ten.

Chapter 4

The Reconstruction of Runway 13R-31L at John F. Kennedy International Airport

Scott Murrell[1] and Guy Zummo[2]

OVERVIEW

This project is an example of reconstructing a hot mix asphalt surfaced runway with Portland cement concrete pavement while minimizing the impact on airfield operations at a major international airport.

BACKGROUND

The Runway 13R-31L Reconstruction Project included rebuilding of one of the longest and busiest runways in the United States (US) while minimizing the impact on airfield operations. John F. Kennedy International Airport's (JFK) Runway 13R-31L (see Figure 4-1) is the second longest commercial service runway in the US at 14,572 feet (4,442 meters) and is used by over 120,000 departing aircraft each year.

The runway's original construction consisted of 12 inches (30 cm) of Portland cement concrete (PCC) on 6 inches (15 cm) of stone screenings placed 200-feet wide (61 meters) and 10,000-feet (3,048 meters) long. The runway was placed into service in 1947. Two separate contracts in 1958 extended the runway to its current length using 12 inches of PCC on 6 inches of stone screenings while reducing its width to 150 feet (46 meters). From the 1970s until 1993, the rehabilitation of Runway 13R-31L has been performed by adjusting or replacing centerline lights and overlaying with hot mix asphalt (HMA).

PROJECT PLANNING

Project planning began with the assumption that a runway rehabilitation using HMA would be performed. The most recent rehabilitation was completed in 1993. At that time, the existing HMA surface was milled and overlaid with an HMA surface course and the runway centerline and leadoff lights were adjusted to final grade after the paving. Nightly runway closures were used to accomplish the construction, with the runway returning to service each day. With average annual operations exceeding

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120,000 departures and 21,000 arrivals, the expected service life for the rehabilitation was 10 to 12 years. This is consistent with other AC surfaced runways at JFK.

Following the 1993 rehabilitation, the pavement condition was monitored using pavement management techniques. By 2002, JFK's Airport Pavement Management System (MicroPAVER) predicted a Pavement Condition Index rating of "Poor" for 2004. During bi-annual inspections, pavement engineers observed longitudinal and transverse cracks, raveling and oxidation, consistent with the "Poor" Pavement Condition Index, and determined that a pavement rehabilitation contract was required.

Figure 4-1. Aerial View of JFK Airport with Runway 13R/31L Highlighted

Since the next scheduled rehabilitation was postponed while a long-term plan for the runway and the associated taxiway system was being developed, an interim repair was performed in 2004. This repair consisted of milling and overlaying with HMA approximately 2500 feet (762 meters) of the runway's 50-foot (15.24 meter) keel (center) section in the touchdown zone and crack sealing the open paving joints.

Also during 2004, an operational study of the runway was initiated. This study, titled "Design Options and Functional Program Development for Rehabilitation of Runway 13R-31L at John F. Kennedy International Airport and Cost/Benefit Analysis for Planned Fillet Modifications at Selected Taxiway Intersections" modeled the existing runway operation, tested the impact of various enhancements including moving the displaced thresholds and changing the locations and geometry of taxiway entrances and exits. Study products also included delay reduction estimates and the associated cost savings to the airlines. The 2007 result of this study was a new conceptual plan for this runway and associated taxiways to maximize capacity and minimize delays.

At the same time, the New Large Aircraft of the future became the A-380 scheduled to arrive at JFK in August of 2008. JFK is designated a Group V airport under FAA Classifications. The Port Authority of NY & NJ (PANYNJ), which operates JFK, performed multiple studies over the years to determine the airfield modifications necessary to accommodate FAA Group VI designated aircraft in general and the A-380 specifically. Based on these studies and discussions with the FAA a number of required airfield modifications were identified including widening Runway 13R-31L from 150 feet to 200 feet (46 to 61 meters). Larger fillets, widened shoulder and blast pavements were incorporated into the planning. Preliminary calculations showed that runway strengthening was not required. The scope of the Runway 13R-31L project then changed from simply rehabilitation to rehabilitation and widening.

Another development that would impact the project scope was the significant growth in air traffic operations at JFK starting in 2005. Between 2004 and 2007, annual plane movements increased from 320,000 to 440,000. This growth led to additional regional airport delays. In response, the JFK Delay Reduction Program (DRP) was developed. The DRP includes eleven improvement projects for moving aircraft to and from the runways more efficiently. The Runway 13R-31L taxiway entrance and exit modifications and relocated runway thresholds recommendations of the 2007 Operational Study were included in this program. The scope of the 13R-31L rehabilitation & widening project changed again to include delay reductions measures.

During the summer of 2007, a Constructability Study was performed in conjunction with a life cycle cost analysis. Two alternatives were fully developed.

- Rehabilitation using HMA – including a 9” thick (23 cm) overlay
- Reconstruction with PCC – including 18” thick (46 cm) PCC

Two staging options were considered:

- Nightly closures – 10:00 pm to 6:00 am the following morning. The runway reopens to operations each day.
- Staged full closures – Three stages 12,000 feet (3,658 meters)each to the intersection with Runway 4L-22R and the remaining 2000 feet (610 meters).

The construction duration for each alternative and staging approach was estimated (see Table 4-1). Airfield lightning and the associated electrical work were on the schedule’s critical path.

		HMA	**PCC**
Nightly Closures	Construction Duration	24-30 Months	N/A
	RW 4L-22R Closure	10 Days	
	RW 13R-31L Shortened	45-90 Days	
	RW 13R-31L Closure	275 Nights	
Staged Full Closures	Construction Duration	18-23 Months	18-23 Months
	RW 4L-22R Closure	10 Days	14 Days
	RW 13R-31L Shortened	70 Days	75 Days
	RW 13R-31L Closure	120 Days	120 Days

Table 4-1. Construction Duration of Staging Alternatives

The life cycle cost analysis was performed using a 3.5% discount rate. The initial cost for the HMA rehabilitation was 3% less expensive than the PCC reconstruction. The life cycle cost for the PCC construction was 35% less expensive than the HMA rehabilitation.

At the completion of the Constructability Study a series of briefings were held with the airlines and the FAA to present the study's findings and to get their buy-in to the final plan. The major concern expressed during these briefings dealt with the uncertainty of getting the runway placed back into daily service if the nightly closure option was chosen. A delay in the runway's return to service causes airline delays. Based upon the feedback from these sessions, the life-cycle costs, and the fact the PCC option would, in essence, be a new runway with minimal maintenance, the PCC option was chosen.

Following a series of meetings with the FAA and the airlines operating at JFK the PCC alternative with staged full closures was selected. Final Design on the Reconstruction of Runway 13R-31L began January 1, 2008.

LESSONS LEARNED DURING THE PLANNING PHASE

JFK's pavement-management-system-condition predictions provided the needed lead-time for planning, design and construction of a runway rehabilitation project. The pavement management system also provide information which helped engineers focus on which areas of the runway required temporary repairs in order to extend the runway service life until it was reconstructed.

Having an up to date operational study of the runway proved invaluable. When the growth in air traffic operations led to delays, a conceptual plan to improve runway efficiency was already developed and ready for implementation.

Keeping abreast of the development and production of New Large Aircraft and studying its impact on airfield infrastructure was also useful. Modifications to FAA standards were already negotiated long before the first A-380 landed at JFK. The modifications to Runway 13R-31L required to accommodate Group IV aircraft were identified before planning the runway's reconstruction.

Performing the constructability study and cost benefit analysis and meeting with the airlines and the FAA during the planning phase resulted in better cooperation throughout the project. These meetings gave the airlines operating at JFK an understanding of the project's goals and challenges. It also allowed them to influence the project scheduling and staging.

DESIGN

The Design scope of the project included:

- Reconstruction of the Runway with 18-inch (46 cm) PCC
- New and realigned taxiways with either HMA or PCC pavements

- New HMA shoulders and blast pavements
- A new storm drainage system compliant with NY State storm water regulations.
- New electrical infrastructure including provisions for future runway-status lights.
- Re-grading approximately 100 acres (40.5 hectares) of grass areas within the runway safety area and reseeding
- 7.5 acres (3 hectares) of artificial turf in areas subjected to high jet blast

Design drawings were prepared using AutoCAD Civil 3D design software. In many ways, the design of Runway 13R-31L is typical for a US commercial service runway. FAA Advisory Circular requirements for Airport Design, Airfield Lighting and Pavement Design were followed. In addition, the Innovative Pavement Research Foundation (IPRF) recommendations' for in pavement lighting details were incorporated into the design. However, some significant exceptions to normal practice were incorporated.

Pavement Design

The FAA's FAARFIELD pavement design program does not provide for the design of a concrete overlay of an HMA surface on a concrete pavement. To overcome this, a sensitivity analysis was performed. The existing pavement was considered an undefined base and a variety of elastic modulus values were used in the analysis. PCC thickness results ranged from 15-20 inches (38 to 51 cm). The 18-inch (46 cm) overlay selected considered the existing asphalt and existing PCC as an equivalent asphalt pavement with an elastic modulus of 200,000 psi (1380 mPa). Eighty-six aircraft types operate at JFK, which exceeds FAARFIELD's input capabilities, so similar aircraft were grouped and a representative aircraft used in the design. Twelve representative aircraft were used for design, including the A-380 (Table 4-2).

AIRCRAFT TYPE	DESIGN ANNUAL DEPARTURES
A320-200 Twin Std	44942
B737-800	2451
B737-900 ER	136
B767-300 ER	20650
B787-9	350
A300-600 Std	3708
A330-200 Std	1780
B777-300 ER	4038
A340-300 Std	2779
A340-300 Std Belly	2779
A340-500 opt	1082
A340-500 Belly	1082
B747-400	6874
A380-800	4032

Table 4-2. Design Aircraft

To optimize the surface grades the design called for milling the existing HMA runway surface to 6 inches (15 cm) below existing grade. Since PANYNJ already had good experience placing PCC on asphalt-stabilized base, it was decided that the PCC would be placed directly on the milled surface. The concrete mix requirements limiting drying shrinkage also influenced the decision not to place an asphalt bond breaker on the milled surface. The specifications called for the milled surface to meet a ¼-inch grade tolerance and a ¼" (0.6 cm) in 10-foot (3 meter) smoothness tolerance. Whitewashing the milled surface with a liquid membrane-curing compound prior to placing the PCC was specified to eliminate bonding of the PCC pavement to the milled surface and to lower the surface temperature (Figure 4-2)

