Airfield uses of asphalt

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1. Introduction

Most of the world's paved roads are surfaced with asphalt, which gives good performance and durability under the most heavily trafficked conditions. Asphalt mixes are also widely used in the construction of hard standing and parking areas for both light and heavy vehicles. They are therefore eminently suitable for use in the construction and surfacing of access roads, perimeter roads and vehicle parking areas on airfields.

Asphalts give good performance and durability under the wide range of climatic and traffic conditions. More and more often asphalts are used for industrial areas or for specific applications, such as base courses for railway tracks. Asphalt is also widely used in airport construction, although this usage is not always recognised. A recent survey resulted in the following data on its usage on airfields:

Table 1

	Total of airports	Asphalt pavement	Concrete pavement	Others
All types	362	226	70	66
Runways > 3000 m	126	58	37	31

This shows that a majority of airports are in fact constructed with asphalt pavement. This document gives information and examples about the type of asphalt used. In airports, there are different areas such as runways, taxiways, aprons and parking areas. For each, the required specifications could be different particularly for surface courses. For parking and aprons, good resistance is needed to puncturing, to fuel and to chemical agents. For other surfaces, a good skid resistance is necessary. Asphalt mixes provide the answer to these various requirements.

In addition to these uses, asphalt mixes are widely employed in the surfacing of runways and aircraft handling areas on a wide range of airfields, from international airports regularly used by the heaviest airliners, through military airfields carrying high performance jet aircraft and the smaller domestic airfields regularly used by light or medium-sized aircraft to the smallest private airfield used by light single or twin-seat aircraft.
In Europe, the construction and surfacing of military airfields is the responsibility of the each nation's Defence Ministry, whilst responsibility for the civil airports usually rests with the civil or municipal aviation authorities. These organisations often have their own standard specifications for this type of work.

2. General considerations

Without hard paving, access may be difficult to the airfield, flying may be restricted in inclement weather or the facilities may not come up to the minimum standards required by the regulatory authorities for passenger carrying. The following areas on a typical airfield are likely to require hard paving:

- runways;
- taxi-ways providing access to runways;
- aircraft parking, re-fuelling or servicing aprons hanger floors;
- car, bus or commercial vehicle parking areas;
- access roads.

In each of these areas different considerations apply. For example, runways require good skid-resistance and surface water drainage for good braking while avoiding aquaplaning, an even surface regularity to ensure passenger comfort and minimum risk of damage to delicate electronic components and adequate strength to support the high wheel-loadings of modern aircraft. Where jet-engined aircraft operate, freedom from loose particles on the surfacing is an additional, essential requirement to avoid the expensive damage that can be caused to jet engines from ingestion of foreign objects (known as Foreign Object Damage or FOD).

For aircraft parking areas the main requirement is adequate stability under high wheel-loadings; for paved areas where aircraft will undergo re-fuelling and servicing, the principal considerations are adequate stability under wheel-loads and heavy point loads from maintenance machinery as well as good resistance to oil and fuel spillage.

Asphalt mixes can be very suitable for some of these applications but less suitable for others. Proprietary surfacings have been developed for situations where traditional asphalts are likely to be unsuitable. Apart from cement/polymer-grouted asphalts a number of proprietary thin asphalt surfacing treatments as well as Stone Mastic Asphalt (SMA) have been developed which may well be suitable alternatives.

The various situations are dealt with in more detail in the following notes.

2.1 Runways and taxi-ways

Runways and taxi-ways both need to be constructed with sufficient strength to carry the moving aircraft but from the surfacing point of view the difference between the two is that runways require a higher degree of resistance to skidding and aquaplaning in view of the higher speeds involved. One means of achieving the latter, employed on many runways in Europe, is to use a porous open-graded surface course known as porous asphalt or 'friction course' as the running surfacing. This acts as a drainage layer to prevent surface water adversely affecting aircraft tyre grip on the surfacing in wet weather.

Beneath friction course a strong impervious binder course of, for example, asphaltic concrete or an impervious existing surfacing is required, laid to adequate falls.

When resurfacing work is being undertaken on runways, it is essential that the existing surfacing is of good regularity and laid to adequate falls or is made so by applying a regulating layer if a porous surface course is to be applied. This is to ensure that water is not retained in the new surfacing to lead to heavy ice formation in winter.

Where relatively light aircraft are involved standard road surfacing materials may provide good durability and adequate performance.

2.2 Hanger floors

Hanger floors can be subjected to extreme severity of use in the form of heavy point loadings and regular spillage of grease and oil. This can give rise to serious damage to normal asphalt surfacings and these are therefore not recommended for this type of flooring. Special proprietary materials, e.g., epoxy asphalt or sand/cement/polymer grouted asphalts, or alternative forms of construction such as concrete, will be more appropriate in such circumstances.

2.3 Aircraft parking, re-fuelling and maintenance areas

Where re-fuelling or maintenance operations are to be undertaken, the same considerations apply as for hanger floors. However, where areas are simply intended for aircraft parking, high-strength design asphalt mixtures, particularly high-stone content asphalts have been used for the purpose and should prove satisfactory. Where a degree of oil resistance is required asphalt mixes containing proprietary oil-resisting binders should be considered. Where the larger aircraft are involved, epoxy asphalt may well prove the most suitable surfacing.

