**PIARC – WORLD ROAD CONGRESS**

**AIRFIELD PAVEMENTS SEMINAR**

# Overview: The Differences between Airfield Pavements and Roads

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## ABSTRACT

Airfield pavements must facilitate safe aircraft ground operations. This in turn necessitates special design considerations in respect of several key functional requirements.
The structural design and evaluation of airfield pavements can involve wheel loads up to 28 tonnes and arranged in various multiple configurations. Surface serviceability requirements can necessitate special considerations in respect of material specifications, construction and maintenance of airfield pavements. This includes the need for high friction levels to facilitate effective and efficient braking and steering of aircraft at high speeds and in wet conditions. Aircraft are also susceptible to damage from loose materials on a pavement surface. These potential sources of damage are generally referred to as an FOD (Foreign Object Damage) hazard. Safeguarding against the FOD risk therefore necessitates airfield pavements having high surface integrity. A further complicating factor is the difficulty of gaining access to carry out maintenance on airfield pavements especially on a runway. Other special design requirements can include resistance to fuel spillage, de-icing chemicals and jet blast.
The design and serviceability requirements together with the potentially serious consequences of failure necessitate a separate approach to the design, construction and maintenance of airfield pavements. This paper will provide an overview of some of the key engineering issues, highlighting differences and synergies between airfield pavement and road works.

## KEY WORDS

Functional requirement /pavement strength/runway friction/surface evenness/surface integrity/Foreign Object Damage/Maintenance

## INTRODUCTION

An airport runway could be described as a straight wide road about 2 miles long that typically has either a bituminous or a concrete surface. Indeed with particular regard to the rubber tyre/pavement interface the design principles for the safe ground support of aircraft and road vehicles are very similar and much of the technology used in airfield pavement works is derived from highway engineering. The pavement materials are much the same as for a road, as are the methods of material testing and the construction laying equipment.  So when we are constructing a runway, why don't we simply build a short wide road?
In the early years of airfield pavement works the design parameters were very similar to that of a road and so the first paved runways in the late 1930s and early 1940s

were effectively designed as short wide roads. What subsequently changed was the development of aircraft technology. Aircraft became much larger, faster and altogether more sophisticated. This substantially changed the design parameters and brought in special considerations with particular regard to safety of aircraft operations. The following sets out some of the key facets of airfield pavement engineering and how it diverges from highway engineering with particular regard to bituminous materials.

## FUNCTIONAL REQUIREMENTS OF AIRFIELD PAVEMENTS

The pavements must facilitate safe aircraft ground operations. In order to do this they must meet certain specialist performance requirements. The following sets out the main requirements.

1. High strengths and stability to withstand the shear stresses induced by heavy wheel loads and high tyre pressures.

2. Good friction between tyres and pavement, especially in wet conditions.

3. Surface evenness to provide good rideability.

4. Robust pavement surfaces free from loose material and sharp edges that might endanger aircraft.

5. Pavements that are durable and can be economically maintained.

6. Resistance to fuel spillage and jet blast, de-icing chemicals and action of sweepers including snow and ice removal.

## NATIONAL AND INTERNATIONAL OBLIGATIONS

The advances in aircraft technology and performance together with aviation becoming a primary means of transport both regionally and globally put more focus on safety issues and the need for international standards. In 1944 the International Civil Aviation Organisation (ICAO) was formed with the signing of the Convention on International Civil Aviation by 52 countries. From October 1947 ICAO became a specialised agency of the United Nations linked to the Economic and Social Council (ECOSOC). The above Convention set out the purpose of ICAO and agreed to some key principles including the need for international civil aviation to be developed in a safe and orderly manner. The ICAO Standard and Recommended Practices for Aerodromes were first promulgated in 1951.The current Standards contain some design criteria in respect of airfield pavements. These include limits on grades and profiles and evenness also layout and friction requirements, a load classification and strength reporting system and maintenance requirements. The emphasis is on what is required rather than how it is to be achieved; consequently there is little detail in respect of structural design, material specifications, construction quality matters and maintenance systems. The contracting states to ICAO are responsible for setting and regulating standards of safety and operation within their own borders in accordance with ICAO criteria; often this involves more detailed requirements and higher standards than is set by ICAO. Hence the airfield pavement engineer in

designing, constructing and maintaining these facilities must do so with regard to National and International obligations. In the year 2000 there were 185 contracting states to ICAO.
Military aerodrome authorities generally follow ICAO Standards but with some specific additions/deviations to meet specialist requirements.