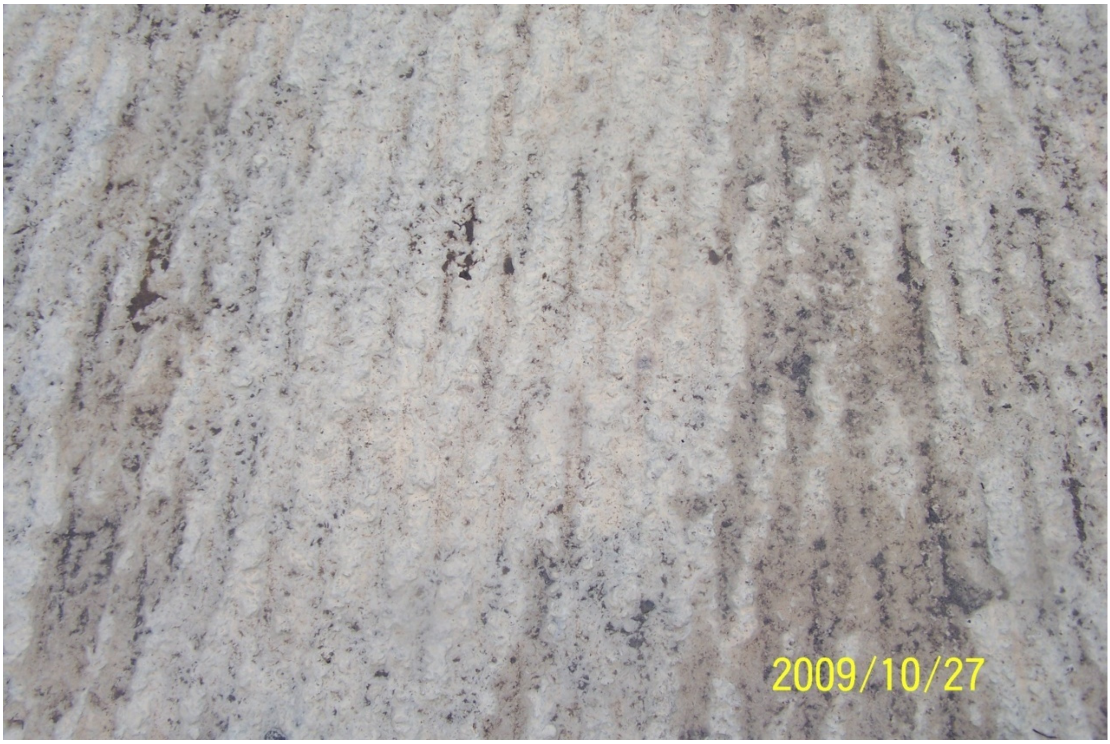

Figure 4-2. Whitewashed Milled Surface

The slab size is 25 foot by 25 foot (7.6 by 7.6 meters). The slabs are doweled in both directions using 1-1/2-inch (3.8 cm) dowels, 20-inches (51 cm) long, spaced at 18 inches (46 cm) on center. Pre-molded joint sealer was chosen for the joints due to their durability and proven performance at JFK.

Concrete Mix Design

The Port Authority's Materials Engineering Unit developed and tested mix designs to establish specifications, which would result in a durable Portland cement concrete pavement that meets strength requirements. The following adjustments to the FAA P-501 Portland Cement Concrete Pavement standard specification were developed:

- Graded Aggregate – See Table 4-3
- Total Cementitous content not exceeding 550 pound per cubic yard (194 kg/m^3), with a minimum of 40% slag cement
- Permeability ≤1500 coulombs when tested in accordance with AASHTO T277.
- 28 days drying shrinkage less than 0.40% when tested in accordance with ASTM C157.

Sieve Size	**Percentage by Weight Passing**
2 ½	100
2”	90-98
1 ½”	76-88
1”	67-79
¾”	65-77
3/8”	48-60
No. 4	30-42
No. 8	27-37
No. 16	20-30
No. 30	16-22
No. 50	4-10
No. 100	0-4

Table 4-3. PCC Aggregate Gradation

The contract also included provisions that water / cement ratio and air entrainment requirements be met to qualify for flexural strength incentives. These additional mix design/specification requirements were approved by the FAA and included in the project specifications.

The contract required that the PCC paving be supplied from an on-site plant to provide a continuous supply of concrete as well as to reduce the amount of trucking required on the public roadway system. The use of slag in the mix has the added benefit of reducing the PCC's carbon footprint. Provisions were included in the contract for barging the aggregates to the work site.

The contract was designed to allow the PCC to be placed either by slip-forming or by side forms. The option was left to the contractor to permit flexibility during construction to meet the contract’s schedule requirements.

Reuse of Removed Pavement

In addition to milling 50,000-cubic yards (38,228 cubic meters) of asphalt from the surface of the runway, removal of PCC and HMA surfaced taxiway pavements were also included as a part of this project. Instead of trucking all this material off site for recycling or disposal, the design allowed for reuse of the removed pavement as subbase materials. This on-site reuse is the most sustainable use possible of removed pavement.

Runway Intersection Grading

Since the design of Runway 13R-31L specifies for the finished surface to be one foot above the existing surface, the grading of the intersection with Runway 4L-22R required special consideration. To ensure that the design did not result in a rough riding pavement the PANYNJ contracted with APR Consultants to verify the design. APR performed a simulation of a variety of aircraft operating across the intersection on Runway 4L-22R, checking for unwanted aircraft response to the proposed profile. The verified design was incorporated into the runway grading plans.

Other Design Phase Activities

Although during planning the project was broken into three main stages during design, 24 sub-stages were incorporated into the contract.

During the design phase a peer review of the project was performed. The design, staging approach and time of completion were all scrutinized. Another design phase activity was the prequalification of bidders. In addition to demonstrating the financial capacity to deliver the project, prospective bidders were required to show that they could meet certain production rates for PCC and HMA paving and airfield lighting installation.

A Contractor's Forum was then held with the prequalified bidders. The Forum included a project briefing by design and construction management staff, a site tour and a question and answer session. The 70-percent complete design drawings were given to the prequalified bidders at the Contractors Forum.

Special Contract provisions were also developed for this project. Damages for delay of up to $6,000 per minute and $300,000 per day were included in the contract. These penalties were significantly higher than in any other PANYNJ runway paving contracts. Additional compensation for early completion was also included in the contract. Up to $10 million could be earned by the Contractor for completing certain stages and the overall contract early. The Contract was awarded June 25, 2009, and the project moved into the construction phase.

LESSONS LEARNED DURING THE DESIGN PHASE

The use of three-dimensional design software was an invaluable tool in optimizing the grading of the project.

FAA's FAARFIELD pavement design program is a powerful and user-friendly tool for use in developing pavement thickness designs. FAA Technical Center staff was very helpful in providing advice on how to use the program to obtain an appropriate design for the special traffic mix and existing pavement construction at JFK.

Upfront testing to validate concrete mix design requirements provided the FAA with the data they needed to approve the Port Authority's changes to their standard specification. As a result, mix design requirements, which were optimized for local conditions, were included in the specifications.

Staging a project of this magnitude is a long and arduous process that is a critical part of the design. Staging must begin early in the final design process, receive the appropriate attention and buy-in by all. The airport, FAA and the airlines are key participants in the development of the staging. A peer review provided the agency with validation that the design and contracting approach was appropriate for a runway project that was significantly more involved than any project that was attempted in recent years.

The Contractor Forum provided another avenue for the engineers to communicate the intent of the design to the prospective bidders. This may have contributed to the bid price being extremely close to the engineer's estimate.

CONSTRUCTION

The construction contract included:

- 200,000 cubic yards (152,911 cubic meters) of concrete
- 240,000 dowels
- 55 miles (88.5 kilometers) of joint seals
- 325,000 tons (295,000 metric tones) of HMA
- 12 miles (19.3 kilometers) of drainage pipe
- 1500 in-pavement lights

The first major component of the construction undertaken was the construction of the Taxiway "KC" test section. The 800-foot by 100-foot (244 by 30.5 meter) test section was included in the contract so that the means and methods of construction could be evaluated and refined prior to closing Runway 13R-31L for construction. The test section included all items that would need to be constructed during the subsequent runway closures, including but not limited to AC paving, PCC placement, milling, drainage infrastructure, seeding and lighting infrastructure. Requirements were included to simulate the milled surface of the runway. The test section PCC pavement was grooved, so that all construction operations were proven prior to moving onto the runway. The Taxiway "KC" test section was successfully completed in November 2009.

On March 1, 2010, the runway was closed to operations, thus beginning the 120-day closure for the construction of Stage I. The work within the Stage I area included approximately 12,000 feet of the runway, taxiways, airfield lighting and signage, and drainage. Construction began with installation of a barrier/security fence enclosing the work area and a roadway leading off the airfield. The barrier/security fence effectively removed the Stage I area from the airfield and minimized the need for airfield operations staff to escort contractor staff and equipment. Even before the site was enclosed, milling and removal operations began. The Contractor quickly realized that a two-pass milling process provided a surface that met the specification, and met the production requirements. Installation of airfield lightning systems also began on day one.

Whitewash was applied to the milled surface (see Figure 4-2 above) at a rate of one gallon per 200-square feet (3.8 liters per 18.6 square meters) to serve as a bond breaker. Dowels on chairs were installed at the transverse joints. In-pavement lights were installed within cages (Figure 4-3) as recommended by an Innovative Pavement Research Foundation Study.[1]

Figure 4-3. Reinforcing Cage around Light Can with Alignment Jig In-place

The same batch plants and pavers used for the test section were used to pave the runway. A GOMACO GP-4000 was used to pave the initial alternate lanes and a GOMACO GHP-2800 slip-form paver was used to pave in-fill lanes. Grade control was established using GPS based laser. A burlap drag finish was applied and liquid membrane compound used. An early entry saw was used to cut the transverse joints.

A performance grade (PG) 76-22 binder was used in the HMA placed on taxiways. HMA with PG 64-22 binder was used for the shoulder and blast pavements. The

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[1] Sonsteby, O. (2008). “Constructing In-Pavement Lighting, Portland Cement Concrete Pavement”. IPRF Report 01-G-002-03-1

HMA-mix-design gradation requirements are shown in Table 4-4. During Stage I, paving production rates peaked at 4750-cubic yards per day for PCC and 5000 tons per day for HMA.

Sieve Size	**Percentage by Weight Passing Sieve**
¾”	100
½”	72-98
3/8”	60-82
No. 4	40-56
No. 8	28-39
No. 16	19-24
No. 30	13-19
No. 50	8-16
No. 100	5-10
No. 200	3-6

Asphalt, as a Percent Weight of the Total Mixture = 5.2 - 6.2

Table 4-4. HMA Aggregate Gradation

All PCC and HMA acceptance testing was performed by PANYNJ Materials Engineering. The average 28-day flexural strength of the PCC was 1,105 psi (7.6 mPa) with a standard deviation of 92 psi (0.6 mPa). The average permeability was 667 coulombs with a standard deviation of 92. Port Authority surveyors checked final surface grades. Less than 0.4% exceeded the grade tolerance of .04 foot (1.2 cm) prior to grinding, Smoothness acceptance was based on profile measurement using a lightweight profilomenter, which was then evaluated using a California Profilograph simulation. The final surface, after limited grinding, had an average profile index of 6.7 inches (17 cm) per mile, using a 0.2-inch (0.5 cm) blanking band. The runway was reopened to air traffic at 11:40 am June 28, 2010, one day ahead of schedule (Figure 4-4) and remained open for the duration of the contract.

Figure 4-4. Stage I Completed and Runway Reopened

The remaining sections of the runway were broken into two main stages, the intersection with Runway 4L-22R, and the runway east of the intersection. Following the completion of Stage I, construction moved to the runway east of the intersection.

Between September 16 and 29, 2010, Runway 4L-22R was closed for paving of the intersection. Over 1,500 feet of Runway 4L-22R was resurfaced with HMA to meet the PCC on Runway 13R-31L. When the runway paving was completed the true profile was measured using an automated rod and level and an aircraft simulation was performed to verify the smoothness of Runway 4L-22R. Aircraft response was within acceptable limits (0.4g). The construction was essentially completed before the winter of 2010 approximately one year ahead of schedule.

One apparent benefit of the early completion incentives was the unprecedented level of detailed scheduling and daily monitoring that was implemented during all construction stages. The prime contractor and his subcontractors reported their progress, planned construction, identified issues, and implemented recovery plans at daily meetings intended to maintain the project's schedule.

As with any large construction project, issues arose that were not anticipated during either the planning or the design phases. A series of lessons learned meetings were held after the completion of the test section, and after the runway was returned to service.

Participation included Port Authority of NY & NJ's Engineering staff, JFK Operations staff, and contractor representatives. Some of these sessions were moderated by an outside consultant and covered design, operational and construction issues.

