DFW CONCRETE BLOCK PAVEMENT TAXIWAY CONSTRUCTION

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SUMMARY

The first concrete block pavement constructed on an airport in the United States was constructed at Dallas/Fort Worth International Airport during 1990. The use of concrete blocks on three taxiways at the airport proved a construction expedient and the pavements have performed as expected. This paper addresses the following issues: how DFW decided to use concrete blocks, concrete block pavement design, project specifications, and performance of the system to date.

INTRODUCTION

Concrete block pavements are a flexible pavement system comprised of individual, small precast concrete units locked together by sand vibrated into the joints. These concrete blocks are placed over a compacted layer of bedding sand, over a base course and subbase course, over a prepared subgrade.

Concrete block pavements have often been designed to support heavy loads and are used extensively in Europe. The first use of concrete block pavements on an airport was at Luton International Airport in the early 1980s. Since placement at Luton, more than 1.5 million square feet (139,353 m^2) of concrete blocks have been placed in the United Kingdom alone for aircraft parking areas, turning circles, taxiways, shoulders and maintenance areas. This pavement system has proven its ability to withstand heavy loads and aggressive environments.

This paper addresses the design and construction of 29,000 square yards (23,500 m^2) of taxiway pavement at Dallas/Fort Worth International Airport (DFW) using concrete paving blocks as the primary pavement element. The situation and circumstances that led DFW to consider constructing the first concrete block pavement on a commercial airport in the United States were very complex, with far reaching impacts. These same circumstances made what may normally have been a straight-forward design challenge, a very difficult decision for the owner. The paper has been structured to first address the owner's perspective on the project, and second to address the actual design and construction considerations and processes.

BACKGROUND

The 29,000 square yards (23,500 m^2) of concrete block pavement constructed at DFW are part of a construction project known as Taxiway B and C, shown in Figure 1. This project was developed as part of an ongoing effort by DFW to combat aircraft delays and enhance airfield utilization. A primary concern of

