THE RENOVATION OF THE RUNWAYS ON BRUSSELS NATIONAL AIRPORT: FAST AND HIGH-QUALITY EXECUTION

C. DE BACKER & G. GLORIE
Belgian Road Research Centre, Brussels, Belgium
c.debacker@brrc.be
g.glorie@brrc.be

ABSTRACT

The three bitumen-paved runways of Brussels National Airport were renovated in depth between 1996 and 1999. As it was unthinkable to put any of the three runways out of service for an extended period of time, it was decided to close one runway each year for a maximum duration of one month. High-quality work was nevertheless required to go together with speed of execution. The first step taken to meet this double objective was to subject the pavements of the runways to a thorough condition survey. The design for their renovation and the consequent specifications were based on the results of this survey. After the contract had been awarded, the feasibility of the solutions suggested by the contractor was examined on trial areas; these areas also served to calibrate the nuclear gauges to be used for checking the densities achieved in laying and compaction. Thanks to the know-how of the contractor and to intensive and systematic verifications during execution, the works were completed within the specified times and to the satisfaction of the client. After seven years of intensive service, the pavements are still in perfect condition and allow to hope for a longer life than initially designed for (twelve years).

KEYWORDS: AIRFIELD / PAVEMENT / AUSCULTATION / MAINTENANCE WORKS / INSPECTION OF THE WORKS / QUALITY

1. INTRODUCTION

The three runways on Brussels National Airport were renovated in depth between 1996 and 1999. As it was unthinkable to put them out of service for an extended period of time, a short pain for large gain approach was opted for, by closing one runway each year for one month. This required the timely performance of thorough condition surveys of the existing pavements, to provide a basis for carefully considered designs and specifications. The feasibility of the solutions suggested by the contractor to meet the contract specifications was first examined on trial areas; these areas also served to calibrate the nuclear density gauges to be used during the actual execution of the works. The leitmotiv throughout the project was to deliver a high-quality product within the specified time. This was achieved among other things by including penalty and bonus clauses and providing for thorough inspections in the contract specifications.

2. PROBLEM STATEMENT

Owing to the substantial growth of the traffic on Brussels National Airport and the resulting increase in mechanical loads, the pavements of the runways had reached the end of their lives after about fifteen years of service.

In view of the many cracks appearing in the pavements, the company managing the infrastructure of the airport decided to renovate the three runways. The following time schedule was adopted for the renovation:

- August 1996: runway 07L/25R (the takeoff runway under normal conditions), except the joint head (25R) with diagonal runway 02/20;
- August 1997: runway 07R/25L (the landing runway under normal conditions);
- August 1998: southern head (joint head with runway 07L/25R) and northern head of diagonal runway 02/20 (which is mainly used when the wind blows from the north or east);
- August 1999: the remainder of runway 02/20.

Also included in the renovation were the adjacent areas connecting up with the various accesses to the runways.

At the request of the managing authority, the Belgian Road Research Centre (BRRC) participated in the designs of the renovation and in the inspections during execution.

3. CONDITION SURVEY AND DIAGNOSIS

3.1 Structure of the runways

Each of the runways is between 3,000 and 3,600 m long. The actual runways are between 45 and 50 m wide, marked out by light beacons, and bordered on both sides by a shoulder strip varying in width between 5 and 7.5 m.

Before renovation, the structure of the runway pavements consisted of a (between 20 and 35 cm) thick surfacing in asphalt concrete laid on the original runways in cement concrete slabs (constructed between the late fifties and the early sixties). An antiskid layer (resin-bound surface dressing) had been applied over virtually the entire area of the asphalt concrete. The joint head of runways 2/20 and 07L/25R consisted of 30 cm thick slabs in prestressed concrete laid over the old concrete pavement. The structure of the shoulders was much lighter, with about 12 cm of asphalt concrete on a lean concrete base.

3.2 Condition survey

With a view to assessing the required extent of renovation, the runways were subjected to a thorough condition survey including:

- measurements of bearing capacity;
- measurements of evenness;
- a detailed visual inspection (performed with the SAND system of BRRC). The data from this inspection was plotted on maps to represent the density of deficiencies;
- systematic core sampling (some fifty cores per runway), among other things to check the bond between layers and the condition of the asphalt, to measure the thicknesses of layers and – if possible – to determine the cause of the cracks in the surfacings;
- an analysis of the asphalt base courses to estimate their residual lives, with a view to their partial incorporation in the new structure.