Dozens of issues were covered during these meetings. The major ones are presented below, and are being implemented in new runway and taxiway construction projects.

LESSONS LEARNED DURING THE CONSTRUCTION PHASE

Test Section

A large test section was designed into the contract. The intent of this test section was to test materials in-place for quality assurance and to allow the contractor to become familiar with the Port Authority testing and inspection requirements, airport operational requirements, security requirements, haul routes, production rates, etc. The schedule allowed for 3.5 months of time between the completion of the test section and the start of the 120-day closure. During this time, the contractor was able to fine tune his mix design, construction means and methods, as well as adjust his schedule for the upcoming 120-day closure.

All parties agreed that the construction of a large, fully functional test section and the 3.5-month preparation period was essential to moving forward with the confidence that the work within the 120-closure could be completed on schedule.

Two of the major lessons learned from the test section included the on-site batch plant's production as well as the PCC placement rates. The duration of the test section was such that neither the on-site batch plant nor the slipform paver reached the production rates required to meet the 120-day schedule. This posed a scheduling problem during the 120-day closure.

The on-site batch plant was incapable of delivering the amount of concrete that the original 120-day schedule specified. The two major issues were the delivery of the large aggregate into the hopper and the delivery of the cement to the top of the silo. Due to the size of the large aggregate, the delivery into the hopper was slower than required to fill the hopper in the time to meet maximum plant production. Several modifications to the hopper were performed during the construction, but the contractor was not able to achieve maximum plant production.

In addition, the cement delivery to the top of the silo from the cement pigs was also slower than what was required to meet maximum plant production. Several modifications to the cement delivery system were performed, but the contractor was not able to achieve maximum plant production.

The PCC was placed using a transfer vehicle(s) to the slip-form paver. These transfer vehicles frequently broke down and often had to be supplemented by the dumping of the PCC on the ground in front of the paver via dump truck. This, combined with the large aggregate and cement delivery issues, forced the batch plant to run more hours per day than scheduled as well requiring the addition of PCC paving days to the schedule.

Construction contracts need to include the language that during the test section the batch-plant and paving train must demonstrate that they can continuously provide the required amount of PCC to meet or preferably exceed the construction schedule.

Area Available for Contractor's Use

As one can imagine the land available for contractor's use at JFK is at a premium. We were able to assign approximately 20 acres (8.1 hectares) for contractor's use. This area includes the area for the batch plant, material storage, stockpiling of materials and excess soil for testing, etc. In reality, this was not nearly enough area. The areas where construction was being placed needed to serve as temporary storage areas, remote areas of JFK were turned into storage areas, and areas newly constructed become storage areas. In the end, we needed approximately 60 acres (24.3 hectares) of land available for contractor's use.

Construction contracts need to include sufficient areas for contractor's use to avoid the work area becoming a storage area, which leads to double- and triple-handling of materials, haul route issues and construction delays.

Guards and Escorts

During the Contractor's Forum, a major concern voiced by the contractors was the availability of haul route and worksite perimeter guards, and airside escorts for contractor vehicles, which was occasionally an issue during previous construction contracts when escorts become an issue during peak-construction vehicle movements.

To mitigate these issues, the 120-day construction stage was fenced off by an airside security fence and gate controlled by the contractor eliminating the issue of escorts, and the guards for the haul route and areas outside the fence were included in the contract to be included in the lump sum portion of the contractor's bid.

The incorporation of these two items into the contract was essential to the on-time completion of the contract, as well as eliminating contractor issues with guards and escorts.

Security and Operations Involvement

Security is a major concern with any construction project being undertaken at an airport, but is especially critical for projects being constructed in aeronautical operating areas. In addition to the guards and escorts previously discussed, staff from JFK Security and JFK Operation Groups attended daily construction briefings where issues, if any, were addressed and the contractor's work plan for the day was presented so that any required security or operational issue could be in-place prior to the start of work.

The inclusion of Security and Operations staff in the daily construction briefings helped to insure that construction was not interrupted due to security or operational concerns.

Incentives and Liquid Damages

This project was bid with the inclusion of a significant liquidated damages and bonus structure. The goal was to provide the contractor with the incentive to complete the major stages on schedule while providing sufficient penalties if they did not. The Port Authority, in selling this project to the airline community, committed to returning a major portion of the runway back to service within 120-days. After extensive internal discussions between Design, Construction, Contract, Law and Facility staff, the concurrence was that significant liquidated damages and bonuses would help achieve this goal.

Liquidated damages of $300,000 per day were added to the contract for every day delayed beyond the 120-day phase and $5,000 per minute for the 14-day closure. Liquidated damages for other stages and for the return to operations of taxiways were included.

Bonuses for the on-time completion of the three major phases, 120-day closure, 14-day intersection closure and the project closeout were $5,000,000, $2,500,000 and $2,500,000 respectively.

It is not possible to definitively determine if the bonuses or liquidated damages for the 120-day closure and 14-day intersection closure contributed to the on-time delivery of these stages; however, the consensus is that they did. As a result, they have been added to a subsequent taxiway project and will be included in future runway projects.

Weather and Schedule

The runway closure occurred on March 1, 2010. This month turned out to be one of the wettest months of the year. In fact, it snowed only a couple of days before the first Portland cement lane was scheduled to be paved. The paving was delayed several days, thereby placing the schedule in jeopardy only days into the contract and raising concerns with the project team.

While the contract specified the historical amount of days of rainfall in excess of 0.1 inches (0.25 cm) per month and a clause pertaining to the extension of time for bad weather in excess of what was included in the contract, the contract also specified that a detailed production schedule be submitted to the Engineer for approval.

What was not clearly defined in the specifications was how these possible weather delays were to be included into the schedule and then how to adjust for months where less than the historical rainfall days occurred. Also missing from the contract was clear language that poor weather may not necessarily result in a schedule delay if the activities of the day are not weather sensitive, such as excavation and materials delivery. The contractor's schedule did not address weather days or a recovery plan as presented.

Future contracts need to be specific as to how weather days are to be factored into the schedule, what specific construction activities will result in extensions of schedule for weather delays, and a recovery plan if the number of weather days were exceeded.

Pre-purchase of Materials

Due to the long-lead time for large quantities of electrical infrastructure, including lighting cables and light cans, these items and their associated hardware were pre-purchased by the Authority and turned over to the contractor. The Authority developed a tracking system to monitor the production and delivery of approximately $9 million in materials. The Authority also needed to provide a secure location to store these materials.

As a public agency, we were required to prepare documents for three independent bids for this pre-purchase of materials. This was a time consuming process to prepare the pre-purchase documents and extreme care needed to be taken to insure that all electrical materials for the installation were included in the pre-purchase order.

In order to insure an accurate order, Design, Construction, Facility and Maintenance staff were involved in the pre-purchase documents. Because of this collaborative effort, the pre-purchase of materials was successful and will be included in future construction documents where large quantities of long-lead items are required. The key to a successful pre-purchase is to start early to allow for potential delays from the supplier and adequate QA/QC testing.

Pavement Cores in Milled Areas

An extensive pavement-coring program for the runway was undertaken. One item that was overlooked was comparing the existing asphalt lift interfaces to the designed milling depths. During the milling of the runway prior to the PCC overlay, there were areas where the HMA pavement delaminated below the designed milling depth due to the HMA layers delaminating at the previous lifts due to the action of the milling machine. On a typical mill and HMA overlay project, this is not an issue, but on this contract, maintaining the smoothness of the milled surface was critical to prevent the PCC pavement from locking-up with the underlying AC surface.

This issue resulted in a post-award contract change to pave a sand-asphalt layer in the delaminated areas to create a smooth surface to place the PCC. This added both time and cost to the project. Future contracts will more carefully analyze the core data and an AC leveling course will be considered where necessary to avoid this issue.

AC Leveling Course

Construction duration and schedule was a major concern during the design of this contract. Every effort was made to limit the amount of work in each stage where time was critical. We chose to place the PCC on a milled surface. Great lengths were taken to specify and construct a smooth milled surface. The contractor milled the AC two times, the first to remove the bulk of the AC and the second to establish grade and a milled surface to meet the specifications. This was a successful but time-consuming process.

As was demonstrated with the placement of a sand-asphalt layer, the placement of an AC leveling course would not have significantly added time to the construction schedule. It would however have added cost to the project. When a smooth milled surface cannot be achieved, the use of AC leveling course should be used.

Pavement History Maps

As discussed an extensive pavement coring program was performed during design development. From this program and from existing construction contracts, a pavement history map was developed. This map was used for pavement design, removal quantities, etc. Even with pavement cores spaced a few hundred feet along the shoulder and blast pavements, we experienced areas where we expected to have more pavement then we had in place. This resulted in a designed mill and overlay area requiring a field change for the removal of existing pavement and the construction of full-depth pavement.

Once this condition was discovered during construction additional pavement cores were cut and additional full-depth pavement was constructed under a design change. This change resulted in additional cost to the project.

In future contracts, in any areas where pavement is being removed by milling a substantial base is to remain to overlay, additional cores will be taken., especially in areas where the existing pavement thickness results in the desired minimum to overlay after milling.

PCC Plant and Back-Up Plant and Backup Plan Requirements

The contract was structured to allow the use of either side form or slip-formed PCC. If slip-forming was chosen, the contract required the construction of an on-site batch plant as well as a "back-up plan" to be implemented if problems occurred with the on-site plant.

The contractor chose slip-form paving and a batch plant was erected on-site. The "back-up plan" proposed by the contractor was the construction of a smaller batch plant and additional supply from a local supplier. This "back-up plan" was accepted. As discussed earlier, the main batch plant did not produce PCC at the rate required to meet the projects schedule. The smaller back-up plant was older and had numerous problems before being fixed and on-line towards the end of the 120-day stage.

The contractor used a local supplier to provide the additional PCC required and added a night shift placing concrete on the in-fill lanes with a separate crew. The outside supplier also provided PCC for transition slabs, duct banks, etc. during the day shift.

In hindsight, it was a mistake to require an on-site batch plant with only a back-up plan. The off-site supplier required additional materials testing staff for quality assurance at the plant, additional trucking, and additional concrete inspectors. Every time the main-batch plant experienced a problem there was a delay in the delivery of the PCC to the slipform paver for varying lengths of time. This could have been avoided if there were two fully operational batch plants on-site.

Future contracts will require two independent plants, each capable of supplying the required amount of PCC to meet the production schedule be constructed before the test section and both be used at their rated capacity during the test section. This will add additional expense to the contractor's bid to erect and maintain two plants, but the expense is warranted to insure that the job is built on time with a reliable and continuous supply of PCC.

Truck Staging Areas

In addition to the deliveries of aggregates, dowel bars, crushed stone, drainage pipes and structures, approximately 60,000 truckloads of AC and PCC alone were required during the 120-day closure. While every effort was made by the contractor to stagger the deliveries, there were at times trucks parked along many of the roadways at JFK. This was unacceptable during peak traffic hours at the airport.

Construction contracts need to be specific as to the available area for truck staging, and the use of alternate staging areas off-site needs to be investigated if sufficient areas cannot be dedicated on site.

Surface Management System

To support the airfield operating requirements, a temporary surface management system using Aeorbahn and IRPOSnet was developed. The surface management system monitored arrival and departure rates and gate availability. The surface management system included interaction with each airline's ramp control coordinators, FAA Air Traffic Control Tower staff, terminal operators and Port Authority Staff. The result was that airport/airspace constraints were developed to manage the construction impact on ground operations. This system was an overwhelming success in mitigating taxi delays, addressing capacity constraints and minimizing disruption to airline schedules during construction. This system will be used for managing impacts for future construction contracts.