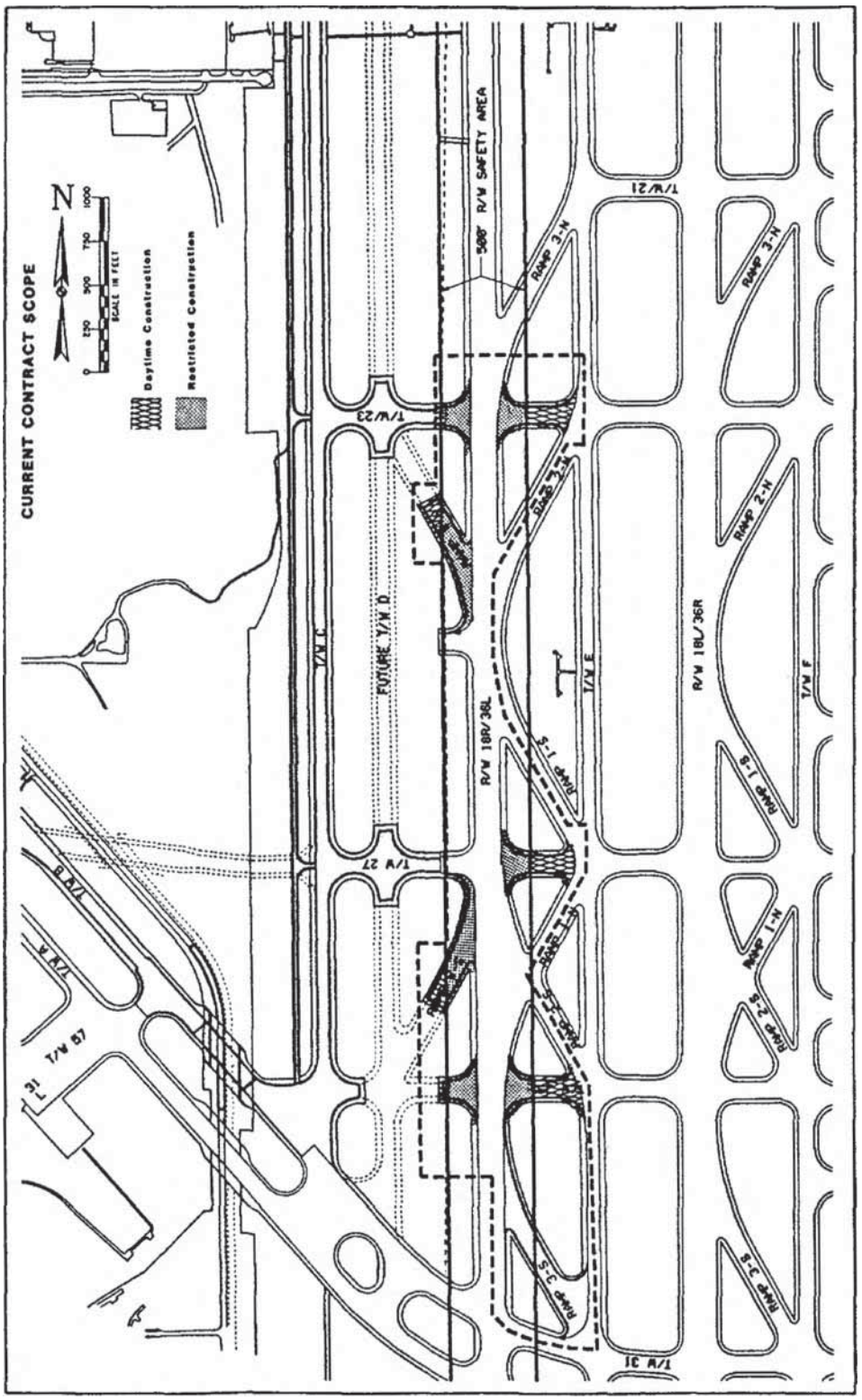


Figure 1. Construction Project Location.

airport management operating large hub airports is aircraft delay. Flight schedules are compromised because aircraft have to queue for approach and departure slots, or use of taxiway and terminal gates. The results of delay are increased operating costs for the airlines, and passenger inconvenience. A DFW study concluded that construction of Taxiways B and c, and other associated taxiways on the airport's west side, could significantly reduce delays.

The airport is currently experiencing an increasing level of aircraft activity in the West Support Area. Taxiway C will provide support area users with better access to the airfield taxiway system, and specifically the runways on the west side, as well as providing access to undeveloped sites on the west side of the airport. This improved access will allow for the development of additional cargo and maintenance facilities needed to meet growing demand.

The Taxiway B and C project involved construction of 160,000 square yards (133,780 m^2) of taxiway pavement plus paved shoulders, lighting, drainage, and high pressure fuel pipeline relocations; 160,000 cubic yards (122,326 m^3) of earthwork; and, a taxiway bridge (49,300 square foot (4,580 m^2) deck), at a cost of $20 million. Since a substantial portion of the pavement work on the taxiways associated with Taxiway C, namely Taxiways 23, 27 and 29, was to be performed within the active Runway 18R/36L safety area, there was a need to close the runway at some times during the construction process.

Ideally, the best way to perform work in a runway safety area is with a complete, continuous closure of the runway for a minimum number of days during the best weather and longest daylight period. The continuous closure procedure involves low risk, controllable construction and is preferable to a nightly closure/daily re-opening. The nightly closure/daily re-opening involves increased construction costs and complex construction operations, thus creating difficulty in obtaining the desired concrete quality and resulting in significant impacts on daily airline schedules, aircraft, and the public.

DFW Airport currently has six runways: four parallel north-south, and two parallel diagonal runways. With six runways, it may appear that closing a runway for a short time to accommodate construction should not be a problem. However, DFW is an extremely busy airport and further analysis was needed to determine the cost impact to the airlines on a runway closure.

The characteristics of DFW operations were the basis for the analysis. DFW Airport is currently the second busiest airport in the world. During an average day there are approximately 2,100 aircraft operations. An operation is defined as either an aircraft take-off or landing. DFW is also a "hub" airport with hub and spoke operations. Simply stated, a hub and spoke operation is one where an airline has a number of flights from different cities arriving at the airport within a short period of time and then departing to a number of different destinations. These inbound aircraft are on the ground only long enough to allow passengers time to connect to other departing flights. This operation happens several times throughout the day and is known as a "complex" or "bank" of flights.