3.3 Diagnosis

The findings from the survey described above were as follows:

- short cracks originating in the antiskid layer or in the surface course were most frequent. Most of them were shallow (often limited to the first or sometimes propagating to the second layer of the surfacing). Though affecting the entire areas of the runways, they were mostly concentrated in the touchdown and rolling zones;
- the few transverse cracks were due to the reflection of joints from the old concrete pavement through the asphalt surfacing;
- the edges along open longitudinal joints were spalled to a considerable depth in the asphalt concrete. This deficiency extending over the full length was mainly observed in runway 07L/25R (the takeoff runway under normal conditions);
- runway 07R/25L (the landing runway under normal conditions) had the additional defect of poorly bonded layers in the asphalt surfacing;
- although the binder of the asphalt base courses in the runway that was first renovated clearly exhibited local signs of ageing, the asphalt still stood up very well to fatigue cracking. As a result, this analysis was not repeated for the subsequently treated runways.

4. RENOVATION DESIGNS AND SPECIFICATIONS

4.1 Structural designs

Considering the information from the condition survey and the diagnosis – especially for bearing capacity and the depth and concentration or position of most cracks –, it was decided to replace the following depths of surfacing:

- takeoff runway 07L/25R (1996):
  - → 6 cm over the entire area (168,000 m²);
  - → 13 cm in the most severely deteriorated portion (90,000 m²) as apparent from the map made in preparing the diagnosis;
  - → shoulders: no treatment;
- landing runway 07R/25RL (1997):
  - → 17 cm over the entire area (200,000 m²);
  - → 12 cm on the shoulders (53,000 m²);
- joint head of runways 02/20 and 07L/25R (1998):
  - → 30 cm, that is, the full depth of the concrete pavement (50,000 m²);
  - → 6 cm on the shoulders (9,000 m²);
- runway 02/20 (1998 and 1999):
  - → 13 cm over the entire area (111,000 m²);
  - → 6 cm on the shoulders (24,000 m²).

Some deficiencies (including a few transverse cracks) required an even greater depth of renovation.

The material removed by milling (or demolition) was replaced with one or more layers of asphalt concrete – depending on the thicknesses to be laid – and a 6 cm thick surface course in stone mastic asphalt (on the takeoff runway renovated in 1996) or a 5 cm thick surface course in asphalt concrete (on the other runways). An antiskid layer was applied over the new surface courses of the runways and the access zones (except on the shoulders).

4.2 Anticracking layers

Anticracking layers were locally used in the new structures:

- in runway 07L/25R (1996), an anticracking layer was placed over the full area of the portion removed by milling to a depth of 13 cm. This layer was to prevent the reflection of cracks from non-renovated underlying parts of the existing pavement structure into the new layers. Since the prior inspections had revealed that these cracks were few in number, relatively shallow, and little active, a SAMI (rate: 1.5 kg/m²) was chosen for the anticracking layer;
- in runway 07R/25L (1997), an anticracking layer was placed at a depth of 10 cm over the full area of the shoulders, and extended 1 m beyond the border with the actual runway. This extension was to bridge a wide crack that had formed at this border as a result of the difference in structure between the shoulder and the runway. In addition, the surfacing of the shoulders severely suffered from reflective cracking due to the presence of a lean concrete base. Major movements were, therefore, to be expected in those places, even after renovation. That is why a SAMI (rate: 1.4 kg/m²) on a reinforcement in glass fibre geogrid was opted for as an anticracking system;
- the same system had been considered for runway 02/20 and the joint head of runways 07L/25R and 02/20. However, in view of the laying difficulties encountered in 1997, the glass fibre geogrid was replaced with a polyester geogrid. In the joint head of the two runways the system was placed at a depth of 25 cm, just above the regulating course applied to the concrete slabs of the original runway. In runway 02/20, the anticracking system (2 m wide) was laid at -13 cm, while taking care to bridge the cracks between the actual runway and the two shoulders.

