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Long-term Monitoring of High Performance Airfield Pavement Surfacing

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Abstract: This paper presents in service performance for seven regional and major international airports in the UK, covering different performance related runway surface courses, from the time of installation to in service. The wet friction monitoring at these airports was carried out by using Continuous Friction Measurement Equipments (CFME) over 6 years in service. Longer temporary total ungrooved runway lengths have been successfully adopted at several UK airports where the authors were involved in the resurfacing work, without any issue associated with the early-life surface friction; this resulted in early completion, reduced airfield down time and cost saving. Records to date, demonstrating the ability of well-designed surfacing material to maintain very good friction characteristics since the opening of the runways, are also presented.

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***Key words**: Cost saving; In service performance; Performance-related design; Ungrooved asphalt.*

Introduction

Low maintenance yet durable and sustainable airfield infrastructure has become very important in the current economic climate. At the same time, however, airfield infrastructure must face the ever increasing demand in aircraft utilization, climate change, new generation aircraft and green credentials. To cope with these challenges a family of grooved and ungrooved airfield asphalt concrete material have been designed based on performance encompassing workability, durability and mechanical properties to meet the local environment and loading condition for use in runways and taxiways in the UK. The applied performance related design includes testing on material properties and performance directly correlated with the target properties and climatic (in situ) condition, in accordance with the procedure described in STAC Design Guide [1]. The material produced using this design approach is widely known as Béton Bitumineux pour chausées Aéronautiques (BBA), or in another word, Airfield Asphalt Concrete.

BBA is a standard airfield asphalt surface and binder course in France (NF EN 13108-1) which has track record over 30 years. Until 2006 however, it has never been used nor an option for resurfacing UK airfields. Consequently, the introduction of BBA was met by challenges and initial reservations from the UK industry. At the time of writing this paper, BBA has been used on seven UK airports, the latest one being Manchester International Airport resurfacing works in summer 2011. Challenges met during the development stage of the above material, from mix design, field trials to major contracts, construction issues and in service performance are presented in this paper.

Feasibility Study

As a part of the feasibility study on these materials, performance assessments were carried out on the laboratory produced samples, comparing the performance of typical UK and French airfield surfacing materials. The results, summarised in Table 1, suggest that BBA can be expected to have better overall performance than Marshall Asphalt (MA) surface course which is generally used in UK airfield pavements. MA is an Asphalt Concrete type of material which is designed using Marshall mix design method and laid as grooved when used as runway surfacing; typical properties of this material can be found in Specification 13 (Defence Estates) [2].

When designed as grooved surface course, the enhanced mechanical properties of BBA material enabling better retention of the groove. The improved resistance to groove failure of BBA over MA is illustrated in Fig. 1. This laboratory performance was also confirmed by field inspection; the most recent annual inspection carried out in 2012 suggested that the condition of grooves on the oldest site, having 6 years old BBA surface course, remained sharp i.e. it was in excellent condition.

Mix Design

There are four types of BBA material: closed and gap graded, each grade with 0/10mm and 0/14mm aggregate sizes; each can be used for binder and wearing courses in new construction and overlay. There are three classes of BBA (i.e. BBA1, BBA2 and BBA3) specified under the French specification (NF EN 13108-1) based on the frequency and weight of aircraft and the airport climatic regions, to give the characteristics of mix constituents, volumetrics and the level of performance tests required. The French performance related mixture design methodology is illustrated in Fig. 2 together with brief description as shown below.

Since 2006, BBA has been used on seven UK airports, four of which are grooved and based on islands - Sumburgh (Shetland Islands), Tiree, Ronaldsway (Isle of Man), and Jersey (Channel Islands); and three ungrooved on mainland airports including Southend, Perranporth and Manchester. Apart from the project at Southend, the mix design and production for all of these schemes

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Table 1. Summary of Laboratory Performance Assessments.