DFW is American Airlines' largest hub, and American has approximately 400 aircraft departures each day. The airline has 12 complexes scheduled throughout each day, beginning with aircraft arriving for the first complex at 5:30 am and ending with the last aircraft departing from the last complex at 11:00 pm. A typical complex lasts for 1 to 1-1/2 hours, with a group of aircraft scheduled to arrive for the first 30 to 40 minutes, a break of 25 to 35 minutes while passengers change planes and aircraft are serviced, and ending with the same group of aircraft departing for other destinations during the final 20 to 30 minutes of the complex. There are an average of 40 aircraft in each of American's complexes, with a peak of 50 aircraft during the busiest and most popular times of travel (early morning, mid-day and early evening).

Delta utilizes DFW as its second largest hub, having approximately 300 flights each day. Delta operates in a manner similar to American, with 11 complexes throughout the day, and an average of 26 aircraft in each complex.

During the complexes, all of DFW's six runways are utilized simultaneously, with three runways used for arriving aircraft and three used for departing aircraft. During inclement weather, when aircraft must rely totally on their instruments to land, only four of the runways can be utilized.

The cost of runway closure to the airlines, based on this intense operation, was studied by the Southwest Regional Office of the Air Transport Association (ATA). The cost analysis concluded that closure of Runway 18R/36L, during weather at or near IFR (instrument flight rule) minimums, would prove to be near catastrophic to airline schedules. With Runway 18R/36L closed, capacity would be reduced by 50 percent in bad weather, resulting in delay costs of up to $131,000 per day. Even during good weather the closure would result in delay costs of up to $110,000 per day.

With this severe impact on the airport "user", final plans for construction work in the safety area (Area A) of Runway 18R/36L had to be changed so work was limited to nighttime construction only. The contract for construction was awarded with the requirement that work in Area A only be permitted during nightly 14 hour closures, occurring from 2000 hours to 1000 hours, for a 114 day period.

Soon after construction began, the ATA asked that DFW investigate alternative pavement sections for the work in Area A, with the objective of reducing the nightly closure from 14 hours to a maximum of 12 hours. At the same time, the contractor indicated concern about being able to complete the Area A work, as designed, in the time allowed. The contractor proposed using concrete block pavers in Area A in order to complete more work each night and reduce the risk of not meeting the deadline to reopen the runway each morning.

This background, along with the design of a concrete block paver section, as outlined in the second part of this paper, led to the decision to install the first concrete block pavement on a commercial airport in the United States. However, even when all the design work was done, and the cost was negotiated to be no more than the original design, and two hours were shaved off the nightly runway closure time, the decision to use the blocks was not easy. The decision was complicated by the Federal Aviation Administration's (FAA)

position not to approve the block pavement system and declaring that portions of the project were ineligible for FAA reimbursement (75 percent of the cost).

The airlines, however, considered the reduction of runway closure time from 14 hours to 12 hours nightly so crucial to their operations that they offered to replace the money lost by FAA ineligibility with their corporate funds. The savings to the airlines for the additional two hours of runway opening amounted to approximately $37,000 per day, or over $4,300,000, over the 114 day period of work in Area A. Therefore, design adequacy remained as the only issue in whether or not DFW would be a pioneer in placing the first block pavement on a United States commercial airport.

PAVEMENT THICKNESS DESIGN

After the decision was made to use concrete blocks for the surfacing course of Taxiways 23, 27 and 29, it was necessary to develop a block pavement design that was equivalent to the 17 inches (432 mm) of portland cement concrete, over 9 inches (229 mm) of cement treated base (CTB), over lime-stabilized subgrade that was originally designed and bid. The design method that was used to develop the concrete block pavement cross-section was a modification of the FAA's Advisory Circular 150/5320-6C, Airport Pavement Design and Evaluation. This modified method has been approved by the FAA and is described in a document published by the National Concrete Masonry Association entitled, Airfield Pavement Design with Concrete Pavers. The flexible pavement design charts were used to develop the total required pavement thickness, however, the concrete block plus sand layer was substituted for the required thickness of asphalt concrete. The base and subbase requirements are the same as those for any conventional asphalt concrete pavement construction.

To use the FAA design procedure the following pavement design parameters must be determined: the critical aircraft, the number of equivalent annual departures of that critical aircraft, and the subgrade strength in terms of California Bearing Ratio (CBR).