4.3 Mix designs for the asphalt layers

The mix compositions of the asphalt concrete base courses are those commonly used in ordinary roads carrying traffic volumes lower than 16,000 vehicles/day. The only additional requirement was for a voids content < 6 % (rather than 7 %) on average and < 9 % (rather than 10 %) individually. The risk of rutting in airfield runways is, indeed, smaller; on the other hand, a lower value for maximum voids content increases the durability of the pavement.

In preparing the first contract specifications (for runway 07L/25R), the initial choice fell on a surface course in stone mastic asphalt (SMA). This material combines two important characteristics: relatively low voids content ensuring good performance for durability, and potential for high skid resistance – which is an absolute requirement on airfield runways. Hence it was assumed that with SMA it would be possible to omit the expensive antiskid layer. However, the results of various studies that came to notice after the job had been awarded urged for a different design.

The tests carried out in those studies indeed indicated that a new SMA surface course would not meet the requirements of the International Civil Aviation Organization (ICAO) for skid resistance in renovating an airfield pavement. Winter behaviour would be a problem as well, since comparative laboratory measurements of friction coefficients performed at BRRC demonstrated that, for equally effective winter maintenance, SMA would require twice the amounts of turnouts and de-icing agents as an antiskid layer. For that reason, the managing company decided to require the application of an antiskid layer on the SMA surface course suggested for takeoff runway 07L/25R.

For the subsequent jobs (in 1997, 1998 and 1999) it was decided to apply a surface course in asphalt concrete, in view of the requirement for an antiskid layer. However, because of the risk of cracks originating in the antiskid after a few years and propagating to the surface course owing to the strong bond between the antiskid and the surface course, the resistance to cracking and the flexibility of the latter had to be increased. That is why the ordinary bitumen for the surface course was replaced with an elastomer-bitumen.

Specific requirements were made for this binder, to make sure that the modification of the bitumen yielded the desired improvements in performance under cold (low-temperature flexibility) and hot conditions (stability) and in bond between binder and aggregate. These requirements are presented in Table 1.

Table 1: Specifications for the PMB binder
for the type1B asphalt concrete surface course on runway 02/20

<table>
<tr><td colspan="10">CONVENTIONAL CHARACTERISTICS</td></tr>
<tr><td colspan="4">Penetration (1/10 mm)</td><td colspan="6">50 – 130</td></tr>
<tr><td colspan="4">Softening temperature (° C)</td><td colspan="6">≥ 65</td></tr>
<tr><td colspan="4">Kinematic viscosity (mm²/s)</td><td colspan="6">≥ 900</td></tr>
<tr><td colspan="4">Ductility (cm)</td><td colspan="6">≥ 40</td></tr>
<tr><td colspan="4">Elastic recovery (%)</td><td colspan="6">≥ 50</td></tr>
<tr><td colspan="4">Fraass breaking point (°C)</td><td colspan="6">≤ -18</td></tr>
<tr><td colspan="10">BOND (between binder and aggregate)</td></tr>
<tr><td colspan="4">Percentage of stripping (%)</td><td colspan="6">≤ 30</td></tr>
<tr><td colspan="10">RESISTANCE TO AGEING</td></tr>
<tr><td colspan="4">Kinetic constant (h^{-1})</td><td colspan="6">≤ 2.10^{-4}</td></tr>
<tr><td colspan="10">RHEOLOGICAL CHARACTERISTICS (frequency: 1.6 Hz)</td></tr>
<tr><td rowspan="3"></td><td colspan="4">Unaged binder</td><td colspan="4">Binder after 240 h of ageing</td><td rowspan="3">Ratio (2)/(1)</td></tr>
<tr><td colspan="2">T = 52 °C</td><td colspan="2">T = 22 °C</td><td colspan="2">T = 52 °C</td><td colspan="2">T = 22 °C</td></tr>
<tr><td>│G*│ (kPa)</td><td>m</td><td>G* cos δ (kPa) (1)</td><td>m</td><td>│G*│ (kPa)</td><td>m</td><td>G* cos δ (kPa) (2)</td><td>m</td></tr>
<tr><td>Min.</td><td>10</td><td></td><td></td><td></td><td>30</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Max.</td><td></td><td>0.8</td><td>2,000</td><td>0.7</td><td></td><td>0.7</td><td>4,000</td><td>0.6</td><td>6.5</td></tr>
</table>

G*: stress/strain
δ: phase difference between stress and strain
m: heat sensitivity indicator

For the rest, the composition of the asphalt concrete for the surface course was to meet the requirements for roads carrying 16,000 vehicles/day, especially as far as resistance to rutting was concerned.