CONCLUSIONS

With any successful project, careful planning, including early buy-in from the FAA, tenants, and a quality design result in a successful construction phase. The planning, design and construction of JFK Runway 13R-31L can serve as a case study on how to deliver a project of this type successfully. Additional steps taken during the planning and design phase, such as prequalification of contractors, constructability analysis, peer review, optimization of the concrete mix, and getting approvals for completion incentives proved beneficial to construction. The requirement of a large test section, post-test section lessons learned sessions, coupled with superior quality assurance inspection/testing resulted in a quality runway.

This project signifies a new approach to runway design. Participation, commitment and the buy-in of the critical elements by all stakeholders were key to the advancement of this project. Airlines needed to trim schedules, JFK hired additional inspection, scheduling and operational personnel, a joint trailer compound was built to house both the contractor and Port Authority of NY & NJ staff, and a project website was established to keep all parties informed of progress. This unprecedented cooperation made this project a success.

Chapter 5

Coordination And Logistics Management: Creating CALM at Los Angeles International Airport

Roger Johnson[1]; Intissar Durham[2]; and Warren Sprague[3]

ABSTRACT

Los Angeles World Airports (LAWA) has embarked on a major effort to renovate and upgrade aging facilities throughout Los Angeles International Airport (LAX), especially in the Central Terminal Area (CTA) of the airport. The order of magnitude of on-going and planned construction projects within the CTA over the 5+ year construction period is unprecedented in the history of LAX. In total, these projects will be undertaken by LAWA, and LAWA's tenants using multiple contractors, all working in the CTA at any given time. This scale of activity, unless carefully coordinated and managed, has the potential to disrupt passengers, tenants, and other users and occupants in the CTA. It also can create unanticipated logistical and construction conflicts between contractors on various projects, possibly affecting schedules and costs. This paper describes LAWA's program to improve the coordination and logistics management of these projects with the goal of minimizing construction related impacts to tenants and passengers within the CTA.

INTRODUCTION

Los Angeles World Airports (LAWA) has embarked on a major effort to renovate and upgrade aging facilities throughout Los Angeles International Airport (LAX), especially in the Central Terminal Area (CTA) of the airport. The CTA encompasses nine passenger terminal buildings, parking structures, a central utility plant, the iconic Theme Building, the FAA Control Tower, and numerous other facilities (see Figure 5-1). In 2010, 59 million passengers passed through the terminals in the CTA.

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Figure 5-1. Los Angeles International Airport (LAX) Central Terminal Area

The renovation and upgrade effort is anchored by two major projects. The first is a $1.545 billion upgrade of the Tom Bradley International Terminal (TBIT) that will provide greater capacity to the terminal's west side with new gates to comfortably accommodate passenger loads for next generation aircraft, such as the A-380 and B787, a great hall for premier dining and retail shopping, upgraded customs and immigration federal inspection areas for more efficient passenger processing, and secured corridors between Terminal 3, TBIT, and Terminal 4 so that connecting passengers can conveniently get from one terminal to the next (see Figure 5-2, Figure 5-3, and Figure 5-4). The Tom Bradley International Terminal West Expansion is the largest public works project in the history of the City of Los Angeles.

The second major project is a $438 million effort to replace the 50-year old existing Central Utility Plant (CUP) with a more modern and energy efficient facility (see Figure 5-5 and Figure 5-6). The new facility will provide additional capacity for air conditioning, heating and lighting of the airline terminals and other airport buildings, which will enhance passenger comfort and the reliability of utility service and safety.

Figure 5-2. Construction of the Tom Bradley International Terminal West

Figure 5-3. Exterior Rendering of the completed Tom Bradley International Terminal West Improvements

Figure 5-4. Interior rendering of the completed TBIT West Great Hall

Figure 5-5. Replacement Central Utility Plant Construction

Figure 5-6. Rendering of Completed Replacement Central Utility Plant

Other significant projects include a $270 million effort to upgrade / replace all aging elevators, escalators and moving walkways at LAX which have exceeded their useful life expectancy and a $271-million renovation / modernization of Terminal 6 that will increase lobby space, replace traditional ticketing counters with new check-in kiosks, bag-check stations, a behind-the-scenes in-line baggage handling system, additional security screening checkpoints, and other improvements. In addition, there are over $1 billion in other projects scheduled over the next 5+ years that will ultimately affect virtually the entire CTA.

The order of magnitude of on-going and planned construction projects within the CTA over the 5+ year period is unprecedented in the history of LAX. In total, these projects will be undertaken by LAWA and LAWA's tenants using multiple contractors, all working in the CTA at any given time. For example, at one point, there will be as many as 14 separate contractors in Terminal 6 alone. Many of the projects are initiated by the airlines, concessionaires, and other tenants, and consequently, are not under the direct control of LAWA.

This scale of activity, unless carefully coordinated and managed, has the potential to disrupt passengers, tenants, and other users and occupants in the CTA. It also can create unanticipated logistical and construction conflicts between contractors on various projects, possibly affecting schedules and costs.

In response, LAWA, with the assistance of their consultant AECOM, developed the CALM (Coordination And Logistics Management) program to address these issues. CALM's mission is "*minimize construction related impacts to tenants and passengers within the CTA*." It is anticipated that CALM planning and activities will be expanded in the future to cover the entire airport, not only the CTA.

CALM PROGRAM FUNCTIONS

1. To meet this mission, the CALM group focuses on six main activities:

2. Gather, compile and update data --- The program has built and is continually updating a project specific time and space database of floor plans, activities and schedules which is collected from a wide variety of sources as shown in Figure 5-7. The schedule shows contractor activities by phase for each week of the year. "Activities" include work inside actual barricaded construction areas as well as anticipated contractor access and work in the staging areas.

Figure 5-7. Sources of Project Data

3. Publish project data --- Information from the database is issued on a regular basis to LAWA divisions as well as to airlines and other tenants so that all are aware of, and can plan for, upcoming construction activities and related impacts.

4. Develop and publish standards --- New guidelines and procedures have been developed to: promote consistency in approaches to safety, security, construction

barricading, messaging, and signage; minimize tenant and passenger exposure to noise and dust; and clearly articulate the level of detail on contractor phasing plans expected of each of the contractors as part of their submittals for final project approval.

5. Review and approval of contractor logistics and staging plans ---- As part of the project approval process, the CALM Team reviews contractor's phasing and logistics submittals for conformance to LAWA guidelines. In addition, CALM reviews these submittals in context with other projects system wide (current and future) to analyze how they interface with other projects. CALM also analyzes the cumulative impact of construction within a specific area and makes recommendations on timing to minimize disruption to passengers. The cumulative impact analysis takes into account future projects as well as current and on-going maintenance.

6. Analyze LAWA resources and systems ---- The CALM team evaluates compiled data to quantify construction impacts on LAWA resources (project management, inspection, other staffing, maintenance, financial, and equipment) and makes recommendations on systemic changes required and on highest and best use of available assets. An example includes making adjustments to the LAWA project approval process. The changes improved user friendliness, and are better to accommodate multi-phase projects and non-traditional procurement processes, and reduce costs for tenants, contractors and LAWA. One significant modification was to designate one approval point of contact for each tenant project in order to provide higher quality service to airlines and other tenants.

7. Utility Shutdown Process --- A key concern is the number of planned utility shutdowns expected as part of the projects. Planned utility shutdowns as part of construction and maintenance activities in the CTA historically average 10 to 15 per month. Planned shutdowns have increased to well over 150 per month, a rate that is expected to continue during the multi-year construction period. The CALM Team led an effort to clearly define the responsibilities, resources, protocols, pre-emptive measures, and contingency plans for requesting, coordinating and implementing planned utility shutdowns. This process has been integrated into LAWA's Design and Construction Handbook.

CALM ORGANIZATION

The CALM Team is composed of five elements: Management; Area Resident Managers; Utility Shutdown Control Center; Logistic Expeditor Group; and Communications Group. Their roles and responsibilities are described below.

Management

The Calm Manager works with LAWA Executive Management to obtain goals, establish the work plan and objectives for the CALM Team, and is responsible for ensuring the objectives are achieved. In addition, the Manager analyzes systemic or procedural concerns that could negatively impact CTA building programs and customers and makes recommendations for adjustments. Examples of the CALM Manager's responsibilities include:

Develop construction look-ahead schedule: Compile data and develop the best estimate on anticipated scope, location, and timing of future LAWA Capital Projects, Tenant, and Maintenance type projects for use in resource scheduling, logistics planning and construction packaging and sequencing.

High level logistics planning: Build and update CTA area plans showing areas of construction, barricades, materials delivery routes and storage, alternate vehicular and passenger routes, curb and road closures or restrictions, rubbish removal, contractor parking, etc.

Develop concise, consistent road map for tenant and LAWA contractors. This includes the development of easy to follow and consistent processes that are then communicated clearly to the contractors and then enforced across the board.

Develop and distribute clear communication methods for timely and continuous updates on construction activity at the airport.

Set quality standards and clear objectives for CALM team.

Area Resident Managers (ARMs)

The ARMs are the critical interface between CALM and construction contractors. They serve as the single point of contact for construction logistics for all LAWA Project Managers within their designated areas of work, generally defined as groups of terminals. They are thoroughly familiar with the scope and schedule for all projects within their area and attend all construction meetings and project design meetings. The ARMs are responsible for identifying areas of conflict in scope and schedule and facilitating resolution of conflicts with appropriate LAWA staff.

ARMs are also responsible for leading development of comprehensive plans for aircraft ramp usage, construction areas within terminals, road and curb impacts, as well as extracting look-ahead data for construction barricades, utility shutdowns, and other public area activities that would affect passengers or the tenants. The ARMs keep the CALM scheduler and GIS manager updated on changes to project schedule and scope.

Utility Shutdown Control Center (USCC)

Planned utility shutdowns have become increasingly complex at LAX due to the increase in construction activity and the age of the facilities' infrastructure. By nature, utility shutdowns affect a variety of stakeholders, including tenants, airlines, security personnel, and various departments within LAWA (IT, Commercial Development, Maintenance) as well as the traveling public. Impacts to life/safety and security systems are particularly critical when considering utility shutdowns.

To minimize negative impacts, CALM worked with various stakeholders to develop procedures and guidelines for contractors to use when requesting a utility shutdown and created the LAWA Utility Shutdown Control Center (USCC) which is responsible for coordinating and managing the review and approval process and of all Utility Shutdown Requests (USR).

Under the system, a contractor needing to shut down a utility must submit a USR to the USCC, along with an analysis of the impacts of the shutdown. The impact analysis identifies all systems, operations, and stakeholders that will be affected by the proposed shutdown of the utility and specifically what that impact is. This analysis also identifies the affected stakeholders and the resulting impacts to their operations.

When a contractor submits a utility shutdown request along with a required impact analysis, the USCC undertakes a technical review of the request and impact analysis, coordinates with stakeholders impacted by the USR, and coordinates the schedule with affected LAWA Divisions for the utility shutdown. Based upon the findings identified in the impact analysis, a contingency plan may be required, which identifies actions necessary to mitigate disruptions and maintain operational readiness during a utility shutdown. Contractors are required to provide all necessary management and material to execute the contingency plan(s), when needed.

Upon a satisfactory review of the USR, the Utility Shutdown Control Center will notify the LAWA Project Manager to schedule a Stakeholder Coordination Meeting. The purpose of the meeting is to review all elements of the utility shutdown including the review of impacts and applicable contingencies to assure all known elements have been addressed.

