High Performance Asphalt for Airfield Pavement

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ABSTRACT: Due to the expected increase in air traffic movements around the world and its impact on the environment, the requirement to build more sustainable and low maintenance airfield infrastructures has become very important. One solution consists in using high performance asphalt materials in order to provide a better sustainable whole life cost solution for these pavements. Performances of binder play a key role in the performances of the asphalt pavement as the properties of both are linked. Using Polymer Modified Bitumen Asphalt materials for runway and taxiway represents an alternative solution to traditional Marshall Asphalt (MA). This type of products for wearing course and binder can improve considerably the airfield pavement performances regarding the Rutting resistance, thermal susceptibility or even Fuel resistance. Due to new generation of aircraft more and more aggressive, use of rut resistance asphalt base course is also mandatory. Asphalt Concrete manufactured with Hard Grade bitumen like “High Modulus Asphalt” with improved mechanical characteristics can lead to longer service life, by preserving resources and bringing also cost savings as maintenance is reduced. This type of Asphalt Concrete showed on major airport projects his potential as a viable alternative to the traditional airfield pavement materials for base course such as Crushed Rocks or Dense Bitumen Macadam.

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. Asphalt is also widely used in airport construction, although this usage is not always recognized. A recent survey shows that a majority of airports are in fact constructed with asphalt pavement. 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. For aircraft parking areas the main requirement is adequate stability under high wheel-loadings; the principal considerations are adequate stability under wheel-load 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 and premature failures can occurred if inadequate products and pavement design method are used.

This paper focusses on the presentation of characteristics and performances of asphalt materials using specific type of bitumen and their impact on asphalt pavements durability illustrated by some case studies.
2. Key Parameters For Airfield Pavement

2.1 Adequate Pavement Design Method

(a) French method – STAC Guide

The official French method is established by the STAC (Civil Aviation Technical Service). The flexible structure is designed by the CBR method in which an equivalent theoretical thickness and a linked thickness of the materials are determined to protect the support soil under the repeated passage of the traffic.

These two minimum allowable thicknesses are determined with calculation charts (programmed since 2007 in the DCA software). Aeronautic structure design is purely empirical and the materials are distinguished by coefficients of equivalence.

The structure to be implemented was established by weighting the thicknesses of the layers by the corresponding coefficients of equivalence so that these two real thicknesses were less than the allowable thicknesses.

The coefficients of equivalence were determined for each type of material based on the American AASHO tests carried out in the 1960s in the United States. The mechanical qualities of the materials evolved, particularly with the introduction of high modulus materials. The STAC therefore carried out life-size experiments at the end of the 1990s in order to take these new materials into account in the pavement design method.

The new instructions thus define coefficient of equivalence for High Performances Asphalt Concrete allowing for the optimization of the pavement structures:

(b) American method - FAARFIELD

The method developed by the FAA includes structural design calculation software called FAARFIELD. This method is not just used in the United States; it has been exported to many other countries.

The thickness to be used is determined by the finite element method in which the structure design criterion is that the stress created under the most constraining landing gear is less than an allowable value which is dependent on the resistance to bending.

Each layer is characterized here by its modulus and its Poisson ratio. The pavement thickness is set so that the CDF (cumulative damage factor), i.e. the sum of the damage caused by all of the aircraft, is less than 1. For each aircraft, the surface deformation of the platform is calculated with a linear elastic model. From an empirical fatigue relationship, we can derive an allowable aircraft traffic level. The elementary damage associated with this aircraft is the ratio between the real traffic and the allowable traffic.
This approach is valuable firstly because the feedback from experience is substantial and also because it is based on rational considerations, even though empirical aspects remain. It makes it possible to take into account the real values of the moduli of the materials (as long as the temperature and frequency conditions to be taken into account are set) and to thus make use of High Performances Asphalt using Polymer Modified Bitumen or Hard Grade Binder.

2.2 Performances based specifications of Asphalt Concrete

Up to now specifications of Hot Mixes in most of the countries worldwide are still based on the Marshall Method and empirical recipes. Even if this approach has demonstrated its suitability until a recent past it finds its own limits especially in cases of ultimate conditions of traffic. In order to meet highest requirement asphalt pavement layers must

i. Resist to rutting at high service temperature under high axle load (Bitumen stiffness)
ii. Resist to fatigue cracking (use of PMB)
iii. Be workable for easy laying and compaction
iv. Be waterproof for preserving underneath structure
v. Be sustainable and resist to the abrasion and effects of water
vi. Be cost effective

Meeting the above requirements imply to re-consider the method of designing and providing predictive testing methods based on performances specifications. In Europe, the formulation method for asphalt mixes used is defined by standards. It is characterized by an approach based as much as possible on the performances of the mixture. For materials that play a structural role, it can be classified in the "fundamental" approach. Asphalt Concrete follows the requirements of the following European standards:

a. NF EN 13108-1 concerning the specifications for asphalt mixes
b. NF EN 13108-20 concerning the formulation method

The mix design method requires specifications on the components and particularly the aggregate, but it involves 5 tests which define the level of the study to perform on the asphalt mix:

a. The Gyrator Compaction test and the water resistance test -> level 1
b. Resistance to rutting -> level 2
c. The stiffness modulus -> level 3
d. Resistance to fatigue -> level 4
Superpave Mix Design method in the United States introduce also this type of “performances” testing for Asphalt Concrete, not anymore only based on Marshall method.