5. PRELIMINARY STUDIES AND TRIAL AREAS

Before commencing work on a runway, the contractor laid down the design of the asphalt mixes on the basis of an analytical study confirmed by a Marshall study. In addition, he ordered the specific tests required by the specific conditions of contract, especially for the rheology of modified binders.

After these tests had been conclusive, trial areas were constructed, among other things to:

- check the possibility to meet the contract requirements for each asphalt layer with the materials, compositions, equipment and construction procedures suggested by the contractor. In case of failure, the trial area had to be reconstructed. This actually occurred in 1997: the contractor had to modify the characteristics of the suggested PMB, as the asphalt concrete surface course in which it was used proved to offer inadequate resistance to rutting;
- establish a correlation between the densities of the asphalt mixes as determined from investigations on core samples and from nuclear gauge measurements, respectively.

Work could start as soon as all the contract specifications were met.

6. EXECUTION OF WORKS

In view of the expected disruption of airfield activities by the closure (or shortening) of a runway, the completion times set for the works were extremely short. The contractor, therefore, had to take all the necessary measures to meet the time limits. These measures related to the use of manpower, the production of the asphalt mixes and the asphalt laying equipment, but the main thing was an excellent organization of execution. Asphalt laying was the major part of the job, but had to be fitted into a larger operation including among other things the milling off (or out) of existing surfacing material, the application of anticracking layers, the laying of the antiskid, the application of markings, and the re-installation of the entire light beaconing system.

A few figures characterizing the execution of the works are given in Table 2.

Table 2: Execution data

Year	1996	1997	1998	1999
Runway	07L/25R	07R/25L	02/20 (stage 1-2)	02/20 (stage 3-4)
General contractor	ASWEBO			
Total scheduled completion time	35 d	30 d	30 d	30 d
Total actual completion time	35 d	28.5 d	27 d	24 d
Demolition of 30 to 35 cm of concrete pavement (m²)			53,000	
Milling				
• quantity (t)	47,000	102,000	22,000	55,000
• number of machines	3	7	5	5
Anticracking layer				
• type	SAMI	Glass fibre geogrid + SAMI	Polyester geogrid + SAMI	Polyester geogrid + SAMI
• quantity (m²)	109,000	55,000	55,000	13,000
Asphalt laying				
• quantity (t)	47,000	102,000	65,000	55,000
• number of days	12	19	11	9
• max. No. of hours/day	16	18	18	18
• coating plants	Ghent (300 t/h) + Puurs (160 t/h)	idem	idem	idem
• max. production/day (t)	5,000	6,300	7,000	7,000
• max. No. of finishers in staggered operation	5	5	5	5
Work force (milling + anticracking layer + asphalt laying (max./day)	120	130	140	120
Antiskid (m²)	150,000	190,000	110,000	121,000
Beacons (No.)	650	800	700	350
Marking (m²)	15,000	17,000	20,000	12,500

7. INSPECTIONS

Inspections were made throughout the various stages of the works. They related to:

- the materials used;
- the asphalt production in the coating plants;
- the compositions of the asphalt mixes;
- the condition of the surfaces after milling;
- the laying of the mixes;
- the voids in the compacted layers;
- the characteristics of the completed surfacings.

A first series of inspections (materials, mixes, production data) was performed at the coating plant, under the supervision of an external laboratory technician accredited by the client.

The contractual tests on the asphalt mixes were made on site by an independent laboratory. Personnel of the managing company and of BRRC jointly monitored the laying of the asphalt layers and determined their characteristics.

All the results of the tests and inspections were interpreted by BRRC staff constantly present on site. This staff was responsible for suggesting corrective actions to deal with any arising problems, and for giving advice enabling the managing company to make the necessary decisions.

7.1 Materials

Only approved or certified materials were allowed.