**AIRCRAFT LOADING AND PAVEMENT DESIGN**

**Figure 1. Heavy Aircraft with Multiple Wheel Undercarriage**

Transport aircraft have increased massively in size over the last 60 years and now have Maximum All Up Weights up to 400 Tonnes. In the near future All Up Weights will exceed 550 Tonnes when the Airbus 380 enters service. As shown in Figure 1, large heavy aircraft require multiple wheel undercarriages to safely transmit the load onto the pavements. With heavy wheel loads in close proximity there is a considerable amount of load interaction through the depth of the pavement and also

in the underlying subgrade, which in turn necessitates a specialist approach to the structural design, and evaluation of airfield pavements.
For military aircraft and in particular the fast jets, tyre pressures can be up to 2.5 MN/m2. When this is combined with heavy wheel loads and regular channelised trafficking, e.g. a principal taxiway, even high stability asphalt surfaces can be prone to rutting as shown in figure 2.


**Figure 2. Rutting In Upper Bituminous Layer**

Figure 3 highlights the differences in load parameters between a typical busy international airport and a typical busy fast road. For roads the load parameters are such that most Design and Evaluation (D & E) methods have been developed in terms of a standard wheel or axle load with tyre pressures less than 1 $MN/m^{2,}$ the number of load repetitions however can be very high. For airports, the aircraft types using it can vary in size considerably with All-Up-Weights up to 400 tonnes with various wheel gear configurations and single wheel loads up to 28 tonnes and tyre pressures typically between 0.7 and 2.5 $MN/m^2$. The number of load repetitions however even for busy airports is considerably less than a busy, fast road.

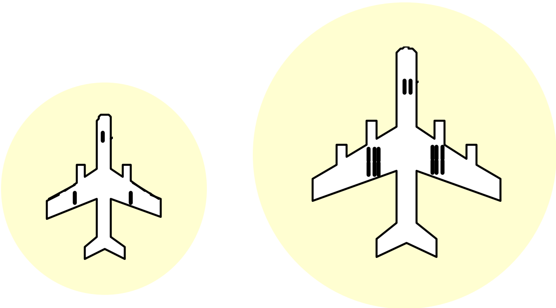
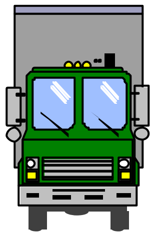
| Busy International Airport | Busy High Speed Road |
| --- | --- |
| Traffic Mix<br>Wheel Gear Configuration<br><br>Wheel Loads - 5 - 28 Tonnes<br>Tyre Pressure - up to 2.5 $MN/m^2$<br>0.5m Equivalent Departures of<br>Critical Aircraft - 20 years |  <br>Commercial Vehicles<br>Standard Wheel - 4 -5 Tonnes<br>Standard Axle 8 - 10 Tonnes<br>Tyre Pressure <1/$MN/m^2$<br>100m standard axles - 20 years |

**Figure 3. Table showing differences in loading roads/airfields**

The result of these differences in load parameters is that airfield pavements invariably need to be stronger and thicker than roads. In addition other special considerations such as the critically operational need to retain good shape and profile especially on runways and the effect of heavy wheel loads traversing joints further accentuate the differences in pavement designs between airfields and roads. Hence whilst there are a number of common processes in the development of Design & Evaluation methods for roads and airfields, e.g. pavement design theory, material properties and load test methods, there is still a need for a separate approach for the overall development, calibration and validation of D & E methods for airfield pavements.

## JET BLAST

Jet blast can seriously degrade pavements. Much is dependant on the aircraft type and the nature and frequency of operations. Figure 4 gives some data on jet blast for typical large transport and military fast jets. It can be seen that the intensity of the jet blast from military fast jets is normally much greater than for large transport aircraft; however large transport aircraft have a greater overall magnitude of jet blast.
For the pavements the critical areas for jet blast are where aircraft are operating at or near full power and are slow moving (e.g. at the start of the take-off run), or where they rotate at take-off. In these areas jet blast can over a period of time have a serious degrading effect on the permanent surfaces, even when they are well constructed. But if there are any weaknesses in the construction or maintenance in these critical areas then past experience has shown that jet blast is capable of causing massive and dramatic failure of the pavement.

| Aircraft Type | Velocity 5m from rear of aircraft | Maximum Temperature 5m from rear of aircraft |
|---|---|---|
| Military Fast Jet | > 2000 mph | > 1000°C |
| Transport/Civil | Circa 300 mph | Circa 100° |

**Figure 4. Jet Engine Blast Data for Typical Military and Civil Aircraft**

## SKID RESISTANCE

The basic concept for skid resistance is much the same for roads and airfields having regard to the common factor of the tyre/pavement interface. However several design issues are specific to airfields and roads and result in different approaches to the setting of standards.