3. High Performance Asphalt

3.1 High Modulus Asphalt for Base Course

The worldwide trend tends to substitute soft binders by harder grades more adapted to stringent and severe conditions. Bitumen grades can be specified by their penetration, viscosity or Performance Grade. Most of local specifications now have extended their range to harder grades up to 20/30 or 40/50 (penetration grade) or higher Performance Grade (like PG 70-22 in the USA) and even 10/20 or 20/30 in Europe.

Use of harder penetration bitumen grade to strengthen the asphalt layers and thus reducing the risk of rutting is now the trend. It applies to all asphalt layers. Authorities have gradually switched from 80/100 pen bitumen to 35/50 within 25 years. This grade represents now about 70% of asphalt pavement to date in France on national roads.

Harder grades (10/20-20/30) are now commonly used for base course in specific situations such as roundabouts, heavy trafficked lanes, trucks parking, toll gate and industrial platform where standards grades of bitumen can’t withstand such high stresses and especially to design High Modulus Asphalt, called “Enrobé à Module Elevé” in France (EME).

The formulation of “Enrobé à Module Elevé” EME is closed to traditional Bituminous Base Asphalt. The aggregate mix is usually continuous graded with approximately 60-65% chippings and the filler content stands around 7%. The current chipping sizes are 10, 14 or 20mm but the most commonly one is 14mm.

Designing Hot Mix Asphalt according to the European standardization is based on mechanical performances. Freedom is given to select the appropriate aggregate mix, bitumen grade, source and dosage to achieve the following requirements given in the table 1 below.
Table 1. Comparative performances GB (Bituminous Base Asphalt) vs EME - NF EN 13108-1

|                              | GB2 | GB3 | GB4 | EME2 |
|------------------------------|-----|-----|-----|------|
| Water resistance Duriez ratio r/R | > 0.65 | > 0.70 | > 0.70 | > 0.75 |
| Rutting Test @ 60oC          |     |     |     |      |
| - after 10,000 cycles        | %   | < 10 | < 10 | < 7.5% |
| - after 30,000 cycles        | %   | < 10 | < 10 | < 7.5% |
| Complex Modulus at 15oC/10Hz | Mpa | > 9,000 | > 9,000 | > 11,000 | > 14,000 |

To achieve a good workability at the application the mixing temperature of EME should be around 180oC corresponding to the viscosity that provides good coating (0.2 Pa.s). Any type of mixing plant is suitable provided that the burner is set for this temperature.

Regarding airfield pavement, use of “Enrobé à Module Elevé” as base course offer the following benefits:
1. Better strength and durability leading to at least 15% reduction in layer thickness,
2. Better rutting resistance than traditional asphalt,
3. Durable and long life material, therefore maintenance and repair may be limited only to surface course only at longer intervals,
4. Ease of laying with consequence increased productivity, reduction in construction period and construction cost together with less disruption to airport operations

3.2 Polymer Modified Asphalt for Wearing Course

Typical airfield flexible pavement construction can consist of asphalt layers using Dense Marshall Asphalt surface course, which generally provides poor ride quality and skid resistance.

Low skidding resistance at the runway pavement surface represents a major hazard for the aircraft traffic operations in wet weather condition. One of the most important criteria during routine maintenance is the requirement for longitudinal wet friction coefficient. Traditional Marshall Asphalt cannot provide sufficient skid resistance unless they are grooved.

However new standard asphalt material used in Europe are able to provide high performances for wearing course for airfield pavement, especially for runway by using Polymer Modified Bitumen.

The most widely polymer used is the SBS (Styrene–Butadiene–Styrene) because of higher performances provided. It represents more than 80% of the PMB market. Performances are not proportional to the amount of polymer as many parameters have an influence on the final quality (type of polymer, type and origin of the bitumen).

