# AIRFIELD PAVEMENT DESIGN WITH CONCRETE PAVERS


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Summary


This paper summarizes a comprehensive manual on the design of airfields constructed with interlocking concrete pavements (1). The 80 page manual also provides the design engineer with essential information for comparing interlocking concrete pavements with conventional pavements based on functional and structural characteristics, as well as life-cycle costs. This paper presents an overview of its contents.


Background

Most commercial airfield pavements in the United States are constructed according to the guidelines and specifications published in a series of "Advisory Circulars" by the U.S. Federal Aviation Administration (FAA). These have become standard references for design engineers in designing and evaluating different airfield pavements. They are applied by many states, counties, municipalities, and by airport authorities throughout the U.S. When FAA shares the cost of an airport project, adherence to their standards is a condition of funding.

Interlocking concrete pavements in airfields are new to North America, and have needed standard design procedures and specifications for these applications. This need has been met through the development of a comprehensive manual. Emery and Knapton (2) first expressed the idea of transferring FAA design methods to interlocking concrete pavements. Anderton (3) with the United States Army, Corps of Engineers, published a design manual with guide specifications aimed at military airfield applications. The latest manual by the authors is a further development in that it provides airfield pavement designers with guidance in the following areas:

- o Description of System and Components
- o History of Use on Airports
- o Attributes and Selection Criteria
- o Structural Design
- o Pavement Rehabilitation with Pavers
- o Life Cycle Cost Analysis
- o References

- o Specification for Concrete Paver Construction
- o Ancillary Standards
- o Typical Construction Details

escription of System and Components

terlocking concrete pavements for airfields consist of minimum 80 mm thick concrete ivers on 25-30 mm of coarse bedding sand. The compacted aggregate base material beneath e sand and paver layer is typically cement or asphalt stabilized. For lighter, general aviation rcraft up to 267 kN maximum takeoff weight, an unstabilized compacted aggregate base can utilized.

istory and Use on Airports

ne first recorded use of concrete pavers on an airfield is at London Luton Airport, England 1983 (4). Luton Airport has been a laboratory for determining the potentials and limitations concrete pavers in airfields. Urethane joint stabilization and sealing was first used there and bsequently used in other airport applications. Experience at Luton on runway pavement bject to full power jet thrust has indicated that concrete pavers should only be used in static d low-speed areas (5). Such areas include low speed taxiways, ramp and apron areas subject ly to low engine speeds, tug-in/tug-out operations, and exclude areas subject to reverse jet rust, "power back," operations.

ver the past decade some 30 airports, mostly commercial air carrier and military, have used ncrete pavers. The total area in use worldwide is approximately 600,000 $m^2$. Concrete vers have shown to withstand loads from repeated traffic from Boeing 747's and aircraft ith similar wheel loads (6)(7).

ttributes and Selection Criteria

ne pavement designer requires a working knowledge of different pavement materials to sure selection of an appropriate pavement system. The selection should be based on aluation of:

- o operational requirements (i.e. safety and reliability)
- o environmental and climatic considerations
- o constructability and operational disruption during the construction process
- o structural requirements (i.e. aircraft loading)
- o construction budget
- o maintenance requirements
- o cost-effectiveness

When considering airfield pavement, concrete is the preferred pavement for aircraft parking, aprons and ramps. Asphalt is generally selected when there are operational benefits or budget constraints. When compared to conventional asphalt or poured concrete, interlocking concrete pavers meet these criteria for aircraft pavements:

A stable surface
Resistance to fuels, hydraulic oils and de-icing chemicals
Resistance to static loading
Adequate skid resistance
Can be painted or colored units used for pavement markings
Fast construction and reinstatement
Less costly reinstatement
Rapid removal of surface water and snow

A stable surface - Jet aircraft are susceptible to damage from loose material drawn into engine intakes. Damage from ingestion of materials, birds, etc., into jet engines or damage to the airframe is referred to as foreign object damage (FOD). It is essential that any surface does not produce FOD and that it remains intact. Concrete pavers with chamfered edges and uniform joint spacing will reduce the probability of this situation developing to unacceptable levels. Since the degree of interlock and stability depends on the joint sand, its loss is eliminated by stabilization with sealants (5).

Resistance to fuels, hydraulic oils, and deicing chemicals - For aircraft parking positions, hot mix asphalt pavements are subject to deterioration from spilled jet fuels, aviation gas, and hydraulic oils. Although coal tar sealers can be used to protect the hot mix asphalt surface, they have a finite life and typically requires re-application on a 5-year cycle.