Category	Test Condition	Test Method	0/14mm MA	0/14mm BBA2 C
Mixture Type			MA	BBA
Nominal Aggregate size			0/14mm	0/14mm
	French Test Methods			
Complex Modulus*	E* (15°C, 10Hz)	NF EN 12697-26	4900 MPa	13300 MPa
Deformation Resistance**	RD (10000 cycles, 60°C)	NF EN 12697-22	14.4%	3.9%
Duriez*	r/R (18°C)	NF EN 12697-12	0.98	1.00
	British and AASHTO Test Methods			
Stiffness*	ITSM (20°C)	BS EN 12697-26	1000 MPa	3000 MPa
Deformation Resistance**	p(3600) (40°C)	BS DD 226	1.2%	0.9%
Fatigue Resistance*	200 (20°C)	BBA HAPAS SG3	5000	7000
Resistance to Moisture	ITSw (25°C)	AASHTO T283	399 kPa	726 kPa
Damage*	RTS (25°C)		122%	96%

Note: *Higher values denote better performance. **Lower values denote better performance

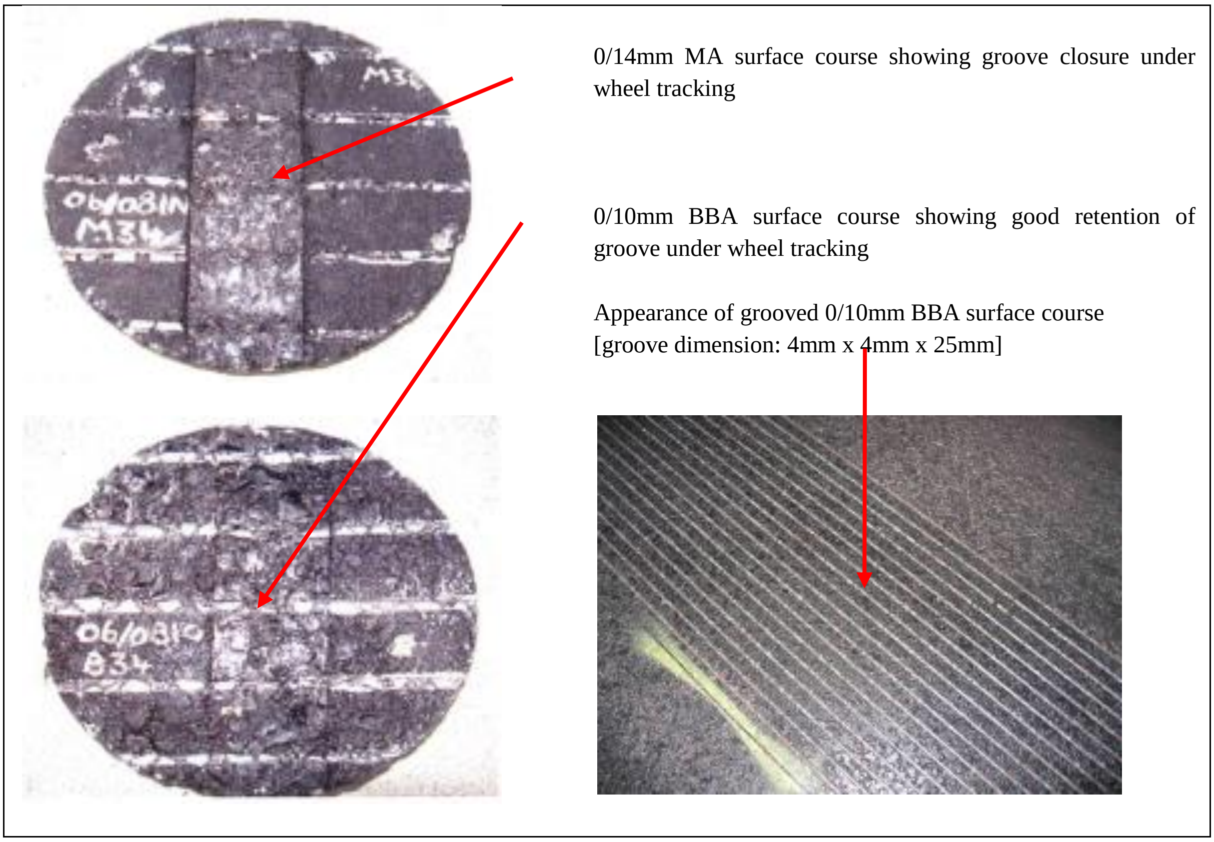
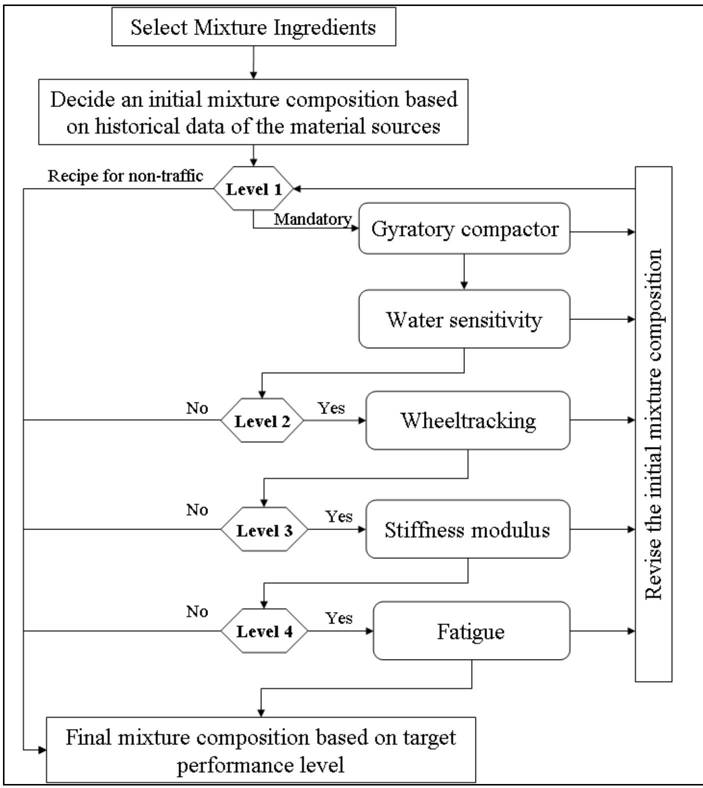