For airfields, skid resistance on runways especially in wet weather is the most critical situation. Major design considerations include an ICAO limit on the maximum crossfall of 1.5% on principal runways (ie compared with a typical limit of 2.5% for roads), runways can be up to 60m wide and hence potentially have long, slow, surface water drainage paths, also surface texture on airfield pavements tends to be limited by the need for high surface integrity and avoidance of FOD and undue wear of aircraft tyres. Other special factors include aircraft travelling at speeds of up to 200 mph on a runway, crosswinds, the risk of skidding and aquaplaning in wet weather, the need for aircraft to be able to stop within the length of a runway and the fact that runway friction is an operationally critical issue with consequent high risks and small margins. Surface evenness for drainage purposes is also very important and there is little margin for loss of shape including structural failure of one or more layers.

Vehicles on roads are travelling at lower speeds than aircraft on runways and also surface texture is not so constrained by other functional requirements. On the other hand there are more variables on roads in terms of circumstances, e.g. geometry of the road, site lines, speed restrictions, urban areas, pedestrian crossings, junctions, roundabouts, also standards of drivers and cars.

Hence whilst the basic concept and factors affecting friction between tyre and pavement surface are very similar for airfields and roads, the rationale behind the setting of standards, including ongoing monitoring is different.

## SURFACE INTEGRITY

FOD is short for Foreign Object Damage and is a term used to describe damage to an aircraft attributed to a foreign object. The term is also used to describe a piece of debris or object, which would potentially cause damage to an aircraft.

FOD poses a great risk to flight safety in that is has the potential to cause the loss of an aircraft. Aircraft are very susceptible to damage from loose material being drawn into engine intakes. Loose materials or sharp pavement edges can also damage tyres (ie one of the main FOD problems), hydraulic systems / undercarriages and aircraft skins.

Pavements that ravel, crack or spall are a primary FOD risk. Perhaps the nearest risk on roads is that of windscreen damage from loose stones, however there is a considerable difference in order of magnitude of the risk. Consequently airfield pavements at airports used by modern jet aircraft have a more onerous failure criteria in respect of surface integrity compared with roads.

## ACCESS FOR MAINTENANCE WORKS

Getting access to carry out maintenance work and especially major restoration works on runways and primary taxiways on a busy airport is normally very difficult. It isn't feasible on runways to use cones and contra-flow systems as for roads. Hence unless the airport has multiple runways and primary taxiways that aren't fully utilised, it is sometimes a case of carrying out maintenance works at night and in winter. This usually entails daily handovers for aircraft operations and as a consequence puts a special focus on selection of materials, specifications, methods of construction and quality control having regard to the various functional requirements and critical safety issues. The difficulties in getting access for and carrying out such major maintenance works makes durability of airfield pavement surfaces a key issue. This in turn comes back to quality of materials and construction.

## INTERACTION OF FUNCTIONAL REQUIREMENTS AND IMPACT ON THE DESIGN, SPECIFICATION AND MAINTENANCE OF AIRFIELD PAVEMENTS

General.

The combination of the above requirements result in a different set of dynamics for the design, construction and maintenance of airfield pavements compared with roads. Figure 5 sets out the interaction of the main issues affecting airfield pavement engineering and also aspects that are common with road technology.