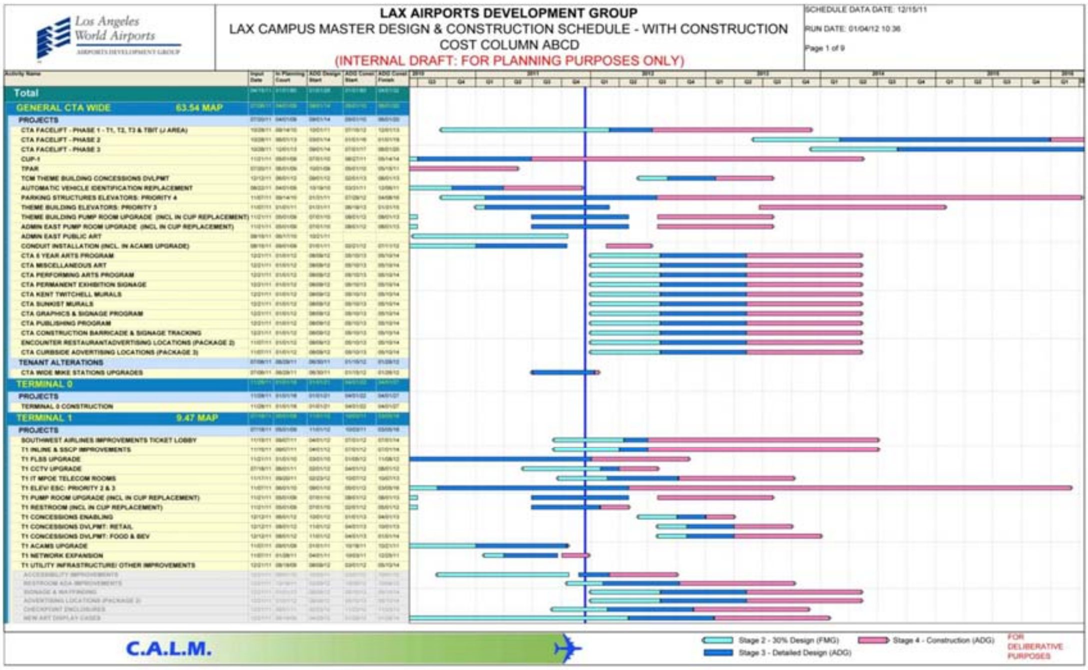
Upon satisfactory completion of the Stakeholder Coordination Meeting, the Utility Shutdown Control Center will obtain final approval signatures and return the approved USR to the Contractor with copies to the LAWA PM and all stakeholders identified in the USR as well as other parties identified by the USCC.

In addition, the USCC maintains a calendar of all utility shutdown requests, based on received notices and contractor look-ahead schedules. USCC staff attends all construction meetings, and extracts current and projected Utility Shutdown Requests (USRs) from contractors' schedules. Finally, the USCC team works closely with LAWA Divisions to anticipate required internal/regulatory shutdowns so that appropriate staff levels can be anticipated, as well as supporting LAWA Project Managers, Construction Inspectors, and Maintenance personnel in fulfilling their duties.

Logistics Expeditor Group (LEG)

The LEG is the information backbone of the CALM Group. The Group builds and maintains a database of the schedule (timing) and location (plans indicating areas of construction, barricades, access paths, etc.) of potential upcoming construction projects. The LEG includes a scheduler and GIS manager.

The scheduler compiles project schedule information for owner, tenant, and other major maintenance projects (both current and projected) and keeps the schedule database current with project revisions (see Figure 5-8). The scheduler works with ARMs to identify and incorporate pertinent phasing information into the master schedule, as well as coordinating with the LAWA's Project Controls Manager for consistency in work breakdown structure (WBS) assignments. Finally, the scheduler coordinates with CALM GIS manager to ensure correct tie-ins between WBSs and the project GIS database.



Los Angeles World Airports
AIRPORTS DEVELOPMENT GROUP

LAX AIRPORTS DEVELOPMENT GROUP
LAX CAMPUS MASTER DESIGN & CONSTRUCTION SCHEDULE - WITH CONSTRUCTION COST COLUMN ABCD
(INTERNAL DRAFT: FOR PLANNING PURPOSES ONLY)

SCHEDULE DATA DATE: 12/15/11
RUN DATE: 01/04/12 10:36
Page 1 of 9

Activity Name | Input Date | In Planning Count | ADG Design Start | ADG Const Start | ADG Const Finish

Total
GENERAL CTA WIDE 63.54 MAP
PROJECTS
CTA FACELIFT - PHASE 1 - T1, T2, T3 & TBIT (J AREA)
CTA FACELIFT - PHASE 2
CTA FACELIFT - PHASE 3
CUP-1
TPAR
TCM THEME BUILDING CONCESSIONS DVLPMT
AUTOMATIC VEHICLE IDENTIFICATION REPLACEMENT
PARKING STRUCTURES ELEVATORS: PRIORITY 4
THEME BUILDING ELEVATORS: PRIORITY 3
THEME BUILDING PUMP ROOM UPGRADE (INCL IN CUP REPLACEMENT)
ADMIN EAST PUMP ROOM UPGRADE (INCL IN CUP REPLACEMENT)
ADMIN EAST PUBLIC ART
CONDUIT INSTALLATION (INCL. IN ACAMS UPGRADE)
CTA 6 YEAR ARTS PROGRAM
CTA MISCELLANEOUS ART
CTA PERFORMING ARTS PROGRAM
CTA PERMANENT EXHIBITION SIGNAGE
CTA KENT TWITCHELL MURALS
CTA SUNKIST MURALS
CTA GRAPHICS & SIGNAGE PROGRAM
CTA PUBLISHING PROGRAM
CTA CONSTRUCTION BARRICADE & SIGNAGE TRACKING
ENCOUNTER RESTAURANTADVERTISING LOCATIONS (PACKAGE 2)
CTA CURBSIDE ADVERTISING LOCATIONS (PACKAGE 3)
TENANT ALTERATIONS
CTA WIDE MIKE STATIONS UPGRADES
TERMINAL 0
PROJECTS
TERMINAL 0 CONSTRUCTION
TERMINAL 1 9.47 MAP
PROJECTS
SOUTHWEST AIRLINES IMPROVEMENTS TICKET LOBBY
T1 INLINE & SSCP IMPROVEMENTS
T1 FLSS UPGRADE
T1 CCTV UPGRADE
T1 IT MPOE TELECOM ROOMS
T1 ELEV/ ESC: PRIORITY 2 & 3
T1 PUMP ROOM UPGRADE (INCL IN CUP REPLACEMENT)
T1 RESTROOM (INCL IN CUP REPLACEMENT)
T1 CONCESSIONS ENABLING
T1 CONCESSIONS DVLPMT: RETAIL
T1 CONCESSIONS DVLPMT: FOOD & BEV
T1 ACAMS UPGRADE
T1 NETWORK EXPANSION
T1 UTILITY INFRASTRUCTURE/ OTHER IMPROVEMENTS
ACCESSIBILITY IMPROVEMENTS
RESTROOM ADA IMPROVEMENTS
SIGNAGE & WAYFINDING
ADVERTISING LOCATIONS (PACKAGE 2)
CHECKPOINT ENCLOSURES
NEW ART DISPLAY CASES

C.A.L.M.

Stage 2 - 30% Design (FMG)
Stage 3 - Detailed Design (ADG)
Stage 4 - Construction (ADG)
FOR DELIBERATIVE PURPOSES

Figure 5-8. Sample Master Schedule Worksheet for C.A.L.M.

The GIS manager develops and maintains the GIS database using LAWA's most current CTA area plans, terminal floor plans, and other information available from historic records and new data submitted by contractors. The GIS system is used to communicate project boundaries, work areas, and phasing on a periodic (monthly, quarterly, etc.) look-ahead basis. It is also used as a planning tool for LAWA and CALM.

The system ties in with the WBS schedule, which is updated on a regular basis. The GIS manager also administers a web portal and application to display, view and print maps and schedule reports from reported data, and develops applications for identifying and highlighting schedule or location conflicts. Finally, the GIS manager coordinates closely with the LAWA GIS data manager in the Engineering and Facilities Management Division to ensure the work product is consistent with overall LAWA standards and is transferable to the Facilitates and Maintenance Group database when projects are complete.

The LEG systems are built around Oracle Primavera, Esri's ArcGIS, Microsoft's SharePoint and SQL Server. By using only commercial, off the shelf software that required minimal custom development, LAWA is not limiting future expansion and customization opportunities inherent in custom built applications.

Recently the group launched a web-based SharePoint site to provide airport-wide access to capital improvement project maps (see Figure 5-9) as well as a variety of other information, including a weekly construction bulletin described below. This application has vastly improved user access to the extensive database and allows instant 24/7 access to data on projects that might be currently impacting operations, emergency response, security activities, or other LAWA functions.

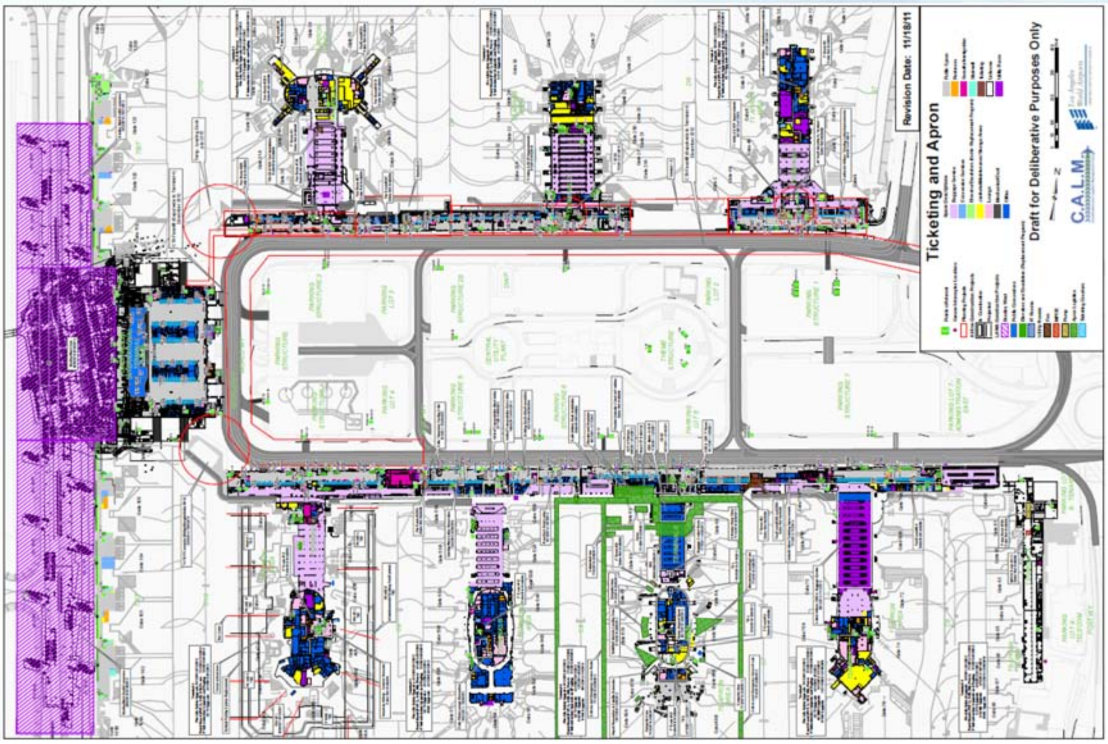
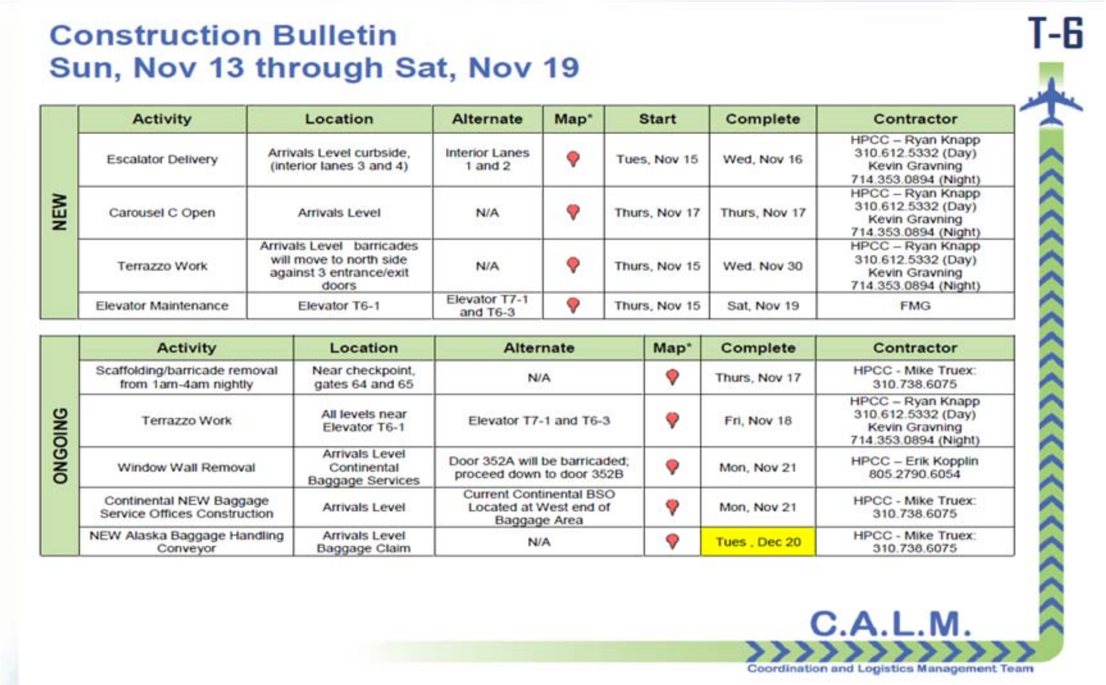