During execution, it was merely checked whether the certificates of origin corresponded to those reported by the contractor in his preliminary study. New tests were made if they failed to do so. This actually happened when a temporary shortage forced the contractor to order aggregates for his asphalt mixes from another supplier.

7.2 Asphalt production in the coating plants

The automatically recorded data on asphalt production was systematically checked. This allowed prompt corrective action when limit values were being systematically or repeatedly exceeded. The following were verified:

- temperatures of binders and aggregates;
- mixing temperature;
- mixing times (“dry” and “wet”);
- the proportions of mix constituents and the weights of batches.

7.3 Asphalt mix compositions

The particle size distributions and binder contents of the asphalt mixes were systematically double-checked:

- first by the contractor himself in the laboratory of each coating plant, under the supervision of an external technician accredited by the managing company. One analysis was made per hour of mix production. Since the results were known and

statistically interpreted within the hour, it was possible to take corrective action when limit values were being systematically or repeatedly exceeded;
- secondly by the independent laboratory on the work site (one analysis per 1,000 m² of mix laid). These analyses constituted the measurements required in the contract specifications.

As stated before, BRRC staff constantly present on site immediately interpreted the results of these analyses. From 1998 onwards, the management of analysis results was fully computerized: electronic forms, automatic calculation of moving averages, division into lots. The electronic forms were sent between the laboratories at the coating plants and the control unit at Brussels Airport through Internet – which was "unprecedented in our country" –, allowing immediate corrective action to deal with any arising problems.

The inspection system implemented that way certainly contributed to the great majority of the results of the contractual analyses meeting the requirements of the contract specifications.

7.4 Condition of the surfaces after milling

The surfaces exposed by milling were treated with a pressurized water jet and then systematically inspected for texture, the presence of any patches of asphalt, and any remaining cracks. On the basis of these visual inspections, the client decided whether any further milling was required.

7.5 Laying of mixes

Asphalt laying was systematically monitored. The following items were checked:

- the temperature of the mix during spreading;
- the treatment of longitudinal joints when an asphalt mix was to be laid "hot against cold", more particularly the width to which the laterally unconfined and, therefore, poorly compacted edge of the cooled adjacent strip of previously laid asphalt was trimmed off, and the effectiveness of the indispensable joint heater in heating the trimmed edge to approximately 60 °C;
- the thickness of the asphalt course;
- surface evenness (three-metre straightedge), with a view to making any corrections when the mix was still hot.

7.6 Voids

The densities of the freshly compacted asphalt layers were systematically measured (one point per 250 m²) with a nuclear gauge. The object of this measurement was twofold: first to detect any inadequately compacted areas with a view to taking immediate corrective action where necessary and, secondly, to serve as a reference for the contractual verifications of voids content. The densities measured were converted to voids using the correlations established on the asphalt of the trial areas. In doing so, allowance was made for the maximum densities measured each day in the laboratory.

Specific measurements of density were made where the surface exhibited signs of defects. Such was the case of a few cold joints, or in areas that looked irregular in aspect. The measurements showed whether the defect was merely superficial or affected the full depth of the layer, in which case the layer was locally replaced.

7.7 Characteristics of the completed surfacings

No core samples were taken from the new surfacings, except where holes had to be made for the lamps of the centre line beacons. These samples enabled the managing company to check the thickness of the surface course.

The longitudinal profiles of the completed surfacings were measured along five parallel lines with the APL. The results were compared to those of the corresponding measurements performed on the old surfacings and were in agreement in the great majority of cases – with a few exceptions, mainly for the longer wavelengths. Slightly lower performance was measured at a few points for those wavelengths, without, however, affecting the feeling of safety or comfort for pilots of aircrafts using the runways.

According to the results of skid resistance measurements with the SAAB Surface Friction Tester, the surfacings amply met the ICAO requirements after they had received their antiskid layers.

8. CONCLUSIONS

A thorough condition survey provided the basis for a specific renovation design for each runway. Subsequent preliminary studies and trial areas resulted in the final choice of layers to be placed.

The excellent cooperation between the client, the contractor and the inspection body during the execution of the works made it possible to construct, within the specified times, high-quality airfield surfacings with a design life of at least fifteen years.

According to information recently obtained from the managing company, the renovated surfacings – the oldest of which has now been in service for seven years – perform excellently.