The traffic information required to develop the concrete block pavement design was provided by DFW. The following aircraft are projected to be in the fleet mix over the next 20 years, which is the design period.

Aircraft Type	Gross Weight lbs (kg)	Wheel Load lbs (kg)
B727	198,000 (89,812)	48,800 (22,136)
B737	150,500 (68,266)	35,800 (16,239)
MD-80	141,000 (63,957)	35,700 (16,193)
DC-10	583,000 (264,447)	54,700 (24,812)
L1011	498,000 (225,891)	57,500 (26,082)
B747	836,000 (379,207)	50,000 (22,680)
B767	388,000 (175,996)	47,000 (21,319)

The DC-10 was determined to be the design aircraft, and the number of equivalent annual DC-10 departures, over a 20-year design period was determined to be 32,623. This level of equivalent annual departures was used as the required design parameter.

To determine the subgrade support value to be used in design, the soil conditions at the site were reviewed. The borings conducted along Taxiway 23 show that the soils are tan to brown and tan sandy clays, silty clays and clays (fill) on tan and gray shaley clay. In some locations an intermediate layer of tan to tan and brown clay was encountered, and in some areas the pavement will bear on gray to blue-gray shale. The cut required for this taxiway is as much as 18 feet (5.5 m) to obtain the required alignment.

Two borings were conducted along the line of Taxiway 27, where the cut is to be as much as 9.5 feet (2.9 m) to achieve the required alignment. The borings showed brown, tan and brown, and tan and gray sandy clays, clays, and shaley clays (fill) on brown and brownish gray clays and sandy clays. The three borings conducted along the location of Taxiway 29 showed soils comprised of brown, tan and gray sandy clays, clays and shaley clays (fill) on tan and gray shaley clays and clay. Cuts up to 10 feet (3.0 m) are required.

The soils in the project area are highly expansive clays which are lime-treated or lime/flyash pressure-injected prior to construction of other pavement layers. The typical characteristics of the untreated and treated soils are as follows:

Material	Maximum Dry Density pcf (kg/m^3)	Optimum Moisture Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
Brown L Tan Clay (untreated)	96.0 (1,538)	24.8	71	32	39
Tan & Brown Silt (lime/flyash injected)	91.4 (1,464)	28.2	63	38	25

To develop a design subgrade CBR value, historical CBR data provided by the airport were reviewed. The historical data indicated that the CBR of the natural (residual) clay soils of the Eagle Ford Geologic Formation range from 2 to 5 percent. In addition to the historical information, the airport conducted CBR tests on existing subgrade material. Tests were conducted on the natural soil, as well as on lime/flyash pressure-injected soils. The natural soil produced CBRs ranging from 2 to 5 percent, while the lime/flyash pressure injected soils were found to have CBR values in the range of 6 to 8 percent. Based on these numbers, and the recommendations of airport staff, a design CBR value of 7 percent was chosen.

Using the traffic and soil information described above the required pavement cross-section was determined to be:

3.15-inch (80 mm) thick Concrete Blocks
1.5 inches (38 mm) of Bedding Sand
27 inches (685 mm) of Cement Treated Base
4 to 5 feet (1.2 to 1.5 m) of Lime-Injected Subgrade (CBR = 7%)

Unlike a typical asphalt concrete pavement, an additional design detail must be addressed in construction of concrete block pavements. This design detail is an edge restraint system constructed along the runway/taxiway, taxiway/taxiway, and shoulder/taxiway interfaces. Edge restraints are required to prevent movement of the concrete blocks. The edge restraint system designed for this project consisted of a 3-inch (76 mm) by 3-inch (76 mm) by 3/8-inch (10 mm) galvanized steel angle that was bolted to a 6-inch wide and 9-inch (229 mm) deep concrete curb that was cut out of the CTB. This angle extended upward to the middle of the block as shown in Figure 2.