Table 2. Properties of pure binder vs Polymer Modified Binder

| PARAMETERS                      | INDICATOR *                              | PURE BITUMEN 30/50 | SBS-MODIFIED BINDER 1.5 % | SBS-MODIFIED BINDER 4% |
|---------------------------------|------------------------------------------|--------------------|---------------------------|------------------------|
| Adhesion                        | % of covered surface                     | 50%                | 90%                       | 90%                    |
| Complex modulus                 | T(°C) for G*/sinδ = 1kPa (DSR SHRP)      | 71.5°C             | 72.1°C                    | 76.5°C                 |
| Flexibility - Cracking at low temperature | T(°C) for breaking elongation 1 % direct tension (SHRP) | -16.1°C            | -19.5°C                   | -26.4°C                |
| Fatigue Resistance              | Elastic recovery at 10°C                 | Fragile (breaks upon) | 59.8%                    | 89.0%                  |
Table 2 clearly demonstrates the added value of SBS elastomer for all parameters. It is important to mention that SBS action is significant at both high and low temperatures.

The official French Civil Aviation Authorities edit a guide with recommendations regarding bitumen mixtures to use for wearing course for asphalt pavement. The main conclusion is that Polymer-modified bitumen should be preferred for surface courses when the requirement is for:

1. an improvement in mechanical performance, in terms of - elasticity and flexibility
2. greater resistance to rutting
3. reduced sensitivity to surface ripping and shearing efforts,
4. greater resistance to hydrocarbons,
5. enhanced durability (due to the thicker coating of binder), with properties unchanged (resistance to rutting, macrotexture maintained, etc.),
6. greater surface cohesion
7. reduced sensitivity to high and low temperatures.

4. Some Case Studies Worldwide

4.1 SSR Airport projects – Mauritius Island

The Runway Overlay and Parallel Taxiway Projects were funded by Airports of Mauritius Co Ltd (AML) in 2012.

The Runway Overlay project (value 25 Million Euros – duration 12 months) included overlaying the existing runway over a length of 3,370m, widening of existing shoulders by 7.5m on each side and reconstruction and widening of existing turn pads. The Parallel Taxiway project (value 40 Million Euros – duration 18 months) included the new construction of a Code F compliant Taxiway, 2,300m long x 60m wide and associated exit links.

Figure 4. Aerial view of SSR Airport

Airfield pavement design was based on the use of innovative Hot Mix Asphalt as Enrobé à Module
Elevé “EME” for the Base Course instead of using Pavement Quality Concrete or traditional Bituminous Bound macadam base. Pavement design was made according to the US Federal Aviation Administration (FAA) method, using the FAARFIELD software, following the Advisory Circular 150/5320-6E Airport Pavement Design and Evaluation. Structures were designed so that the pavements could bear the same aircraft movements expected for the next 20 years. For the alternative design, due to the high temperatures in Mauritius and the low frequency of solicitation, the modulus values were reduced to 6000 MPa for the base course and 1400 MPa for the wearing course.

| Course  | New taxiway - Subgrade CBR > 15 |
|---------|---------------------------------|
| Wearing | 50 mm Marshall Asphalt          |
| Binder  | 120 mm EME                      |
| Base    | 150 mm Cement Bound             |
| Sub Base| 100 mm Granular                 |

Structures using EME layers provide the following advantages:
1. Improved mechanical characteristics leading to pavement thickness reduction and resource preservation (crucial issue for small areas like Mauritius Island)
2. Easy installation and lower maintenance requirements
3. Financial savings (8 % of the cost of pavement structure)
4. Earlier completion time (3 months for each project)

4.2 **SIA – Bangkok - Thailand**

Thai Slurry Seal, construction branch the building sector subsidiary of Tipco Asphalt, has carried out the partial renovation of the surface of Runway 19L of Suvarnabhumi International Airport in Bangkok, at a cost of 4 million euros in 2017.

The work concerned a section of 1 km, a quarter of the total runway length, with replacement of the pavement structure using hot-mix asphalt over a width of 60 meters, the depth being 55 cm for the 30 meters in the centre and only 10 cm for a 15-meter strip either side.

Every year Thai Slurry Seal performs regular maintenance work for the airport, but this project had certain specific characteristics:
1. Logistic constraints due to working in an airport environment
2. Tight timetable (2 months) to plane mill the 16,000 m3 of existing pavement and lay down 42,000 tonnes of hot-mix asphalt over a substantial depth
3. Use of Modified hot-mix asphalt to meet high performance criteria fixed by the client in terms of rutting resistance (less than 2.5% at 100,000 cycles for the base course) and rigidity stiffness modulus over a broad wide temperature range (from 15°C to 40°C)

![Figure 5. SIA Runway renovation project](image)
Highly Modified PMB meeting PG 76 criteria has been used for the wearing course and hard grade binder for the Base course, providing exceptional rutting resistance and high value of modulus. Pavement design was made according to the US Federal Aviation Administration (FAA) method, using the FAARFIELD software. The project was delivered a week early in advance with the complete satisfaction of the client.

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