Fig. 1. Improved Groove Retention of BBA in Comparison with MA.

was undertaken by Colas who also acted as the surfacing contractor.

As an example, the following was one of the specifications for ungrooved 0/14mm BBA D Class 3, designed in accordance with the STAC (2009) [1] to the Level 3 requirements, to carry high traffic frequency (250,000 coverages over 15 years) and unlimited aircraft tyre pressure. In an attempt to anticipate the possible effects of global warming, such as wetter summers and more severe winters, the requirements for resistance to moisture and de-icing liquid were also specified for the mix design. This involved assessments of tensile strength of the material after being subjected to freeze thaw cycles in water and in de-icing solution. The adopted design parameters are summarised in Table 2.

For the Main Work (i.e. the actual resurfacing work on the runway), core samples were removed from the Work and the determined tensile strength values exceeded the minimum specified value (600 kPa). For thin overlay (thickness 50 mm or less), the presence of good bond between the new surface course and the existing layers is a key factor to promote durability of the new overlay; consequently, an interlayer bond strength test was also specified for the Main Work. The Interface bond strength at 20°C between BBA surfacing and the substrate, tested in accordance with British Board of Agrément Highway Authorities Product Approval Scheme Document SG3 Appendix A.3 was set to be greater than 1 MPa; this test protocol for Thin Surface can be found from this



There are four levels of performance in the mixture design:

- Level 1 is mandatory for any material which will be carrying aircraft traffic.
- Level 2 must be carried out for surface and binder course that will be subjected to high traffic of heavy aircraft and includes a verification of the resistance to rutting with large wheeltracking rut tester.
- Level 3 applies to mixes of base and binder courses when the determination of the stiffness is required for pavement design purposes.
- Level 4 must be carried out for heavily trafficked pavements, for mixed used in base layers of new pavements or of overlays in relation to pavement design.

Fig. 2. Mixture Design Principle.

Table 2. Mixture Design Parameters.

Test Parameters	Test Method	Threshold Values
Air Voids After Gyrations		
10 Gyrations	BS EN 12697-31	> 10
60 Gyrations		5 - 9
Richness modulus	BS 594987 Annex E	≥ 3.2
Duriez Test at 18℃ Ratio: r (in MPa)/R (in MPa)	NF P 98-251-1 or BS EN 12697-12 Method B	≥ 0.80
Rutting Test for Heavy Traffic or Special Stress Category. Rut Depth in Percentage of Thickness of Layer for a 100mm Thick Layer at 10,000 Cycles and 60℃, for Air Void Content between 4% and 7%.	NF P 98-253-1 or BS EN 12697-22 Large Device	≤ 7.5 %
Indirect Tensile Stiffness Modulus (ITSM) at 20°C for Air Void Content between 4% and 7%	BS EN 12697-26 Annex C	> 3000 MPa
Resistance to Moisture Damage for Air Void Content Between 4% and 7%		
Tensile Strength at 25°C Before Conditioning, Mean of 3 (TSa)	AASHTO T283 (Include One Freeze Thaw Cycle)	≥ 750 kPa
Tensile Strength at 25°C After Conditioning, Mean of 3 (TSb)		≥ 600 kPa
Tensile Strength Ratio = TSb/TSa		≥ 0.80
Resistance to De-icing Fluid for Air Void Content Between 4% and 7%	Broadly in Accordance with BS EN 12697-41 and BS EN 12697-23	
Tensile Strength at 25°C Before Conditioning, Mean of 3 (TSa)		≥ 750 kPa
Tensile Strength at 25°C After Conditioning, Mean of 3 (TSb)		≥ 600 kPa
Tensile Strength Ratio= TSb/TSa		≥ 0.70