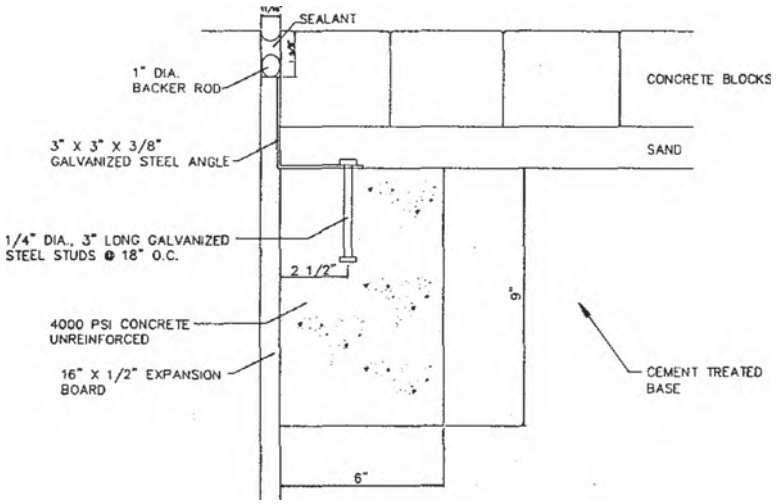


Figure 2. Typical Edge Restraint Detail.

JOB SPECIFICATIONS

Aircraft pavements have the most critical performance requirements of all pavements. They must be durable, strong, stable, safe, smooth, free-draining, resistant to fuel and oil spills, and resistance to de-icing chemicals. Detailed specifications were prepared for this project to address these issues, as well as other issues encountered in large block pavement installations. The specifications dealt primarily with the concrete blocks, the bedding sand, the joint filling sand, and the cement-treated base.

Concrete Block Pavers

The paving units specified for this project were rectangular with a nominal size of 4 inches (100 mm) wide by 8 inches (200 mm) long by 3-1/8 inches (80 mm) thick. The dimensional tolerances for the blocks were +/- 1/16 inch (1.6 mm) on length and width, and +/- 1/8 inch (3.2 mm) on thickness. The blocks were laid in a 45 degree herringbone pattern.

The standard requirements for concrete blocks are outlined in ASTM C936, "Standard Specification for Solid Interlocking Concrete Paving Units". Enhancements were made to the standard requirements for the aggregate type, compressive strength and splitting tensile strength to ensure superior performance. The compressive strength requirement of the samples at 28 days was identical to ASTM 0936, with the average to be not less than 8,000 psi (55 MPa) and with no individual unit to be less than 7,200 psi (50 MPa). A splitting tensile strength requirement was included in this project

specification, and the strength at 28 days was required to be not less than 650 psi (4.5 MPa). This test was conducted in accordance with ISO 4108, "Concrete, Determination of Tensile Splitting Strength of Test Specimens".

Abrasion resistance of the blocks was determined in accordance with ASTM C418, "Test for Abrasion of Concrete by Sand Blasting". The requirement was that the maximum volume loss from the blocks should be 0.915 cubic inches (15 cm^3) per 7.75 square inches (50 cm^3), and the average thickness loss should not exceed 0.118-inch (3 mm).

To increase the block durability, absorption and freeze/thaw resistance requirements were increased above the ASTM minimum. The average absorption was required to be no greater than 5 percent, with no individual block having an absorption greater than 6 percent. Seven percent is the maximum absorption allowed by individual units per ASTM. The absorption tests were conducted in accordance with ASTM C140, "Specification for Sampling and Testing Concrete Masonary Units".

The freeze/thaw durability requirements were in accordance with Canadian Specification Association, CAN3-A2312-M85, "Precast Concrete Pavers". The freeze/thaw durability requirements were as follows: the average weight loss after 20 freeze/thaw cycles should not exceed 0.4 percent of the initial constant block dry weight. The average weight loss after 50 freeze/thaw cycles should not exceed 1.0 percent of the initial constant block dry weight.

Pavestone Company, who manufactured the blocks used on this project, conducted extensive testing on different mix designs and aggregate types to produce a concrete block meeting these specifications.

Bedding Sand

The bedding sand layer is a critical part of the block pavement system. Its purpose is as a construction expedient to allow final leveling of the block surface. Stringent specifications for the bedding sand were developed for this project, to ensure stability and long-term performance. The sand was required to be washed, sharp, naturally occurring silica sand. The bedding sand specified was required to conform to ASTM 033, "Specification for Concrete Aggregates", with the exception of gradation. The specified gradation of the bedding sand was as presented below. The sand was required to be well graded and not vary from the high end limit on one sieve to the low end limit on the next.