Figure 5-9. Sample GIS Project Map

Communications Group

The Communications Group is responsible for generating clear, concise, recognizable communication and support services for construction projects and distributing this information to all LAWA departments, tenants, airlines, business partners and contractors operating in the CTA.

The Communication Group gathers information on upcoming construction activities and impacts and then creates summaries of the information. The group verifies the information for accuracy, and then disseminates appropriate information to the impacted parties on a weekly basis (see Figure 5-10). The group developed and maintains stakeholder contact information, distribution lists and construction communication protocols.



Construction Bulletin
Sun, Nov 13 through Sat, Nov 19

T-6

	Activity	Location	Alternate	Map*	Start	Complete	Contractor
NEW	Escalator Delivery	Arrivals Level curbside, (interior lanes 3 and 4)	Interior Lanes 1 and 2	📍	Tues, Nov 15	Wed, Nov 16	HPCC – Ryan Knapp 310.612.5332 (Day) Kevin Gravning 714.353.0894 (Night)
	Carousel C Open	Arrivals Level	N/A	📍	Thurs, Nov 17	Thurs, Nov 17	HPCC – Ryan Knapp 310.612.5332 (Day) Kevin Gravning 714.353.0894 (Night)
	Terrazzo Work	Arrivals Level barricades will move to north side against 3 entrance/exit doors	N/A	📍	Thurs, Nov 15	Wed. Nov 30	HPCC – Ryan Knapp 310.612.5332 (Day) Kevin Gravning 714.353.0894 (Night)
	Elevator Maintenance	Elevator T6-1	Elevator T7-1 and T6-3	📍	Thurs, Nov 15	Sat, Nov 19	FMG

	Activity	Location	Alternate	Map*	Complete	Contractor
ONGOING	Scaffolding/barricade removal from 1am-4am nightly	Near checkpoint, gates 64 and 65	N/A	📍	Thurs, Nov 17	HPCC - Mike Truex: 310.738.6075
	Terrazzo Work	All levels near Elevator T6-1	Elevator T7-1 and T6-3	📍	Fri, Nov 18	HPCC – Ryan Knapp 310.612.5332 (Day) Kevin Gravning 714.353.0894 (Night)
	Window Wall Removal	Arrivals Level Continental Baggage Services	Door 352A will be barricaded; proceed down to door 352B	📍	Mon, Nov 21	HPCC – Erik Kopplin 805.2790.6054
	Continental NEW Baggage Service Offices Construction	Arrivals Level	Current Continental BSO Located at West end of Baggage Area	📍	Mon, Nov 21	HPCC - Mike Truex: 310.738.6075
	NEW Alaska Baggage Handling Conveyor	Arrivals Level Baggage Claim	N/A	📍	Tues , Dec 20	HPCC - Mike Truex: 310.738.6075

C.A.L.M.
Coordination and Logistics Management Team

Figure 5-10. Sample Weekly Construction Bulletin

The group also maintains a 24/7 Helpline with current notices and future impacts, as well as coordinating with LAWA Public Relations to ensure consistent and accurate construction messages and notices are delivered. The group coordinates with contracted consultants, agencies and third parties as necessary to maintain construction communication integrity and productive method(s) of information dissemination

SUMMARY

The CALM program was developed by LAWA in response to major efforts to renovate and upgrade the CTA at LAX. These projects will be undertaken by over 80 tenant, LAWA, and internal contractors, with multiple projects and contractors operating in the CTA at any given time. The order of magnitude of construction projects slated within the CTA over the next 5+ years is unprecedented in the history of LAX. This scale of activity, unless carefully coordinated and managed, has the potential to disrupt passengers, tenants, and other users and occupants in the CTA. It also can create unanticipated logistical and construction conflicts between contractors on various projects, possibly affecting schedules and costs.

CALM was created to minimize construction related impacts to tenants and passengers within the CTA by ensuring construction projects are coordinated, affected parties are informed well in advance of activates which may impact them, and consistent information on project scope, location and timing is made available to stakeholders in a timely fashion.

The CALM program has provided a number of benefits to LAWA, including:

Early identification and resolution of potential conflicts between projects. The core of the program, the schedule loaded GIS database, allows for identification of potential conflicts between projects early in the process, thereby saving time and money. For example, one project planned to use a portion of floor space for new escalators, while another sought to use the same floor space for a tenant improvement. The projects were on different schedules and if unresolved, the first activity would have been complete before the second started. CALM identified the conflict while both were in the design stage and a solution was reached with minimal design changes, resulting in an estimated $2 million in cost savings had the issue not been resolved until after one or both projects were under construction.

Early identification of potential opportunities for rescheduling activities to minimize impacts from multiple projects and achieve cost savings. The CALM program has identified several instances where multiple projects were planned to work in the same area and impact the same facilities at different times. For example, one project was planned to renovate plumbing in a terminal. The project would involve opening walls and ceilings to access the work area. Another project by a separate contractor was scheduled at a later date to renovate electrical systems in the same area. This project would also involve opening the same walls and ceilings to access the work area. By rescheduling the work to occur at the same time, impacts to passengers and tenants were minimized and cost savings were achieved.

Early identification, resolution and mitigation of planned utility shutdown impacts. Implementation of the Utility Shutdown Control Center (USCC) along with procedures and guidelines for contractors to use when requesting a utility shutdown has resulted in an improved planned utility shutdown process. Fewer unanticipated impacts from shutdowns have occurred, LAWA resources have been more efficiently utilized, and several opportunities for consolidated shutdowns have been identified, reducing the total number of shutdowns.

Ensuring contingency plans to address potential problems during utility shutdowns are developed, when necessary, and communicated in advance of the activity. Requiring contingency plans on certain shutdowns ensures actions necessary to mitigate disruptions and maintain operational readiness during a utility shutdown have been identified and relevant parties are aware of, and are prepared to execute their responsibilities if required.

Ensuring a common knowledge base of construction projects, locations, schedules and potential impacts are available to stakeholders. The CALM team obtains project data from owner, tenant, and internal contractors working in the CTA. These contractors are often working under different LAWA departments (Airport Development Group, Commercial Development Group, Construction and Maintenance, etc.). Having a common source of data combined with a robust system to share and disseminate the information ensures all stakeholders have a consistent data set from which to plan and coordinate for construction logistics and utility shutdowns.

Program Scalability. The CALM program is designed around functions and is easily scalable, both in terms of number of staff and combining or splitting responsibilities. The team can readily grow or contract as project volumes increase and decline, ensuring program costs are in line with the volume of work occurring in the CTA.

Chapter 6

Airfield Construction at Denver International Airport: Creating the Invisible Project

Mark Kelley, P.E.[1]

ABSTRACT

The pressure on major airports to carry out inside-the-fence construction under severely restrained budgets, while at the same time maintaining operations, routinely puts an incredible strain on airport resources. By the time a project goes out for bids, the evolution of events has been planned, engineered, cost managed and coordinated across the enterprise. What happens when such project are carried out however, can be compared to magic – making something that has been invisible – visible, and functional by the various element of the aviation community. This paper outlines these processes using projects and the history of development of Denver International Airport to serve as examples of the perseverance and ingenuity that have been required to successfully and safely fulfill the needs of the traveling public.

INTRODUCTION

As any magician will tell you, the “magic” of making something invisible is the art of misdirection – making you think something is in one place, when it is actually somewhere else. The execution of airfield construction projects is often successful by using this same trick. By applying the philosophy of misdirection and behind the scenes preparation from conception and within the framework of maintaining safe and efficient operations, airport operators and engineers can execute some pretty amazing magic tricks. In this case, “now you don’t see it, now you do.”

Airport Exceptionalism

The current strain on America’s transportation infrastructure has commuters and Departments of Transportation alike frustrated with crowded roads, deteriorating bridges and potholes that could swallow small cars. Shrinking budgets for maintenance, snow removal and improvements compound the pressure for responsible jurisdictions to maintain an efficient and safe transportation system. When funding is available for the improvement of roads and bridges, the delays

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associated with construction can sometimes double or even triple commute times. Notifications of delays due to construction are regularly broadcast by radio, television and internet map services so commuters can plan an early start or alternate route.

Similarly, airports are feeling the strain of decreased funding, deteriorating infrastructure and the need to maintain safe operations. In addition, airports must anticipate increased competitive pressure from airlines, changing needs based on economic conditions such as fluctuating fuel prices and transportation security. When an airfield construction project begins, it has already been planned and built several times by planners, engineers, construction managers and contractors. However, this is where the similarity ends. It is imperative that airfield construction projects be as invisible as possible to the operational performance of an airport.

Airlines spend hours using complicated scheduling programs to devise departure and arrival timing months in advance for every airport they serve. Their ability to maintain those schedules has a direct bearing on their ability to succeed in a very competitive business. Major airfield construction projects on one of dozens of airports an airline serves can impact their on-time performance and cascade that impact throughout their schedule.

Denver International Airport (DEN) is the largest airport property in the United States (Table 6-1). It is the fifth busiest airport (Table 6-2) in the country but has more property than the top two combined (Table 6-1). DEN also ranks as tenth busiest airport in the world. DEN is classified as a Category X airport, which designates both the size and potential security risk of the facility. With the potential for severe winter weather, DEN is equipped with the latest in Instrument Landing Systems (ILS) for all of its severe weather approaches. The airport's high security rating limits access to the airfield, ramps and deicing areas to only those given a thorough background check by the Transportation Security Administration (TSA) through the use of individual threat assessments as well as extensive airfield driver training.