website: http://www.bbacerts.co.uk/product-approval/hapas/hapas-product-sectors.aspx (Last accessed on 18 June 2013). Polymer modified binder (Colflex) was used in the above BBA mix design and polymer modified tack coat (Colbond) to promote bond between layers.

Construction

BBA materials are known to have very good constructability and workability. Past UK and French experience suggested higher outputs for laying BBA material than (say) conventional MA surfacing, for example:

I) During a complete runway closure, up to 14,000 tonnes per day of BBA have been laid by using two on-site plants manufacturing 450 tonnes per hour each.

II) During restricted runway possession time (between 11pm and

5am), the output was about 1000-1200 tonnes per night; this corresponds to 120-160 m per night runway surfaced using 2 paving machines laying dual layers of 70mm high modulus asphalt base and 50 mm BBA surface course, with a width of 8 m each.

III) As much as 200t BBA per hour has been produced and laid by using conventional asphalt plant, to cover 200 m surface course in over the full 45m width of runway in one shift during the construction work.

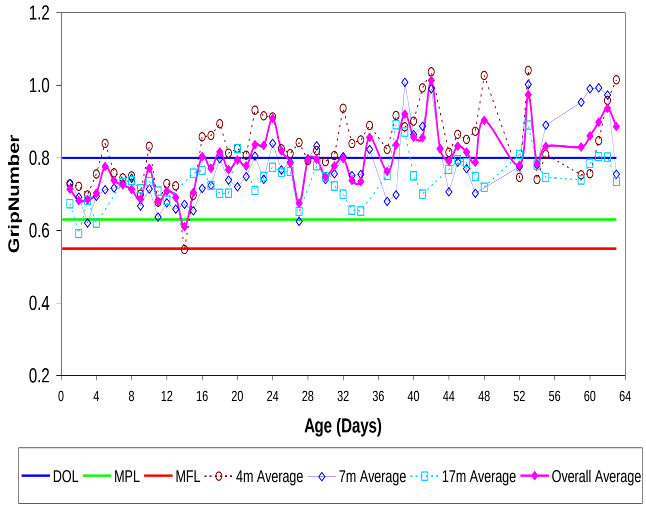
The high binder content and composition of BBA materials have contributed to improved workability and speed of construction of this material. Another benefit from resurfacing with BBA material is that it does not require specialist paving equipment such as pneumatic tyres which are expensive to hire and require specialist operators.

Site observation during runway resurfacing the previously mentioned UK airports suggested that the material can be easily laid and compacted. This was also confirmed by the laboratory assessment that the mixture has good workability when laid and compacted in a laboratory roller compactor. It was found that the variations in air void of cores taken from the main work at Sumburgh airport were ± 1% for BBA as opposed to ± 1.5% for MA. Furthermore, the composition and gradings of BBA appeared to yield lower risk for segregation during manufacturing and transportation of loose coated asphalt to site (when compared against MA materials); this has been evidenced from the more uniform appearance of the finished BBA surface. These would imply better constructability, workability and quality control for BBA than those for MA.

Furthermore, ungrooved asphalt BBA can be fully operational as soon as the temperature of the laid materials has reached the ambient. For comparison, MA surfacing has to wait from as early as 24 hours (and more usually 72 hours), and much longer in cold/wet climatic countries, after the surfacing material had been laid before grooving operation can be carried out with consequent impact on runway operations. Such delay between construction and grooving could have caused a number of inconveniences, including: requirement for the airport authority to declare the runway surfacing as ‘skidding when wet’ until the grooving operation is carried out, and hence reduced ‘perceived safety’; longer construction time; disruption to airport operation since an extended runway closure would be required, and; requirement for budget allowance to carry out grooving operation. In response to safety concerns, airport authorities implement a limitation on the permitted total ungrooved runway length during resurfacing works which also impacts upon the construction programme and project cost.