ASTM Sieve Size	Percent Passing By Weight
3/8 in	100
3/16 in	95-100
No. 8	80-100
No. 16	50-85
No. 30	25-60
No. 50	10-30
No. 100	2-10
No. 200	0

The sand was specified to contain no more than 10 percent acid soluble material. It was also required to have a uniform moisture content within 2 percent of the optimum moisture content. The bedding sand was required to pass a degradation test developed for this project.

Joint Filling Sand

The specifications for the joint filling sand were identical to those of the bedding sand with the following two exceptions: the sand was required to be dry, and have 100 percent by weight passing the No. 16 sieve.

Cement-Treated Base Course

The cement-treated base course was required to conform to Federal Aviation Administration Specification P-304, "Cement Treated Base Course", with the following exceptions. The aggregate gradation used approximated that of the bedding sand. To achieve the required 650 psi (4.48 MPa) strength, 6 percent cement was used. The 27-inch (68 cm) CTB layer was required to be placed in three 9-inch (23 cm) lifts.

Sealant

A soil stabilizer sealant was specified to be placed on the finished pavement surface. This sealant was placed to minimize sand loss from the joints, and to prevent foreign object damage (FOD). The sealant used was produced by American Masonary Protection Inc.

CONSTRUCTION PROCEDURES

Sand Placement and Compaction

After placing the CTB, the bedding sand was spread in a loose, uncompacted layer approximately 1.5 inches (38 mm) thick and screeded to the specified elevations. Care was taken to ensure the bedding sand layer did not dry out prior to placing the concrete blocks.

Concrete Block Placement

The concrete blocks were delivered to the job site where they were placed by hand in the specified 45 degree herringbone laying pattern. The blocks were laid hand-tight. Block placement began at an existing edge restraint to ensure a square pattern. Subsequent block placement began at the existing laying face. Any blocks requiring cutting were cut with a masonry saw and were not allowed to be cut smaller than 1/3 of a block in size.

Compaction

After the blocks were laid on the bedding sand, and after all cut blocks were inserted, the block paving was fully compacted using a plate compactor with a plate area of not less than 2.5 square feet (56 cm^2). This plate compactor was required to transmit an effective force of not less than 10.88 psi (75

kPa). The compaction was continued until the block pavers were level and met the specified tolerances.

Joint Sand

After initial compaction of the blocks, dry jointing sand was brushed over the surface. The pavement was then recompacted using a vibratory plate compactor until all joints were completely filled. Final compaction of the block pavement surface was completed using a rubber coated drum roller.

Sealing

The sealant was placed over the finished pavement surface.

Time Frame

Laying of the 29,000 square yards (23,500 m^2) of the concrete blocks began in early September and was completed in early November.

PERFORMANCE

The grand opening of the concrete block taxiways occurred on December 5, 1990 when a China Airlines B747 cargo plane was taxied to one of the cross-taxiways, was powered down for the grand opening ceremony, and then powered up to taxi to the runway for departure. The concrete block pavement performed satisfactorily during this taxi operation.

CONCLUSION

Three concrete block surfaced taxiways have been constructed at DFW. This surface was selected due to its ease of construction, and its ability to shorten runway closures. The installation costs were comparable to the alternate portland cement concrete pavement, and the maintenance costs are expected to be lower. As existing airport facilities are expanded to meet increased air traffic needs, and when operational constraints are critical, it is anticipated that concrete block surfacing will become a viable alternative to traditional pavement construction. Based on DFW Airport's experience it is anticipated many other United States airports will be considering concrete block pavers for alternate pavement sections.

The near problem-free installation and the traffic, especially the first loaded 747 China Airlines cargo plane, to travel over the block pavers have substantiated the wisdom of the decision. The pavement has performed as predicted. It is anticipated that the FAA, as promised, will accept the pavement design and reimburse DFW retroactively for the cost (approximately $930,000).

The staff at DFW will be considering other applications of concrete block pavers such as roadway repairs in areas that cannot be easily closed due to traffic level, utility undercrossings where the need to access utilities under the pavement can be a concern, and maintenance and fueling areas.