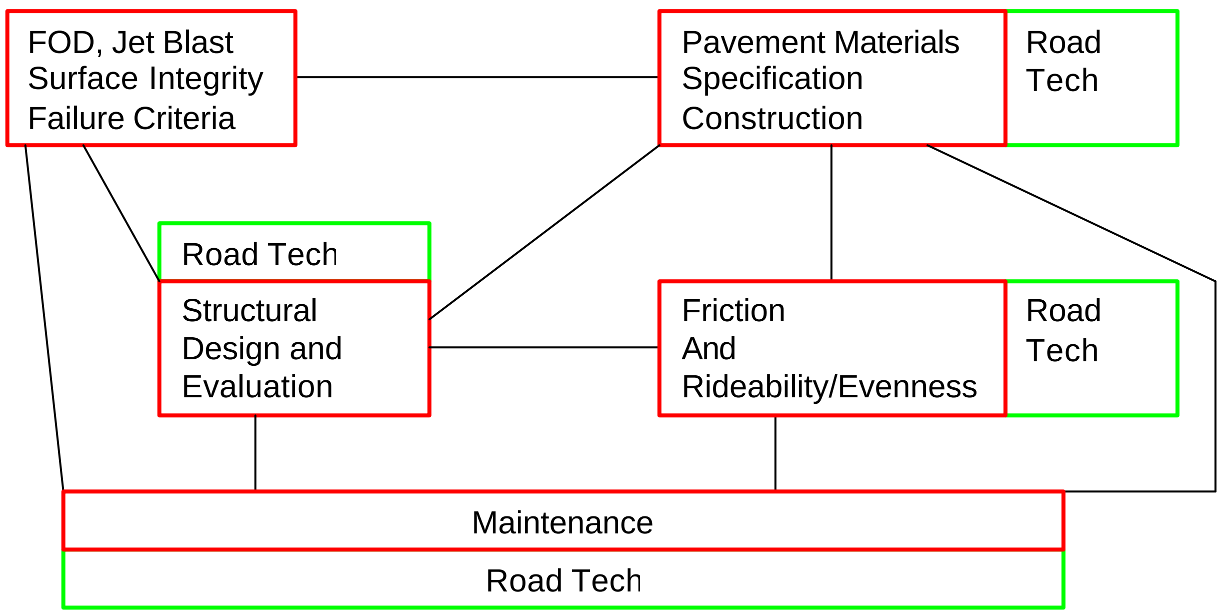



**Figure 5. Interaction of Functional Requirements**

Design

There are some important common aspects on design and evaluation of airfield pavements and roads. These include material properties, design theory and load testing/analysis. However there are also major differences. As previously discussed the loading regimes are somewhat different and also the failure criteria in respect of surface integrity. Another difference is the need having regard to the critical issue of friction, evenness and drainage characteristics, to ensure a very low probability of future loss of shape due to consolidation or settlement of the pavement. Hence it is necessary to adopt a separate approach to the development and calibration of Design & Evaluation methods and the setting of construction practices for airfield pavements.

Maintenance.

There are many facets of maintenance that are common to airfield pavements and roads, including materials, construction methods, the different types of pavement defects and the procedures for investigation and measurement of. However there are also some significant differences as follows: -

- The onerous surface integrity requirement and the management of the FOD risk has a major influence on the maintenance strategy including inspection and sweeping regimes, intervention points for maintenance and the need for a conservative approach to the development and adoption of new repair techniques.
- The difficulties in getting access to carry out maintenance works affects the approach to design and evaluation of pavements and the construction practices.
- Operationally critical criteria in respect of friction and evenness for airfield pavements necessitate a specialist approach to periodic friction testing, evaluation and remedial works.
- The friction criteria on runways are very sensitive to drainage characteristics. This in turn can limit the options for carrying out surface repair works.
- The high disruption costs of carrying out maintenance and restoration works puts a special focus on the need for durable pavement surfaces and hence specifications for surface materials.

Pavement Materials

Airfield pavements are in principle much the same as for roads. However there are several key design and maintenance requirements that put a special focus on material specifications for airfield pavements as follows:

- At busy civil airports and military aerodromes airfield pavements must have high surface integrity, high durability and low maintenance needs.
- The pavement structure must have a very low probability of settlement and consolidation and dependant on the types of aircraft that are to use it, it must also be able to withstand very high tyre pressures. This affects the overall construction concept and especially the need for the upper layers of the pavement to have a high stability and resistance to rutting.
- Runways must have good rideability and high skid resistance characteristics. This can conflict with the requirements for surface integrity and durability.

Achieving a suitable balance, which ensures that requirements are fully met, is a very special consideration in determining specifications for runway surfacing materials. For runway ends additional special design considerations may apply in respect of jet blast and fuel spillage dependant on the nature, type and frequency of aircraft operations; this particularly applies to military aerodromes.

- For taxiways, the friction and rideability requirements are much less onerous than for runways. Also in these areas there are normally less constraints on the maintenance regime. However the more channelised trafficking on taxiways puts a special focus on rut resistance in these areas especially in respect of the upper layers of the pavement. Resistance to mechanical abrasion from turning aircraft is also important.
- For aprons the critical issues are resistances to indentation by standing aircraft with high tyre pressures, also resistance to fuel and oil spillage and to damage from aircraft ground equipment. Dependent on the frequency and type of aircraft operations, these requirements are likely to severely restrict the choice of materials.

In conclusion much of airfield pavement engineering feeds off road technology but a combination of different design parameters, some high risks and small safety margins necessitate a different approach to the design, construction and maintenance of airfield pavements compared with roads. Furthermore in a high risk business there is inevitably a considerable amount of conservatism and consequently a very measured approach to innovation.