Early Life Performance

Low skidding resistance at the runway pavement surface represents a major hazard for aircraft traffic operations, particularly in wet weather. Friction is the mechanism that allows the aircraft to slow down after landing. It needs to be sufficiently high to allow directional control of aircraft on landing and efficient braking over the available runway length. Airport operators generally follow the guidance given by Civil Aviation Authority [3] or International Civil Aviation Organization [4]. The following definitions have



Note: the 4 m, 7 m and 17 m averages denote the rolling average friction at the 4m, 7 m and 17 m offsets from the runway centre line.

Fig. 3. The Lowest 100m Rolling Average Friction During Early Service Life of Ungrooved BBA.

been used by CAA:

- Minimum Friction Level (MFL) is the friction level below which a runway shall be notified as ‘may be slippery when wet’.
- Maintenance Planning Level (MPL) is the friction level below which a runway maintenance programme should be undertaken in order to restore the friction level.
- Minimum Design Objective Level (DOL) is target friction level to be achieved on a new or resurfaced runway within one year.

During monitoring of the early life friction of ungrooved BBA surface course, it was concluded that the MFL had consistently been exceeded within a few hours after laying, as illustrated in Fig. 3. The demonstrated skid resistance (grip number) was assessed by using Grip Tester at 65 km/h at water depth of 0.25 mm in accordance with CAP 683 (CAA, 2010) at regular time intervals, recorded during the recent resurfacing work at Manchester airport [5].

For comparison, early life friction values (tested using the same method) of a 0/14mm MA surface course typically range from 0.4 to 0.6 before grooving; this value would typically exceed 0.7 after receiving grooving. The low initial friction value of ungrooved MA had led to the current practice (CAA) [6] whereby the length of any temporary surfacing must be limited to a maximum TTURL (temporary total ungrooved runway length) during runway construction, unless grooving or improved friction course has been applied. Whilst it is not mandatory, TTURL has been typically 100m. This practice effectively limits the speed of construction and consequently prolongs the completion of the work and may ultimately increase the construction cost.

The application of BBA material, which has been designed as ungrooved, can provide good early surface friction values (as also demonstrated in Fig. 3). This material also offers another practical advantage in that it permits aircraft to land on sections of BBA binder course, designed with adequate texture, that may be used ‘exposed’ or as temporary running surfaces during runway

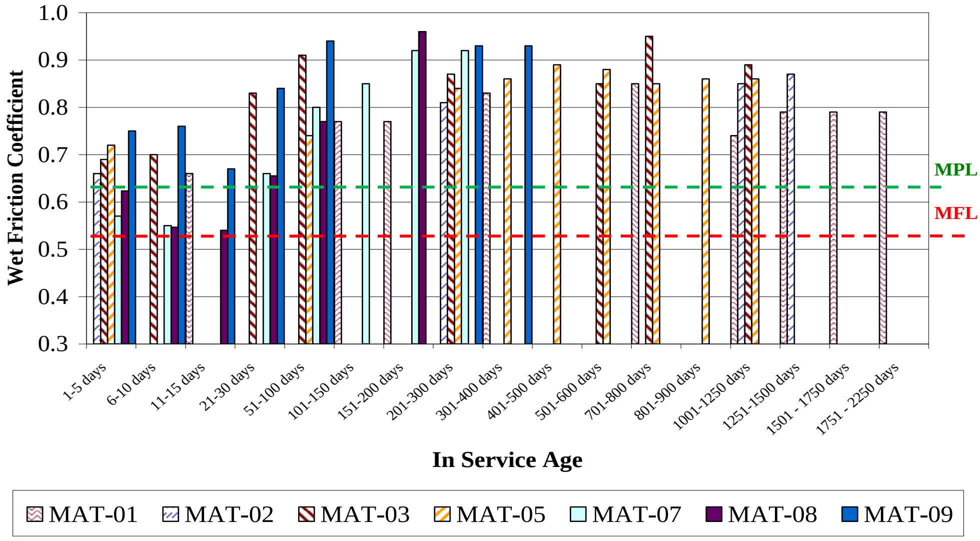


Fig. 4. Wet Friction Values of Grooved (Striped Bars) and Ungrooved (Filled Bars) BBA In-service.

refurbishment works up to the full length of the runway without the customary limits on TTURL associated with MA material and thereby offering a solution for speedy and more economical construction.