2.4 Vehicle parking areas

The thicknesses and types of asphalt used in the various layers of the construction of vehicle parking areas need to be carefully designed with due consideration to the high loadings from large numbers of parked vehicles, higher axle loadings from buses etc. serving those parking areas, and the likelihood of high stresses from tightly turning and manoeuvring vehicles.

2.5 Access roads

The type of construction to be adopted for access roads on airfields will depend on the severity of their use. For roads carrying heavy traffic, the designs specified by national highways' agencies in their "Pavement Design Standards" will be appropriate. Where relatively light use is to be encountered, the design guidelines used by local highway authorities for housing estate roads etc. might well be appropriate.

[N.B. Any footways on airfields can also be constructed according to these local design guidelines).

2.6 Laying considerations

Laying of asphalts on airfields generally follows the same methods and procedures as in the case of roads. One point to be borne in mind when laying porous, open-graded surface courses on runways is that longitudinal joint painting will form a barrier to water draining sideways through the material and could thus reduce its effectiveness. Such painting should therefore be avoided and other methods for forming longitudinal joints should be employed, i.e. joint heating or echelon paving.

3. Typical Examples

In the annex typical examples of airfield uses from different EAPA members are shown, from:

- Denmark
- Finland
- France
- Germany
- Italy
- Norway
- United Kingdom

4. Publications

Other publications dealing with uses of asphalt are available from EAPA. A full list of these publications may be obtained from the EAPA website: www.eapa.org

Annex

Typical examples of uses of asphalt on airfields from various EAPA members are given here after.

Experience from Denmark

1. Design

In Denmark there are no national standards in this area. The structural design period is normally 20 years. In most cases an analytical - empirical design method is used, where the load is determined from the wheel contact pressure, the wheel configuration of the relevant planes and the number of movements. The loads from the planes are determined from manuals from e.g. the Boeing Company.

As mentioned an analytical - empirical design method is used with the software "APSDS". Here the spreading of the load from the wheels (wander) around the ideal path of the plane is included in the calculations.

2. Structures

For the major airports in Denmark cement concrete is not used any more for parking areas. Now semi – flexible pavements (SFP) are used. Typical airport applications of SFP are stand gates, de-icing stands, start-up pads, taxiways and other heavy loaded areas.
Examples of SFP are Rodal, Stabiflex and Densiphalt.

Runways

Normally a traditional asphalt design is used, app. 400 mm of asphalt in total, placed on unbound gravel. The hardest binder used is B 60, and the concept of High Modulus Asphalt is not used. The surface course is normally Dense Asphalt Concrete or Stone Mastic Asphalt, although the very thin overlays are used more and more. It is very important to select the correct aggregate, as the skid resistance is very important.

On the smaller airports Open Graded Asphalt Concrete is also used.

Taxiways

Normally a traditional design is used; 230 - 280 mm of asphalt in total placed on unbound gravel or crushed cement concrete. This crushed cement concrete is taken from old aprons, which has to be replaced.

The surface course is Dense Asphalt Concrete or Open Graded Asphalt Concrete with modified bitumen. Mainly SBS - polymer is used. In some cases stone mastic asphalt is used.

Aprons

In the past cement concrete was used, but not any more. In the areas where the planes are still rolling 40 - 50 mm of SFP (Rodal, Stabiflex or Densiphalt) is used. This is placed on a binder course with B 60. The total asphalt layer including the composite pavement is 220 - 230 mm.

In the areas where the aircraft are parked 90 - 100 mm of SFP is used, on app. 80 mm of high modulus binder course with a modified binder corresponding to Colflex 40 S.

An example from Kastrup airport on very heavy loaded areas is:

Semi-Flexible Surface Course	100 mm
High Modulus SBS Modified Asphalt Concrete[1]	90 mm
High Modulus Asphalt Concrete[2]	60 mm
Reclaimed Crushed Concrete[3]	250 mm
Sub-base	250 mm
Sub-grade assumed to exhibit CBR minimum	7 %.

1. High Modulus SBS Modified Asphalt Concrete is designed with 100% crushed granite aggregate and hard asphalt cement modified with high content of SBS polymer (Colflex 40 S).
2. High Modulus Asphalt Concrete is designed with hard asphalt cement.
3. Crushed granular base can be used as alternative to reclaimed crushed concrete.

3. Mixtures and composition

Generally the same types of asphalt base and surface courses are used in airports as on the roads. They are specified according to the Danish norms for road construction materials. These norms are based on composition demands. In some cases where consulting companies are involved the specification is modified to some extent. This is also the case for military airports.

The very thin surface courses (VTW) are some times used on taxiways, i.e. at Kastrup airport. The Danish specification requirements for these layers are:

The laying shall be done in one working procedure with a paver with an integrated spray bar for emulsion. The asphalt shall be placed on an unbroken film of emulsion.