Over the brief history of DEN, the airport's Planning and Development Division has constructed over 10.4 million square yards (8.7 million square meters) of concrete and asphalt airfield pavement. With that, they have also installed approximately 30,000 airfield lights and signs, hundreds of miles of underground electrical cable, five aircraft rescue and fire fighting (ARFF) stations, dozens of aircraft boarding bridges, a small electrical substation, two 4,000 ton chillers, an industrial waste containment facility, a deicing recycling facility, two maintenance vehicle support buildings and supported hundreds of construction projects utilizing access across the Airport Operations Area (AOA) – over $3 billion of construction.

Of course, being a relatively "new airport" one would naturally think that the vast majority, if not all of that construction was performed before DEN was actually an airport. This is not entirely the case. Since its opening on February 28th, 1995, over 2.2 million square yards (1.8 million square meters) of paving has been installed along with over 8,000 new airfield lights and signs. Two of the AARF stations, all of the boarding bridges, the substation, chillers, industrial waste facility, the maintenance vehicle support buildings and hundreds of the other construction projects all were accomplished after the 1995 opening – over a billion dollars worth. In addition, DEN's Maintenance Division performs thousands of hours of airfield maintenance each year.

Rank by Area	Facility Name	Land Area Covered By Airport (acres)
1	DENVER INTL	33,457
2	DALLAS/FORT WORTH INTL	18,076
3	SOUTHWEST FLORIDA INTL	13,555
4	ORLANDO INTL	13,302
5	WASHINGTON DULLES INTL	13,000
6	KANSAS CITY INTL	10,200
7	PITTSBURGH INTL	10,000
8	GEORGE BUSH INTERCONTINENTAL/HOUSTON	10,000
9	WILL ROGERS WORLD	8,081
10	TUCSON INTL	7,938
11	JACKSONVILLE INTL	7,911
12	INDIANAPOLIS INTL	7,700
13	SALT LAKE CITY INTL	7,700
14	CHICAGO O'HARE INTL	7,627
15	CITY OF COLORADO SPRINGS MUNI	7,200
16	SCOTT AFB/MIDAMERICA	7,003
17	CINCINNATI/NORTHERN KENTUCKY INTL	7,000
18	EL PASO INTL	6,670
19	DEADHORSE	6,506
20	DETROIT METROPOLITAN WAYNE COUNTY	6,400

Table 6-1. Top Twenty Largest Airport Properties
Source: FAA Airports Facility Data, current as of 2/9/2012

Rank by Passenger Traffic	Facility Name	Land Area Covered By Airport (acres)
1	HARTSFIELD - JACKSON ATLANTA INTL	4,700
2	CHICAGO O'HARE INTL	7,627
3	LOS ANGELES INTL	3,500
4	DALLAS/FORT WORTH INTL	18,076
5	DENVER INTL	33,457

Table 6-2. Top Five Busiest Airports in the U.S. and Associated Size
Source: FAA Airports Facility Data, current as of 2/9/2012

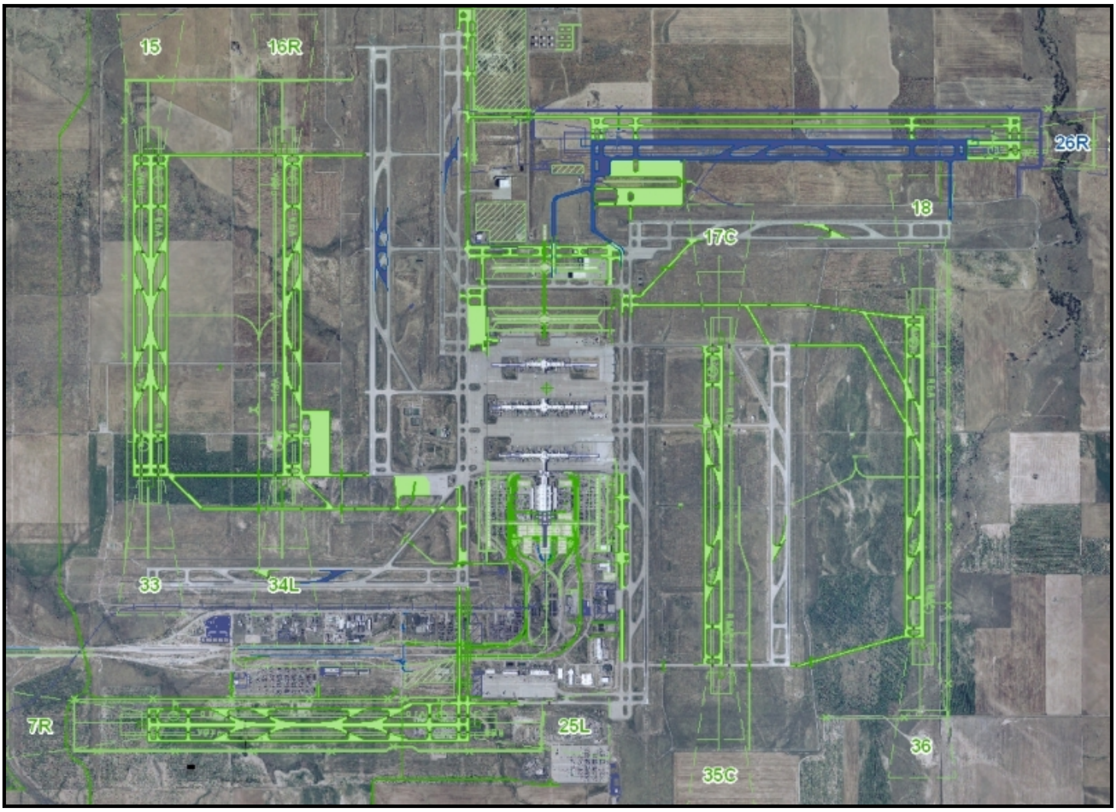

Figure 6-1. Ultimate Configuration of Denver International Airport

All this work is accomplished without lane closures, reduced speed zones or inconvenient detours. It does include, however, hundreds of hours of coordination, planning and development of creative construction delivery options with a goal of creating zero impacts to aircraft movements, airline schedules and transportation security. The success of these construction and maintenance projects actually began with the conception of the DEN airfield design.

The engineers and planners of DEN, having had experience with reaching the ultimate build out of the old Stapleton International Airport (the previous commercial airport that served the greater Denver catchment area), knew that performing construction on an operating airport represented an order of magnitude increase in risk associated with safety, cost and delays. Even the FAA, provider of most of the airfield funding, understands the implications of performing construction on an active airfield as stated in Advisory Circular 150/5370-2F.

“Airports are complex environments, and procedures and conditions associated with construction activities often affect aircraft operations and can jeopardize operational safety. Safety considerations are paramount and may make operational impacts unavoidable.”

In order to mitigate these impacts for the foreseeable future, DEN management sought to reduce the risks associated with airfield construction in a couple ways; first, through the design of the airfield. When planners designed the layout of DEN, they wanted to avoid as many of the inherent causes of inefficient aircraft operation in the design as possible. With prevailing winds primarily from the north-northwest and secondarily the west, the runways would need to be aligned north/south and east/west. The DEN planners felt that with runways laid out at roughly 90 degrees to one another, a midfield terminal plan similar to Washington D.C.'s Dulles International Airport or Atlanta's Hartsfield-Jackson International Airport could be adapted very well.

When the original "master plan" was completed, planners had been able to provide a highly efficient airfield layout that would ultimately include twelve runway complexes arranged in a "pinwheel" configuration. Efficient, in terms of an airfield, means planes can land, taxi quickly, unload passengers and cargo and reload passengers and cargo in very little time (turnaround time). Most airports have limited taxiing space, gate pushback space and are slowed by having to utilize runways for arrivals and departures simultaneously. In some cases, taxiway access to runways crosses other runways increasing both delays and the potential for an aircraft incursion. An incursion is defined by the FAA and refers to two aircraft that collide, have the potential to collide, or pass too closely to one another based on the visibility at the time.

The combination of the pinwheel configuration and the runway spacing allows for a balanced airfield where arrival and departure operations could be scheduled simultaneously without concern for incursions on the airfield or in the airspace surrounding the airport, even in inclement weather. In fact, after a few months of operations, airlines began to realize what the planners had speculated, that the airfield configuration was very efficient. In fact, United Airlines began to divert more non-origination/destination traffic to DEN because of the lower cost and higher speed in turnarounds.

Second, DEN management and elected officials made decisions that today would seem like political suicide. In the late 1980's, passenger traffic began to rise as cheaper airfares became available from new low-cost airlines, like Southwest. This prompted competitive responses from the legacy carriers and soon, with more people flying and fuel costs low, airports across the country were finding that capacity was becoming a very real issue. The airports responded by requesting grants from the FAA for capacity related projects and renovations.

When the "New Denver Airport" (a placeholder name at the time) was contemplated in the early 1980's, there was a long and sometimes aggravated debate between pro- and anti- airport proponents where uncontrolled program costs were often cited as a main criticism to not support the construction of a new airport. Understandably, the City was somewhat tentative to commit funds beyond the initial program amount, which included only three runway complexes. However, with pressure from the FAA and the airlines, plus the fact that the bids for the first runways were well below budget, the City decided that it would be less expensive in the long run to build more runways during the initial construction of the airport than to wait until after the airport was open. This turned out to be very true.

Obviously, construction of a large “Greenfield” airport is not something that would impact airport operations and with the decision to build out five runway complexes, airport executives felt that any additional large scale AOA construction could be avoided for many years to come. This turned out not to be true.

Before the DEN was even opened in early 1995, plans were already in place for the final design and construction of Runway 16R-34L; a 16,000 foot long, 200 foot wide (4,877 x 61 meters) behemoth with slabs capable of accommodating the largest aircraft, fully loaded in the heat of summer and at Denver’s mile high elevation. At over a million square yards of pavement, it was twice as large as any of the other five runways, each at 12,000 feet (3,658 meters) of length. It remains largest ILS equipped runway in North America. The project was completed in 2003 ahead of schedule and under budget and received numerous awards for construction management, design and quality. This project was completed with no impacts to airport operations, airlines schedules or safety.

Planning an Airfield Construction Project

Airfield construction is planned primarily on safety. In addition to the normal safety considerations of occupational construction safety, the safety of aircraft and passengers are paramount. The real challenge, of course, is balancing all three of these interrelated values during the planning and design phases of each project. At DEN, the Planning and Development Division performs no less than four major airfield projects each construction season; so the balancing act is further complicated by the impacts of adjacent projects. Generally, construction work is performed from April to October due to the debilitating effect of snow events. Snow removal operations at DEN involve the orchestration of over 100 pieces of equipment and the added risk of avoiding ongoing airfield construction is highly undesirable. Figure 6-2 is an aerial view of the DEN airport during the remarkable snow storm of 2006, which serves as stark example of the massive snow removal requirements when such adverse weather strikes at the airport.

The project planning process is generally guided by the FAA. An acceptable Construction Safety and Phasing Plan (CSPP) is required prior to the initiation of construction and includes a thorough analysis of the impacts caused by the proposed construction. The process begins with the identification of the geographic areas affected by the proposed construction. These areas fall into two basic categories, project and variable. Project areas are the actual areas affected by direct construction while variable areas are locations of haul routes or material stock piles. It is important that all interested parties understand what this means throughout the duration of the project.

Figure 6-2. Snow Event of 2006: Only Three Runways Open

Once it is clear what the affected area will be, the project team must have a thorough understanding of what normal operations will be affected by each phase of the construction. This includes factors such as the Aircraft Reference Code (ARC) for each runway, the Airplane Design Group (ADG) and Taxiway Design Group (TDG) for each affected Taxiway. (See Tables 6-3 and 6-4) Also, designated approach visibility minimums, available approach and departure procedures, most demanding aircraft based on fleet mixes and operations schedules, declared distances, available air traffic control for airports that do not have full time air traffic control services, airport Surface Movement Guidance and Control Systems (SMGCS) plan and other factors that could be impacted by the activities within the affected area. In order to have a complete picture of potential impacts, preliminary scheduling should be included in the analysis for certain operations as applicable.