In-situ portland cement concrete (PCC) has normally been the material of choice for aircraft parking positions and apron areas. While PCC has generally been found to resist aviation fuels and hydraulic oils, these fluids have been found to have a deleterious effect on some joint sealant materials. This problem is averted by using concrete pavers which do not require the use of joint sealants.

Fears of concentration of aviation fuel accumulating in the sand layer under the pavers appear to be unfounded. Tests carried out at London Luton Airport under the supervision of the County Petroleum Officer indicated that no explosive vapors are present when unsealed sample pavers were removed from an area heavily contaminated with aviation fuel (8). Concrete pavers in airfields are typically sealed to help prevent infiltration of aviation fuel.

In North America urea is used as a pavement anti-icing agent, and glycol is used for aircraft de-icing purposes. These two materials have been known to have a damaging effect upon concrete, due to the very rapid cooling effect within the surface of the pavement, which can freeze any moisture present. An immediate volume increase of approximately 9 percent in the pores holding water can lead to disintegration of some concrete surfaces, especially if the oncrete is saturated.

The Transport and Road Research Laboratory of the United Kingdom has conducted tests on ir-entrained reinforced concrete comparing degradation of de-icing salts to that from urea. Jrea did not adversely affect the durability of reinforced concrete in the laboratory tests. The oncrete exposed to de-icing salt solutions did show lower resistance and greater loss of naterial (9). Tests carried out indicated that the potential for material lost with urea would ot lead to the generation of debris which could cause FOD.

Based on these results, the Canadian freeze-thaw deicing test procedure, CSA/CAN3-A231.2-M85, is recommended for assessing the durability of pavers exposed to freeze-thaw and irport deicing chemicals (10). The test requires that no more than 1 percent of material lost rom a paver when submerged in a 3 percent saline solution for 50 freeze-thaw cycles. The est inflicts stress and potential damage that can be greater than that of airport deicers. By sing this test, an added measure of durability and safety from deterioration is ensured.

Resistance to static loading - Static indentation is often a problem when aircraft with high tire ressures are parked on a hot mix asphalt surface. During hot weather, the stability of the sphalt decreases and the aircraft wheels deform the surface. Over time, these depressions in ne surface will collect water forming "bird baths" and localized ice patches in the winter. Therefore, PCC is often specified due to its ability to resist static indentation. Concrete avers provide the same resistance to static indentation as conventional poured concrete avements, provided that the underlying base and bedding sand are stable..

Adequate skid resistance - The frictional characteristics of airfields are typically measured by neans of a wheeled machine fitted with an attachment capable of depositing water beneath ne measuring wheels. For low speeds, the micro-texture of the pavement surface and the ardness of its aggregate is important to good skid resistance.

avers at Dallas/Fort Worth International Airport, Texas, were tested with Saab skid esistance testing equipment. Results ranged from 0.63 to 0.69 with 0.65 as an average result. ow and high speed (5 and 110 knots) tests were also conducted in 1992 by National Aeronautics and Space Administration (NASA) at the Langley Research Center in Hampton, Virginia. Results with a B-737 tire have shown superior skid resistance over plain PCC. kid resistance measured in the tests was 75 to 80 percent of that typically found on grooved oncrete runway pavements (11)(12) and higher than plain PCC pavement. Further, skid esistance studies on street pavements have shown pavers to have resistance equal to or better an asphalt surfaces (13).

avement markings - Concrete pavers can be integrally colored and used for pavement arkings for gear locations, lead-in lines, gate numbers, equipment, parking areas, and airline lentification. Entire bays can be colored to compliment the architecture of the airport rminal buildings. The units can also be painted with lines and numbers common to airport avement.

Fast construction and reinstatement - When compared to conventional concrete, interlocking concrete pavements can be constructed quickly. In some situations, low speed taxiways need to be constructed adjacent to active runways, or aircraft aprons need to be rehabilitated on a gate by gate basis. Concrete pavers reduce down time of runway closures in the construction of adjacent taxiways. This can save airlines and airports interruptions in operating schedules and costs. For example, the construction of three cross taxiways with concrete pavers at Dallas/Fort Worth Airport in 1990 saved the airlines over $4 million in delays when compared to conventional concrete pavement, by reducing runway closure times throughout construction (6).