Requirements for the emulsion:

VTW type, max aggregate Size	VTW 6	VTW 8	VTW 11
Residual binder on the surface	> 500 g/m^2	> 600 g/m^2	> 700 g/m^2

The binder in the emulsion has to be modified with a polymer of the elastomeric type (SBS or similar). The requirements for the open graded asphalt are:

VTW type, max aggregate Size	VTW 6	VTW 8	VTW 11
Sieve curve,			
Max agg. Size:	5,6 mm	8 mm	11,2 mm
Passing:			
5,6 mm sieve	-	< 55 %	< 45 %
2 mm sieve	< 40 %	12-30 %	10-30 %
0,075 mm sieve	3-12 %	3-12 %	3-12 %
Volume bitumen/Volume aggregate	≥ 0,140		

VTW type, max aggregate Size	VTW 6	VTW 8	VTW 11
Minimum amount of asphalt	25 kg/m^2	35 kg/m^2	45 kg/m^2

The Semi-Flexible Pavements (SFP), consists of a joint-less surface course composed of an open-graded asphalt concrete containing 25-30% voids, which are filled with a special slurry grout. The slurry grout is highly fluid and is able to penetrate the voids in the open-graded asphalt concrete. The fast curing grout locks the asphalt concrete in a fixed structure, which is resistant to deformation, abrasion and attack by fuel and chemicals.

The open-graded asphalt contains app. 4 % standard bitumen, some filler and fibre to achieve a sufficient thickness of the bituminous mortar on the coarse aggregates. There are different types with maximum aggregate size of 8 mm, 11 mm, 16 mm or 20 mm.

The joint-less Semi-Flexible Pavement concept provides the airport with several advantages over the conventional concrete slab pavement.

- Flexible when redesigning airport facilities. Activities, which require breaking up part of the pavement, are highly facilitated by the ease and speed of remedial works provided by the semi-flexible technology.
- Fast curing of SFP is very important for the efficiency of the airport.
- Elimination of joints is important due to environmental requirements and restrictions concerning penetration of any spillage to the ground.
- Friction can be improved by proper treatment of the new SFP surface.
- Better economy (The price of SFP compared to a 300 mm concrete slab pavement is app. 50%).

Experience from Finland

Only asphalt pavements are used in Finland for runways and taxiways on airfields, but where the aircraft are standing for longer times, either concrete- or composite-pavements are used.

1. Smaller airfields

On the smaller airfields the normal asphalt construction is :

top layer	asphalt concrete	AB 16/ 100 (40 mm) (=AC 16)
base layer	base course asphalt concrete	ABK 20-25/ 150 (60 mm)

2. Main airfields

The biggest recent airfield contract in Finland was the extension of the Helsinki-Vantaa airfield, with a third runway being built. The asphalt job was the biggest asphalt job ever undertaken in Finland. In total, 380.000 tons asphalt were laid during three summers (2000 – 2002). The job was carried out by Lemminkäinen Oyj. The following asphalt structures were laid:

2.1 Runways

surface course	AB 16/100	(B 100/150)
binder course	ABS 20/120	(B 100/150)
Bearing course	ABK 25/150	(B 160/220)

The unbound base layers are designed to allow the biggest airplanes to use the airfield. In some areas an other bound base layer (forth layer) is required.

2.2 Taxiways

1. Are built with the same structure as the runways
2. The bearing course is in some places made with two layers of ABK 25/150 (B 160/220)
3. In holding positions the binder course is partly built with a stiffer mix. The mix stiffness was increased by addition of gilsonite. Hydrated lime ($Ca (OH)_2$) was used in some places where tensile strength was needed and adhesion problems were expected.

2.3 Ground water protection

The Helsinki fresh water supply tunnel is situated under the new runway. This means that large ground water protection measures had to be taken on the airfield. Therefore approximately 38.000 tons of impervious dense asphalt concrete (ABT) were laid over the tunnel in order to prevent the de-icing chemicals (acetates) penetrating into the tunnel. The "slopes" beside the runways were therefore built as "basins" laid with the following impervious structure (from the bottom):

bearing course, unbound crushed aggregates (200 mm)
dense asphalt concrete, ABT 16/120 or ABT 20/100-150
dense asphalt concrete, ABT 12/100 or ABT 20/100-150
bentonite mat
drainage grave l (300 mm)
geotextile
moraine filter (0,3-1,3 m)
geotextile
bearing coarse, unbound (200 mm)
earth for normal grass covering

3. General requirements

The top layer asphalt used on practically all airfields is quite coarse asphalt concrete, AB 16. It is designed to have a void content of 2 %. The mix is very near to international standards. A Marshall-stability of 8 kN is required for the trial mix, while 6,75 kN is the minimum stability requirement for the pavement. The skid resistance should be greater than 0,7, when measured with Skiddometer BV 11 at 65 km/h with a 1 mm film layer of water.

4. Maintenance

The main airfields are repaved approximately every 15th year. The main reason for repaving is the weathering and ageing of the binder. In some places frost damage can lead to shorter repaving cycles. As a maintenance procedure, slurry seal, containing max 4 mm aggregates, is used, mainly at smaller airfields, when the surface is weathered.

The joints between the asphalt-lanes are often being refurbished after 10-12 years. A 1 m wide remixer is often used for that purpose. Cracks in the pavement are immediately filled with joint sealants (hot poured SBS-modified bituminous sealants).

5. Chemical resistance

De-icing chemicals, like glycol, are used at the stands, which are often paved with other materials than asphalt.

In Finland a lot of de-icing chemicals are used in order to keep the runways free of snow. In the past technical urea was used, but today mainly biodegradable salts like acetates and formiates are used. Until now there have been no problems with de-icing agents, but in summer 2001 problems arose on two northern airfields, which were paved in year 2000. The asphalt on airfields developed a soft binder-rich, sticky surface with low friction. The reason for this phenomenon has not been found – the formiate used as de-icing chemical is suspected to be one reason for the damage. The airfields were repaved the following autumn by laying a new top layer with polymer-modified asphalt concrete. A SBS-modified binder was used.