In Service Performance

Observations during construction and over 6 years in service on the seven studied airports suggest that the wet friction values, tested in accordance with CAP 683 (CAA) [3] procedure, remain significantly above the MPL; this is illustrated in Fig. 4. These figures also suggest that the stability of the material to retain its friction level during their service life; at the time analysing these data, none of these runways received rubber removal treatment. It is widely expected that the wet friction value increases with age, as the binder coating the aggregate at the surface has been rubbed off by aircraft trafficking, revealing the microtexture and macrotexture of the surfacing material; the speed at which binder is rubbed off will be related to the traffic levels.

Whole Life Cost Pavement Solutions

The laboratory assessments (Table 1) have indicated improved overall performance of BBA materials over MA materials. These findings may suggest longer service life and/or less maintenance work; this would help reducing the requirement for premium aggregates used in maintenance or resurfacing works.

There is also a potential to retexture ungrooved BBA surface course (to restore skid resistance) and/or recycle this high quality material back into the pavement (potentially up to 100% recyclable, although the latter may be limited by contractual provision to 10% by the existing specifications if recycled for use in a surface course, or 50% if recycled for use in binder course [6]. The BBA standard permits the introduction of recycled content in both binder course and surface course being determined by pavement traffic category. Performance of mixes incorporating recycled content must be verified during the laboratory mix design process prior to the construction phase. The work at Jersey (Channel Islands) and Bierset (Begium) Airports incorporated 15% and 25% reclaimed asphalt pavement material, respectively, in the new BBA binder course thereby allowing premium surface course aggregate from the existing surfacing to be re-used. In addition to this, BBA surface course can be incorporated into Repave hot recycling process [6]; this process was successfully applied during the rehabilitation of the Isle of Man airport taxiways. One of the key benefits from this process is that it allows application of very thin layer BBA over in situ recycled asphalt surfacing, resulting in a fully bonded composite bituminous layer delivered in a faster construction time at a lower cost.

Economical advantage can also be seen from the whole life cost assessment, which includes the initial cost of pavement construction or rehabilitation, all the costs of routine maintenance and planned strengthening over the pavement life, and the value of the asset at the end of its service life. Other factors include the engineering cost, traffic management cost during pavement treatment and users cost as a result of delay and increase in aircraft operating cost. Therefore, where the cost of traffic disruption during pavement maintenance and strengthening is high, as the case of majority of busy airports, constructing durable and long life pavement would have a major advantage.

Ungrooved asphalt surfacing such as BBA can be fully operational as soon as the temperature of the laid materials has reached the ambient. For comparison, MA surfacing would require grooving application, which is typically done no sooner than 24 hours after laying, before opening to traffic. Runway closure in particular would cause a reduction in the movement capacity of the infrastructure; this would have a big impact on the airport operations at all levels and potentially a significant loss of revenue. As an illustration, delay cost for closing a runway at Dallas International Airport was around \$110,000 – 131,000 per day in 1990, but this delay cost could have been as high as £13.5 millions per day in the case of a busy UK airport operating with a single runway. Solely due to the absence of grooving at Manchester Airport Runway 1 surface course, savings in the regions of several hundred thousands of British poundsterlings have been reported, and indeed, there has been no rubber removal required since the resurfacing work to date (i.e. 2 years in service). Other savings had been seen from the construction cost (between 15 and 27% less), completion time (26 – 40% shorter) and material quantities (18% less).

Closure

It took five years to reach the position where ungrooved airfield asphalt concrete such as BBA is now considered as a viable alternative to grooved asphalt concrete in the UK. Before 2006 the surfacing material predominantly used on most UK runway pavements was grooved Marshall Asphalt (MA) although grooved Hot Rolled Asphalt (HRA), Porous Friction Course (PFC) or Slurry Seal were also in use. However, following the successful applications of BBA on seven UK airfields, since 2011, ungrooved asphalt is now accepted as a premium surfacing option. Furthermore, an update on the UK CAA guide CAP 781 [7] has subsequently permitted the use of ungrooved BBA as a surfacing option for runway rehabilitation.

The most recent airport resurfacing projects where ungrooved BBA were adopted as runway surface course have demonstrated many benefits such as high stability material with outstanding performance and wet friction characteristics, together with the ease of production and laying which helped to maximise output, and thereby significantly reduce costs, and the minimum impact on runway operations that occurs whilst the resurfacing works are being carried out.

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