Category	Approach Speed (knots)
A	< 90
B	91 - 120
C	121 - 140
D	141 - 165
E	166 or more

Table 6-3. Aircraft Reference Codes

Design Group	Wingspan (feet)
I	Up to 48
II	49 - 78
III	79 - 117
IV	118 - 170
V	171 - 213
VI	214 - 262

Table 6-4. Airplane Design Groups

As with any plan, flexibility needs to be included in the plan and even the design or other contract documents to allow for eventual changes to operations, construction activities or other unforeseen events. During the construction of the sixth runway at DEN, terrorists attacked the United States on September 11th, 2001. Inherent flexibility in how the project was originally planned allowed for the continued construction of the runway complex. The operations of aircraft after 9-11 were, of course, another matter.

During the development of a CSPP planners and engineers make every effort to develop construction phasing that allows the airport to maintain its normal operations. Airport operators, in consultation with airport users, ARFF management, FAA Air Traffic Organization personnel should identify and prioritize the airport's most important operations. Construction activities through project phasing or other means should be planned and designed to safely accommodate such operations. Only when such accommodations cannot be made regardless of importance, should operations be modified. Such modifications may include temporary revisions to approach procedures, restricting certain aircraft to specific runways and taxiways, suspension of certain operations and decreased weights for some aircraft due to shortened runways.

Creating Invisibility

The number one aspect of airfield construction that has the biggest impact on cost and schedule is access to the work site. Since 9-11 delivery of equipment, materials and labor to the project location has been a major challenge. Security needs far outweigh the need for new projects and reaching the balance of a secure capital project comes with a higher price. However, with budget constraints and a lack of a national reauthorization bill, airports find themselves having to go to extreme lengths to justify any significant construction. For those fewer projects that are implemented, creative use of site access, operational cooperation and a technical expertise can optimize the overall impacts on financial resources, operational efficiency, safety and security.

At DEN, nearly a hundred projects are completed each year utilizing very standard access and egress procedures. With the airport's midfield concourse configuration, there is over 4.5 million square feet (0.42 million square meters) of concourse facilities located in the secure area of the airport that are under the complete care of the City and County of Denver. The projects associated with this type of AOA construction include tenant relocations and expansions, airline gate changes and office remodels, boarding bridge replacements, telecommunication upgrades and infrastructure repairs, upgrades and expansions. In every case, access to the project site is only achieved through multiple steps and approvals.

DEN has five access gates, which are all under surveillance with security guards. Every vehicle must be either permitted or inspected prior to entry and all personnel in those vehicles must have valid airport identification. This can pose to be a significant delay for projects that require imported materials such as concrete aggregate. In order to overcome this impact, separate temporary gates may be created in the AOA fence and used specifically for construction access only. These gates are then staffed with security personnel paid for by the contractor under the terms of the contract. Of course, any action of this kind must be included in the CSPP and approved by the FAA prior to construction.

For a contractor to perform the simplest of tasks under a contract that requires AOA access, it must apply for sponsorship from the airport, be trained on the Airport Security Plan, pay for fingerprinting and threat assessment background checks for each employee, pay for employees to be trained and tested for their identification badge, apply and pay for vehicle permits, coordinate deliveries of equipment and materials so they can be escorted on the AOA and be subject to search of any and all vehicles passing through an access gate. In many cases, contractors opt for night deliveries in order to have more flexibility with the timing of deliveries and to avoid delays due traffic congestion. With the airport being a 24/7 operation, this simple magic trick can make deliveries and projects appear overnight with virtually no impact to operations, safety or security.

At the other extreme, the construction or reconstruction of critical airfield systems can involve a much more significant investment in the preparation and execution of construction. For instance, the addition of the Runway 16R-34L complex was a major airfield construction project that had a project area that was 3,000 feet (914 meters) wide and 20,000 feet (6,096 meters) long (and a variable area that was even larger). In order for contractors to access the entire project area, the major construction processes were analyzed separately. Multiple access points were considered, complex delivery schedules reviewed and operational impacts assessed. Airline station managers and chief pilots, FAA, airport operations and security mangers, airport planners and engineers, emergency response staff, adjacent project contractors, air traffic controllers, environmental compliance staff, and many others had a seat at the table and contributed to making a new runway appear with no impacts to airport operations.

In terms of operational impacts, the largest problem turned out to be the easiest to solve. The runway layout plan of DEN was intended to be developed from the inner most runways outwards from the midfield complex. As such, all new runway complexes would be built with the ability to be temporarily separated from the AOA. By utilizing a temporary fencing scheme and mobile security personnel, the FAA, and later the TSA, allowed the construction site to be considered outside the AOA. There were still restrictions on the security of the affected area however, but the requirement of all workers within the AOA to have construction identification and background checks was lifted until the terrorist attacks. It was then determined that all workers would be subject to fingerprinting and background checks, which were performed by the FBI. While this presented some inconveniences to contractors and airport staff, it only caused a minor delay in the construction schedule, which was quickly mitigated through the implementation of new procedures for security and site access.

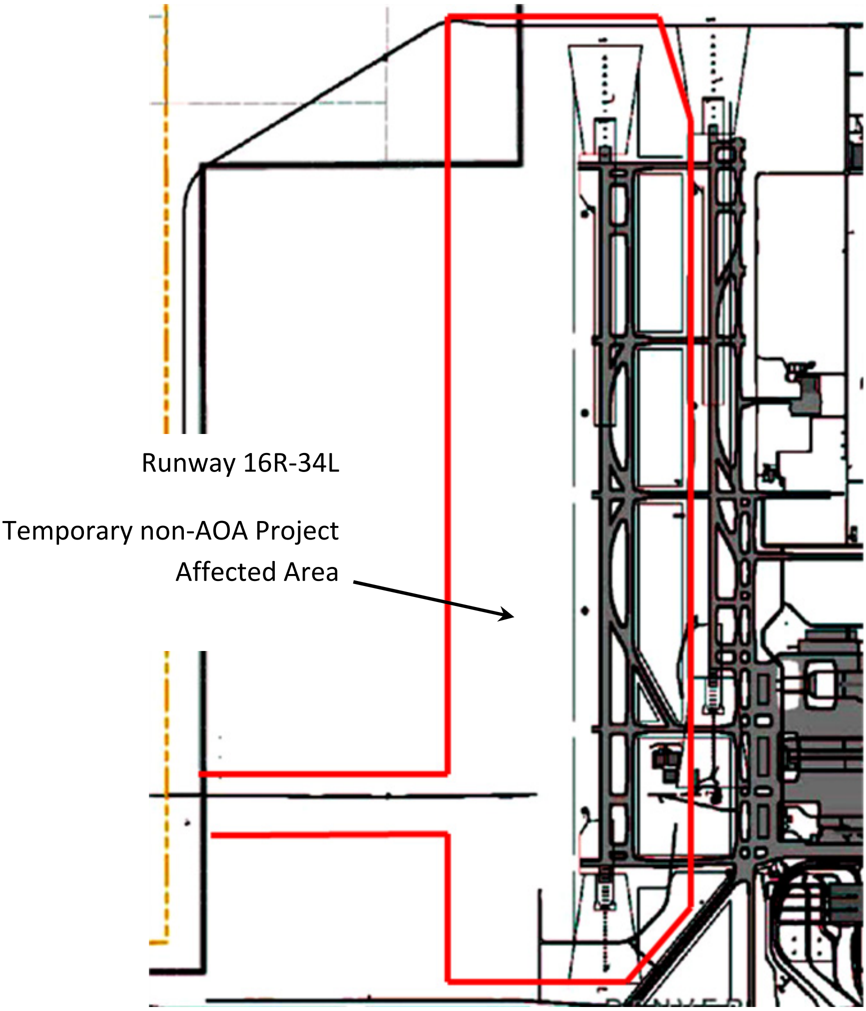

Figure 6-3. Runway 16R-34L Project Area

The approach of isolating a project area from the rest of the AOA is obviously an ideal one, such as the Runway 16R-34L Project Area (depicted in Figure 6-3) but such an option is not always available. In fact, the sixth runway remains the only project at DEN where this trick was ever able to be used. For other projects, more complex plans for access and egress has to be formulated. Often times it means complex traffic control plans during off peak flight operations that require a significant staff of security guards, traffic control devices, traffic control personnel, airport police, standby emergency response personnel, air traffic control personnel and quality assurance inspection.

One such project at DEN was an excavation project in the non-secure (non-AOA) area where the excavated material was transported over one of the two airport exit roadways, through the AOA security fence, over a cross-field taxiway, down a parallel taxiway and placed on either side of a runway to increase the Runway Safety Area. In order to not impact the operations of that runway complex, all work was performed at night, the runway was taken out of service, haul routes were identified and often created, a new gate was installed in the AOA fence, guards posted, traffic control devices and personnel deployed and a site-wide communications network developed. In addition, the airport committed oversight and coordination from the Denver Police and Fire Departments, airport operations and safety personnel and quality assurance staff to ensure public safety and minimal vehicular impacts.

Room for Technology

Today technology has become an important and ever expanding part of transportation planning, design and construction. Even the FAA, long known for maintaining the old "tried and true" philosophy as it applies to its standards, has now updated those standards as part of its initiative known as NextGen. The new requirements are for each airport to perform surveys, aerial photogrammetry and GIS database development to create an electronic airport layout plan or eALP. The eALP is accomplished through the development of an Airport GIS data base. While the needs of the FAA for this update has to do with the development of a national air traffic navigation and control system based on GPS, the resulting geospatial data base has an enormous amount of potential in many aspects of airport business.

The Planning and Development Division is closing on its second year of active GIS surveying and development and has recently submitted its eALP for FAA review. Simultaneously, the Planning Section has been developing an Engineering Spatial Viewer (ESV) to allow enterprise-wide use of the spatial data collected.

How the ESV may affect an airport's ability to effectively plan airfield projects is currently being developed at DEN. By integrating data from ground based systems that track aircraft type and taxiing movements into the ESV, the actual aircraft operational profile can be displayed. Likewise, information from traffic counters allows the integration of vehicle traffic information including vehicles per hour and peaks.

Spatially, the ESV includes tools to create buffers around existing airfield elements that delineate Obstacle Free Zones, Runway Safety Areas, Stopways and Runway Object Free Areas. Because of the need to plan projects in three dimensions, the ESV is equipped to show Clearways, Line of Sight and Terminal Instrument Procedures Surfaces. There will also be an application for to create Form 7460 applications to the FAA based on the imaginary surface requirements through the spatial analysis and exhibit the viewer creates. The Form 7460 is required by the FAA for any proposed or actual construction project that meets the criteria.

By effectively integrating multiple data sources the ESV has the potential to greatly reduce the coordination time necessary for large airfield projects. In terms of project planning, the creation of a geospatial airport viewer can provide planners and engineers with the tools to perform spatial analysis and exhibits utilizing outside data bases, map services and other software programs. Additionally, construction planning can be accomplished by creating various phased construction activity scenarios in the ESV and, since it is web based program, share them with the multiple airport, regulatory and airline stakeholders.

CONCLUSION

Successfully rendering the construction of an airfield project invisible is probably not so much the art of misdirection, but the art of having clear direction. Utilizing the latest technologies, thinking outside the proverbial box and effective communication are the secrets the airport magician uses to make airfield projects suddenly appear with little to no operational visibility.

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