6. Stands

On aircraft stands other materials than asphalt is used. The following materials have been used:

- concrete (> 200 mm)
- roadstones on top of base coarse asphalt
- composite pavements (like Densiphalt)

7. Terminology

AB 16/100	Asphalt concrete	AC 16 (100 kg/m²)
ABK 20	Asphalt concrete, base layer	ACba 20
ABS 20	Asphalt concrete, binder layer	ACbi 20
ABT 16	Dense asphalt concrete (imperveous)	ACd 16

Experience from France

1. General

Asphalt pavements are widely used in France for airports. Depending on traffic and load, asphalt is used for runways, aprons and parking areas. For major airport such as Roissy or Orly, generally cement concrete is used for new pavements, but for the reinforcement of the runways asphalt is preferred.

2. Design

The design of airfield surfaces in France and the method used are described in the following notes, which show how the load is determined, the effect of the number of aircraft movements and the method used for determining the thickness of the structure.

2.1 Number of movements

In France, the design life span is 10 years for airfield surfaces. The airport authority will generally determine and specify the number of aircraft movements. The heaviest aircraft permitted for the airfield is generally used for the design, but another, more complicated method is sometimes used and consists in determining the equivalent traffic per day according to the total number and types of aircraft anticipated.

2.2 Load determination

The French airfield technical department (Service Technique des Bases Aériennes) has written a special document in which the loads of all types of aircraft in service can be found. Those values are then used for design.

According to the required design (runway, taxiway, parking areas), different overload coefficients are taken into account and some examples are given below (table 1).

Table 1

Site	Coefficient
Parking	1.2
Runway	0.8 or 1
Taxiway	1

2.3 Method

The design of airfield pavements in France employs the CBR method, the load of aircraft and the number of aircraft movements. With these different data, the required pavement thickness for an untreated granular material is determined. Then, this total thickness is broken down for other materials with different coefficients as described in Table 2.

Table 2

Materials	Equivalent factors
Asphalt for wearing course	2
High modulus asphalt concrete for wearing course	2.5
Asphalt for base course	1.5
High modulus asphalt concrete for base course	1.9
Cement bound material	1.5
Emulsion bound material	1.2
Untreated gravel	1

This means for example, that 300 mm of untreated gravel is replaced by 150 mm of asphalt for wearing course.

Currently, new methods are being developed to take into account the actual performance of the products and new types of aircraft tyres. However, there is limited information available about these methods to date.

3. Structures

Generally speaking, for new structures, cement concrete is used for aircraft parking areas but this will essentially depend on the aircraft load. For runways and taxiways, asphalt is generally applied. Within the structure, different layers are laid:

- surface course: from 50 to 80 mm thick. Binder is usually 'straight-run' bitumen but sometimes is modified. The latter is often used for big international airports such as Roissy where the runway has been reinforced with high modulus asphalt concrete for the binder course and high modulus asphalt concrete with PMB as the surface course.

- Base and/or binder course(s): from 100 to 250+ mm thick. Binder is also unmodified (but sometimes hard grade) bitumen. The grade of bitumen also depends on the climatic conditions; for example 35/50 grade binder is frequently used.

- Sub-base: either untreated gravel or lime and cement stabilised soil.

The structural thickness depends on the weight of the aircraft, the number of aircraft movements and/or the design life of the pavement, and the bearing capacity of the underlying soil. The total thickness generally ranges from 500 mm to 1000 mm.

For rehabilitation contracts, the structural thickness will depend on the bearing capacity of the old runway and the traffic. Asphalt is generally used and the total thickness of the repair/reinforcement will range from 50 to 200 mm. PMB is often used for the surface course.

4. Mixtures and composition

4.1 General

For the supply and paving of asphalt on French airfields, the general French asphalt standards are applied. For the lower layer mixtures, standards from road construction are used, but there is a specific National standard for airport surface course, although there is sometimes the opportunity to use the standard for road asphalt surface course depending on the circumstances. In the French approach, asphalt has to meet performance-specified requirements, as indicated in the following tables:

4.2 Required specifications for base and binder courses

For the asphalt base layers, examples of requirements are given in table 3:

Table 3

Tests	AC for base course	HMAC for base course
Wheel tracking	< 10 %	< 8 %
Complex modulus	> 9300 MPa	> 14000 Mpa
Fatigue	> 80 10-6	> 130 10-6

(HMAC stands for High Modulus Asphalt Concrete for base course)

These requirements must be met regardless of the type of binder used. The thickness of each layer ranges from 80 to 150 mm depending on the grading.

4.3 Surface course

In France, generally speaking, the standards for road construction are applied for the surface course, but the following guidelines have also been developed (see table 4).