Mechanical installation of interlocking concrete pavements can accelerate construction. Knowledgeable and experienced contractors have used mechanical equipment to accurately place interlocking concrete pavements in St. Augustine, Florida, and Grand Cayman Island, British West Indies. High quality construction can be maintained including conformance of surface elevations to specified tolerances and consistent paver joint widths. Daily productivity per machine and crew ranges between 400 $m^2$ and 600 $m^2$, including filling the joints with sand and compacting the pavers.

Lower reinstatement costs - Pavements in busier airports may need to be repaired rapidly due to air operations limiting access time for work. When repairs to utilities or base are needed, concrete pavers can be removed and reused. They can also be rapidly reinstated in sub-freezing temperatures; however, the bedding sand and aggregate base materials should not be frozen. Once laid and compacted, they can be put into immediate use. Unlike asphalt or PCC, the continuity of the pavement is not damaged by cuts for access to utilities. Generally, pavements with pavers can be reinstated at approximately 25 percent less cost than concrete pavements in a fraction of the time. Procedures for inspection and maintaining are included in manual.

Rapid removal of surface water and snow - Concrete pavers with chamfered edges are capable of rapid removal of surface water and are considered to be as good as, if not better than, conventional pavement in the removal of surface water. Concrete pavers can also be colored to absorb more of the sun's radiant energy to accelerate snow and ice melting.

Concrete pavers have demonstrated a record of snow removal capability by their use in airports in the United Kingdom and Northern Europe. Snow plow blades do not catch on concrete pavers, provided that each unit has a consistent thickness and that a smooth surface is achieved when installed. Smoothness is achieved by an even surface on the base material and the bedding sand. Surface smoothness is further achieved during construction with compaction and final static proof rolling with an 70 to 90 kN pneumatic tired roller.

Structural Design and Pavement Rehabilitation

Airfield pavement design in the US is based on procedures developed by the Federal Aviation Administration (FAA) (14). Other countries use or modify FAA design procedures. This ıal for concrete pavers follows the FAA procedure by developing two procedures, one for aft under 133 kN, and one for aircraft over 133 kN. The FAA pavement design method vs the thickness of the pavement courses to be proportioned and assumes that the ments will be surfaced with either 100 mm or 125 mm of hot mix asphalt. By removing sphalt layer and substituting concrete pavers and sand, the resulting pavement will be at as strong as the flexible pavement that would have been produced using the FAA design s.

is a conservative structural design approach, since dynamic load tests on concrete pavers bedding sand have shown load distribution characteristics greater than that of an valent thickness of hot mix asphalt. Pavement rehabilitation involving an inlay or overlay ncrete pavers assumes the same substitution; 80 mm thick pavers and 25 mm bedding replace 100 mm of asphalt.

cycle Costs Analysis

e United States, when FAA funds are contributed to a commercial airport project, a rement for obtaining funds is submission of a pavement life-cycle cost analysis. The term e life-cycle analysis is typically 20 years. When compared to conventional poured rete construction, the initial cost of interlocking concrete pavements can be 10-20% r. This positions them to have a lower life cycle cost.

ocking concrete pavements are new to airports, so there is little documented life-cycle for this application. The life cycle costs in the manual are reasonable projections based e authors' knowledge of costs in port and industrial pavement applications on the percent vers replaced and periodic sealing required. Because the initial costs are substantially , maintenance projections that may be higher than that in the manual will still yield life-cycle costs than PCC. Airfield pavement construction and maintenance costs, of e, are specific to a given project location. Life-cycle cost comparisons should consider , and the sensitivity of various discount rates applied to the analysis.

fications

nanual includes a guide specification for construction. It is written in FAA format, ır to that used for conventional pavements. The specification includes requirements for y control/quality assurance by the contractor for the pavers and bedding sand products, ıeir installation. Particular attention is given to assurance of the hardness of the bedding The bottle rolling test developed by Lilley and Dowson, similar to the Micro-Deval test, d to evaluate the durability of the bedding sand (15).

al Construction Details

es specifications, test standards and references, the manual includes sample construction s for the new pavement, rehabilitative overlay/inlays, and edges. These give the designer a time saving point of departure for developing construction details.

## Conclusions

The FAA has concurred with the basic approach of designing the pavement as a flexible pavement and replacing the hot mix asphalt wearing surface with concrete pavers and bedding sand (16). Current FAA policy on the eligibility of concrete pavers for funding is to consider case-by-case approval based on site specific merits. This manual contains selection criteria to aid the designer in evaluating the appropriateness and cost-effectiveness of pavers for specific situations. The manual has been accepted by the FAA to guide engineers in designing and specifying interlocking concrete pavements (17).

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