Table 4

	Medium level performance	Heavy-duty performance
Runways	Airport asphalt concrete	HMAC for wearing course or concrete or percolated asphalt (see 5 below)
Taxiways	Airport asphalt concrete or traditional asphalt concrete	HMAC for wearing course or type 3 for airport asphalt concrete

In table 5, performance requirements for airport asphalt concrete and traditional asphalt concrete surface courses are compared:

Table 5

Tests	Airport asphalt concrete			Traditional asphalt concrete		
Type	**1**	**2**	**3**	**1**	**2**	**3**
Water sensitivity	>0.8	>0.8	>0.8	>0.75	>0.75	>0.75
Wheel tracking	<15 %	<10 %	<5 %	<10 %	<7.5 %	<5 %
Complex modulus in Map	> 5000	> 5000	> 5000	>5500	>7000	>7000

Fatigue	> 130 10-6	> 110 10-6	> 100 10-6	> 100 10-6	> 100 10-6	> 100 10-6

It can be seen that the main difference between these two asphalt mixes essentially lies in the complex modulus figures. Layer thickness ranges from 40 to 90 mm depending on the grading.

5. Other

In the French national standard for airport asphalt mixes, information is sometimes given about requirements for transverse joints and for skid resistance. For particular sites, such as aprons or parking areas, percolated (grouted) asphalt is often used as mentioned above but there is not a standard for it. This product consists of an open graded asphalt concrete containing about 25 to 30 % of voids which are filled with a special slurry grout that is highly fluid and is able to penetrate the voids in the open graded asphalt concrete. The fast curing grout locks the asphalt concrete and provides the material with good resistance to deformation, abrasion and fuel and chemical attack.

It is possible to increase the resistance of this product further by increasing the quantity of the grout used. That requires a very high void content in the porous asphalt. The layer thickness of this type of material is between 40 to 60 mm. With a thicker layer, it is difficult to fill the voids in the asphalt satisfactorily.

For fuel resistance, there are special asphalt concretes from different companies but there are not yet standards for these materials.

6. Recent works

In summer 2002, the reinforcement of runway 2 at Roissy was carried out. This runway was of cement concrete slab construction. The solution for this work was the following from the bottom to the top:

- sand asphalt as SAMI (Stress Absorbing Membrane Interlayer), 20 mm thick
- high modulus asphalt concrete for base course, 90 mm thick
- airport asphalt concrete for wearing course, 60 mm thick.

Modified or special binder was widely used for the different asphalts. The work span in the contract was only 15 days.

7. Conclusions

The main advantage of asphalt on airfields is the fact that early trafficking is possible, enabling laying operations to be carried out at night with the runway remaining open to aircraft traffic during the day. According to the type of use specified, there are now many possibilities of employing asphalt with sufficient resistance for airfield surfaces.

Experience from Germany

1. General

For mixing and laying of asphalt on German airports, in general the standards and regulations from road building apply. Additional or stricter requirements are given in the “References for the asphalt construction for airports”, last updated in 1991 but with a new version expected in 2003). This covers both large and heavy trafficked commercial airports as well as smaller airfields. Since airport operating companies are usually private companies (owned by state, cities and others) they are free to make any alterations they want, but they usually follow these references. Planning and tendering is usually done by consulting engineers who mostly use the experience of an asphalt laboratory such as those at universities or testing labs.

2. Determining loads

As an average some load numbers are given in the following table 1. For airports with extra high or extra low loading, alterations must be made.

Table 1

Area	Number of loads	Push factor	Horizontal forces
Head of runways and taxiways	100.000	1.2*	Braking: 0.3 times static load 0.6 times in emergency
Middle part of the runway (approximately 12.5 m on both side of the middle line)	10.000	1.2	Braking: 0.3 times static load 0.6 times in emergency
Side areas of the runway	10	1.2	Braking: 0.6 times in emergency
Parking areas	10.000 **	1.2	Braking: 0.3 times static load 0.7 times statistical load from sideway forces of the plane’s front wheel

*up to 1.5 because of weight movement onto the outer wheel in curves
** dynamic extra load for running turbines included

3. Designing

The designing of the asphalt layers is usually done by either empirical methods or theoretical programs like BISAR, etc. For the empirical methods, the four US methods

- CBR method (Californian Bearing Ratio)
- FAA method (Federal Aviation Administration)
- US Navy method and
- Mc Leod method

are recommended.

4. Asphalt Layers

4.1 Base layers

For the asphalt base layers the standard for the base layer for heavy trafficked roads is applied with regular bitumen 70-100 or 50-70. The minimum binder content has been set 0.4 % higher than in the road standard in order to ensure durability and good adhesion of the bitumen to the aggregates.

4.2 Surface courses

The surface course is always at least 40 mm thick. For runway, taxiways and parking areas, either asphalt concrete 0/11 S or 0/16 S or stone mastic asphalt 0/8 are recommended, all with bitumen 50-70 for commercial airports, but commonly polymer modified bitumen PMB 45 or 65 is used. Again, for the asphalt concrete the minimum binder content is 0.3 % higher than in the road building standard, the void content 1 volume % lower. The requirements for the stone mastic asphalt are the same as in the road standard.

For the surface course a test section has to be laid, minimum 2.5 by 100 m for measuring friction at a speed between 80 and 100 km/h.

4.3 Binder course

Between surface and base courses usually a binder course of 40 to 80 mm thickness is normally expected. Again, the road standard applies with a slightly higher minimum binder content, but the same maximum void content.

5. Other

The “recommendations” also contain a chapter about reinforcing airfields with asphalt layers.

Experience from Italy

1. General

In 1997, the Italian government launched a program for civil airports. Rome and Milan airports were granted the main support, however many other Italian airfields have also been financed.

Moreover, in recent years, the Italian government has significantly changed the airport regulations. The airport is now viewed as a company with full responsibility for its operation and management. In Italy, there are 102 Civil airports and 15 of them have traffic of more than a million passengers per year, while 41 of them have more than 100.000 passengers per year.

2. Design

In Italy there are no national standards in this area. The structural design period is normally 20 years. Both analytical and empirical design methods are used.

When analytical design is used, generally Elastic Layer Programs are used to predict airfield pavement response to gear loads. The load is determined by the wheel contact pressure, the wheel configuration of the relevant planes and the number of movements. The spreading of the load from the wheels (wander) around the ideal path of the plane is included in the calculations.

When empirical design method is used, generally the FAA method is used.

3. Structures

All the runways and taxiways of Italian airports have asphalt concrete pavement. Normally a traditionally asphalt design, 300-350 mm of asphalt in total are placed on unbound or stabilised crushed sub base. In many cases, semi rigid structures are used, with 200-250 mm of asphalt in total placed on cement bound base and crushed sub base. The surface course is normally Dense Asphalt Concrete. Very often modified bitumen is used.

Most runways have the heads in cement concrete and most aprons have cemented concrete pavement.

The pavements of Italian military airports were originally built with cement concrete slabs. Starting from the seventies, consequent upon the increased aircraft speeds, better evenness of pavement surface was required, so most cement concrete pavements were overlaid with bituminous layers. More than 200 mm of bituminous concrete and, more recently, modified bitumen and geotexile, are used to Mixtures and Composition

There are no Italian specifications for civil airport construction materials. Generally the same types of asphalt concrete are used in airports as on the roads.

In the military airports, generally 80/100 bitumen is used in each bituminous layer (base, binder and surface courses). For the surface course, the following parameters are considered:

- Bitumen percentage = 5-7 %
- Residual voids = 3-5%
- Marshall stability = 1000 daN
- Marshall flow = 2/4 mm
- Marshall stiffness > 350
- Aggregates: Los Angeles > 18
  Flakiness index < 20

Also in military airports, the use of harder bitumen with modifiers is also considered.

Recently, in Verona and Aviano military airports, pavements were completely reconstructed and repaved. PMAs (polymer-modified asphalts) were used in both cases. The characteristics of the binders used are shown in table 1.

Table 1

Airport	Verona	Aviano
Penetration at 25 °C in 1/10mm	65	55
R and B softening point in °C	96	104
Fraass breaking point in °C	-18	-18
Residual penetration after RTFOT in %	72	69
Viscosity at 160 °C in poise	6	9
Stability (3 days at 180°C) in °C T/B	95/94	103/101
Modifier	SBS	SBS

In Verona, more than 100.000 m² were repaved after removing about 95 mm of the pavement. A binder and In Aviano, about 150.000 m² were repaved, in this case only a 50 mm surface course was added.

Experience from Norway

The Civil Aviation Administration (CAA) has undertaken a thorough investigation to set national standards for constructing airfields in Norway. Norway, with a population of only 4 million, operates more than 50 airports of which CAA is responsible for 44. Construction of the new main airport for the Oslo area at Gardermoen is based on these new standards.

Before the construction period started both the Norwegian Asphalt Contractors Association and the Norwegian Portland Cement Concrete Society did some extensive work to argue for their solutions of pavement design. Even the construction of full scale tests, located at the new main airport, were established in order to investigate and evaluate 10 different pavement constructions by simulating heavy aircraft take off weight (TOW).

Asphalt versus concrete considerations led to an intense discussion, and a survey of other main international airports was carried out. The results are shown in table 1.

Table 1

Country	Total	Asphalt	Concrete	Asphalt/concrete	Unknown
Canada	53	37	1	12	3
Denmark	20	16	1	3	
Germany	23	8	11	3	1
France	62	26	18	4	14
Norway	19	15	1	3	
Spain	20	13	3	4	
Sweden	11	9	1	1	
UK	60	39	6	15	
USA international	94	63	28	3	
USA Total	388	278	61	49	
Summary	362	226	70	48	18
Percentage		63	19	13	5

Data on the number of airports with runway length > 3.000 m is given in table 2.

Table 2

Country	Asphalt	Concrete	Asphalt/concrete	Unknown
Canada	11	1	6	
Denmark	3		2	
Germany	1	5	1	1
France	5	6		1
Norway			1	
Spain	9	3	4	
Sweden	1	1		
UK	3	1	15	
USA international	25	20		
Summary	58	37	29	2
Percentage	46	29	23	2

All available design methods, except the practice of Transport Canada, gave different results compared to the method that has been used in Norway, but results from the full scale test section confirmed the

Canadian/Norwegian practice. The tender documents were completed with two alternatives, PCC and asphalt, based on a sub soil with CBR 15 and the following constructions:

PCC: 230 mm sub grade gravel CBR > 30
400 mm crushed rock CBR > 100
370 mm PCC

Asphalt: 490 mm sub grade gravel CBR > 30
400 mm crushed rock CBR > 100
150 mm asphalt concrete/Split Mastic Asphalt

Based on the offer from the bidding process, the life cycle costs for the two alternatives were for 7 % interest rate and 30 years service life: 221 NOK/m² for asphalt and 377 NOK/m² for cement concrete (based on prices in 1995).

Gardermoen is one of the better construction sites in Norway, containing non-frost susceptible materials with very high initial CBR values. With the exception of the airports at Roros and Spitsbergen, Gardermoen has the most severe climatic conditions of the airports in Norway. The pavement surface temperature is expected to vary between –35 °C and + 60 °C. With this background, Gardermoen became the first airport in the world with binder specifications based on results from Strategic Highway Research Program (SHRP).

Experience from United Kingdom

1. General

This document deals with the use of asphalt in airfields in various applications, including runways, taxiways, hangar aprons, and service roads, on various recent contracts in the UK. These vary from small regional airfields handling mainly light aircraft to military airfields carrying heavy transport planes, to busy international passenger airports.

2. Design

Airfield pavements in the UK can be designed using a number of methods, usually the Ministry of Defence (MoD), Defence Works Services Functional Standards, but also including requirements of the Civil Aviation Authority (CAA) or to similar standards set by the British Airports Authority (BAA) or local authority or private airfield owners. These Standards typically employ existing British Standards' methods and materials with some slight modifications.

The generally preferred solution is to use Marshall Asphalt for both binder and surface courses, as this is a highly controlled and consistent material, providing a high stability and most of the specialist performance requirements for most airfield applications. These include good ride quality, good friction characteristics, high surface integrity and durability with no loose material, which could result in Foreign Object Damage (FOD) to jet engines, or sharp edges, which could endanger aircraft tyres. Marshall Asphalt is also relatively economic to maintain or replace. Where high friction requirements are necessary, Porous Friction Course is also considered an appropriate option for runways.

Design loadings are evaluated by assessing the pavement sub-grade strength (CBR), and the frequency and type of trafficking, based on the loadings of the aircraft expected to use the airfield, and includes factors such as design life (20 years), tyre pressures, main wheel gear combinations etc.. The loading data is drawn from tables published by the International Civil Aviation Organisation (ICAO) or direct from the aircraft manufacturers. These loadings etc. are compared with charts in the design guidelines and produce a recommended thickness of asphalt pavement. These loadings, amongst other parameters, define the stability required of the Marshall Asphalt mixture. However, with ever-increasing sizes of aircraft and tyre pressures, it is sometimes required to design special heavy-duty mixtures on an empirical basis, using established asphalt engineering design principles.

3. Mixture composition

3.1 Marshall Asphalt

The Marshall Asphalt mixture is evaluated in the laboratory, employing the ingredients to be used for mixing. The method is outlined in BS 598: Part 107, but additional testing is required on the aggregates, in order to establish their suitability in terms of shape, mechanical strength, absorption, soundness (tested by the magnesium sulphate soundness test), PSV, and resistance to stripping (for the coarse aggregates). If the aggregates are found to be suitable, the mixture is tested over a range of binder contents to determine the optimum binder content within defined values of stability, flow and air voids.

Table 1 below gives the aggregate gradings of the available Marshall Asphalt mixtures, Table 2 the requirements of the mixture at that optimum binder content, and Table 3 typical stability requirements for surface course mixtures.

Table 1

BS 410 Sieves (mm)	Proportion by Mass Passing (%)				
	Binder Course		Surface Course		Regulating Course
	28mm Nominal Size Aggregate	20mm Nominal Size Aggregate	20mm Nominal Size Aggregate	14mm Nominal Size Aggregate	10mm Nominal Size Aggregate
37.5	100	-	-	-	-
28	78-100	100	100	-	-
20	-	76-100	89-100	100	-
14	56-80	64-89	78-90	86-100	100
10	-	-	69-83	78-90	95-100
6.3	40-68	46-71	60-75	66-79	77-85
3.35	30-52	32-58	49-63	52-65	51-64
1.18	18-38	20-42	35-49	34-49	42-48
0.425	11-25	12-28	22-33	19-33	27-33
0.150	5-15	6-16	10-18	9-17	8-14
0.075	3-7	4-8	2-6	3-6	4-7

Table 2

Requirement	Binder Course	Surface Course	Regulating Course	Plant Production Tolerance from Design Binder Content
Optimum Binder Content	4.0-7.0 %	5.0-7.0 %	5.0-7.0 %	± 0.3 %
Flow	≤4.00 mm	≤4.00 mm	≤4.00 mm	≤4.00 mm
Air Voids in Total Mix	3.0-5.0 %	3.0-4.0 %	3.0-5.0 %	± 1.0 %
Voids Filled with Binder	67-77 %	76-82 %	N/R	± 5 %

Table 3

Tyre Pressure MPA (psi)	Minimum Stability (kN) (surface course mixtures)		
	Frequency of Trafficking		
	Low	Medium	High
Up to 1.4 (200)	6	8	10
More than 1.4 (200)	8	10	10

Once the laboratory mixture has received approval, it can then be mixed in the plant proposed for supply and laid using the equipment for the contract in a trial area. This trial determines the suitability of the mixture in terms of workability, production and laying rates and consistency as well as compaction etc. If the trial indicates that the mixture is suitable, production can begin. Throughout the supply period, the asphalt mixing plant is subject to rigorous quality control procedures and frequent material testing to ensure the consistent quality of the Marshall Asphalt. These requirements are set out in a quality management system, subject to third party approval and including frequent testing of all mix ingredients, as well as the finished laid asphalt pavement course throughout the supply period. The MoD Standards also include guidance on such things as suitable temperatures and wind speeds for laying (as airfield work is often carried out at night and on exposed sites), and recommended compaction equipment and procedures.

3.2 Porous Friction Course (PFC)

Porous Friction Course has been used extensively on runways in the UK for nearly 40 years. It is basically a high-performance open-textured macadam laid over a dense impervious surface (either Marshall Asphalt binder course or surface course). The open texture of PFC, with its high quality aggregates (typically medium to high resistance to polishing values) and free-draining characteristics improve the braking performance of aircraft and minimise the risks of skidding and aquaplaning.

However, this open texture means that PFC is not suitable as a material for areas where there is a likelihood of fuel spillage, or where aircraft stand or move slowly or routinely make tight turns. It is therefore only used for the main length of runways. It is also normal practice to keep transverse construction joints in PFC to an absolute minimum, because the free draining characteristics can be impaired at such joints. A measure of the "drainability" of PFC is derived during the material trials, from hydraulic conductivity tests (BS DD 229).

Porous Friction Course is designed in a similar way to Marshall Asphalt, in that the aggregates undergo an approval procedure whereby the mixture is trialled initially in the laboratory (with the maximum target binder content being determined when drainage of binder off the aggregate is not considered excessive (procedure from British Standard Draft for Development BS DD 232), rather than in terms of stability, flow or air voids).

PFC contains hydrated lime in order to promote better adhesion between aggregates and binder in such an open-textured mixture, but it is also permissible to use approved modified binders (or binder modifiers) to inhibit binder drainage. The laboratory mixture is then trialled on an area, employing the appropriate plant and equipment for production and laying associated with the works, and finally is continually monitored throughout the contract production and laying processes.

The Tables 4 and 5 below give the basic requirements for Porous Friction Course.

Table 4

BS 410 Sieves (mm)	Proportion by Mass Passing (%)
14	100
10	90-100
6.3	40-55
3.35	22-28
0.075	3-6 *

*To include 2% by mass of total aggregate of hydrated lime.

Table 5

Aggregate	Bitumen Grade† 100/150 or 160/220** % by mass of total mixture (±0.3%)
Crushed rock (excluding limestone), Steel slag	≥ 5.2‡

†Before any modification. ** Dependent on climate of airfield.

‡But never more than design maximum binder content and never less than 5.0% found binder content from production materials.

The materials shown above are the most important for airfield runways, but other areas on an airfield may be constructed in asphalt, but with other considerations. For example, aircraft hard-standings and fuelling areas may need to have improved resistance to high static loadings and attack from aviation fuel. This may be achieved by employing cement or polymer grouted asphalt materials for strength, and proprietary fuel-resisting binders for those areas where spillage may occur. Equally, runway-ends, taxiways and turning areas will each have unique design considerations applied to prevent premature damage and the risk of loss of aggregate leading to potential FOD. A wide range of specialist proprietary asphalt products are likely to meet these needs, as well as ‘traditional’ macadam’s and hot rolled asphalts.

4. Recent Contracts

Table 6 below gives brief details of some major civil airfield contracts carried out in the UK over the past few years. In addition to these, asphalt resurfacing has been carried out at a number of military airfields.

Table 6

SITE	COMPLETION DATE	CONTRACT DETAILS
NORWICH AIRPORT	APRIL 1997	Overlay of existing concrete runway and Southern taxiway surfaces. In total, 7,600t of asphalt material was laid.
LONDON LUTON AIRPORT	OCTOBER 1998	Overlaying and reshaping of the existing runway together with new construction to increase runway size. A total of 50,000t of asphalt material was used which included Dense Bitumen Macadam Roadbase with Marshall Asphalt binder course and surface course.
KENT INTERNATIONAL AIRPORT, MANSTON, KENT	JULY 1999	Overlay of existing porous friction course (PFC) runway with new PFC layer bonded to existing surface with proprietary bond coat.
SOUTHAMPTON INTERNATIONAL AIRPORT	APRIL 1999	Overlaying the existing concrete runway with 21,000t of Dense Bitumen Macadam binder course in varying thicknesses to increase runway cross-fall. This was then surfaced with 8,000t of grooved Marshall Asphalt.
EAST MIDLANDS AIRPORT	MARCH 2000	Carried out to increase the length of the existing runway. The runway width was also increased by 14 metres to 60 metres, and the existing concrete surfacing overlaid with Dense Bitumen Macadam regulating and 100mm of Marshall Asphalt surfacing to reprofile the runway. In total, 163,000t of asphalt materials were required.
LONDON GATWICK AIRPORT	SEPTEMBER 2000	Re-profile runway with Marshall Asphalt binder course and surface course, also hard shoulders with Macadam Dense Binder Course and Close Graded Surface Course during short night time possessions.
LONDON HEATHROW NORTHERN RUNWAY REFURBISHMENT	OCTOBER 2001	Reprofile runway with Marshall Binder Course and Surface Course during short night time possessions.

N.B. The majority of these contracts were carried out at night, or under highly restrictive, short term possession schedules, in order to permit the airfields to remain open for peak flight traffic.

Conclusions

The operational flexibility of asphalt contributes to the success of its use as a surfacing material for airfields, with early high impact trafficking possible. With careful design, asphalt can withstand the high demands of airfield sites for long periods of time, and continuing development of asphalt products will ensure that this remains the case.

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