TOULOUSE AIRPORT – REHABILITATION OF RUNWAY 14L/32R: TECHNICAL - ECONOMICAL AND ENVIRONMENTAL, GLOBAL OPTIMIZATION

J. BILAL,
Division Manager for Studies and Projects – Colas Group
bilal@campus.colas.fr

L. TAULEMESSE,
Area Manager, Sacer Toulouse – Sacer Atlantic
taulemesse@toulouse.sacer.fr

Y. GIMENEZ,
Project Manager, Department of air bases – DDE Haute-Garonne

INTRODUCTION

The Toulouse-Blagnac Airport is one of France's largest international airports. The scheduled traffic in 2006 was approximately 6 million passengers, a 2.7% increase compared to 2005.

In order to cope with the increase in traffic as well as the upcoming arrival of heavier aircraft such as the Airbus A380, the Toulouse Airport ordered the renovation of runway 1 (14L/32R) which is usually used for commercial flights. This renovation was necessary in order to meet the security standards for surface characteristics, and to reinforce the load capacity of the runway. It involved laying a 0.07 m-thick layer of Aeronautic Asphalt Concrete on a 45 m-wide central strip, leaving the 7.5 m-wide lateral shoulders for a lighter, less-costly treatment (after the removal of daytime beaconing).

The Toulouse reinforcement solution was defined using feedback from the experimental pavement carried out in 2001 on the taxiway W60, the goal of which was to validate reinforcement solutions for large aircraft carriers such as Airbus A380, A340-600 and Boeing B777. It aimed at keeping treated surfaces and overlay thickness to a minimum, for a saving of more than 50% of the normal cost.

The project followed an optimised schedule, and is a perfect illustration of a new approach to conception in technical methods of pavement construction work: First, this approach considers the environmental impact of different solutions; second, it seeks the most economical solution possible; and third, it fully meets the client's technical requirements.

1. HISTORICAL BACKGROUND AND EXISTING STRUCTURE

Runway 1 in Toulouse is one of the oldest runways in France. It was built in 1939 with a pavement structure of 0.19 m-thick concrete slabs measuring 5 x 5 m², 800-m long and 40-m wide. Between 1940 and 1943, the runway was lengthened to 1,700 m and widened to 60 m, while keeping the same structure. Then in 1953, it was reinforced and lengthened to 2,500 m, with a flexible structure made up of:

- 0.03 m Dense Graded Mix wearing course,
- Blocking material in semi-penetration,
- Crusher-run aggregate made up of mine-waste limestone.

In 1964, the track was lengthened by 500 m on its west side, with the following flexible structure:

- 0.07 m Dense Graded Mix wearing course,
- 0.20 m unbound gravel, partially rolled and crushed 0/40.
- 0.50 m Alluvial Crusher-run aggregate 0/100.

In 1965, a general 0.09 m-thick reinforcement of the Dense Graded Mix runway was added, and between 1983 and 1984, it was reshaped in a Grave Emulsion from 0 to 0.14 m thick, followed by a 0.06 m to 0.13 m-thick Asphalt Concrete reinforcement.
In 1992, the track was reinforced with a 0.06 m-thick Asphalt Concrete layer.

For the mechanical analysis of the structure and the verification of the reinforcement solutions, we retained the following average thicknesses:

0.06 m Asphalt Concrete wearing course realized in 1992
0.10 m Asphalt Concrete laid in 1983
0.16 m Coated Dense Asphalt
0.14 m Unbound gravel 0/40
0.50 m Crusher-run aggregate 0/80
Subgrade CBR5

2. AIR TRAFFIC

The annual commercial traffic of the heavy planes taken into account to define the reinforcement structure is approximately 50,000 movements distributed as follows:

Aircraft	Movements (per year)	Maximum mass on takeoff (in tons)
Airbus A320 and Boeing B737	40,000	70 to 80
McDonnell Douglas DC -10	810	260
Boeing B747 -400	160	395
Airbus A340-600	50	380
Airbus A380	50	490 to 590

Other aircrafts also use the runway, but their influence on the pavement fatigue is relatively negligible.

3. STATE OF THE RUNWAY BEFORE RENOVATION

The following problems were detected on the surface of the taxiway prior to rehabilitation work:

- construction joints were opening,
- generalized alligator cracking had appeared, particularly along the trajectory of heavy aircrafts' landing gears,
- surface materials were eroded

However, we did not notice any significant deformation, either of the rutting type or those related to the structure's bearing capacity.

IV. EXPERTISE AND REINFORCEMENT SOLUTIONS: TOULOUSE

Current practice in reinforcing and adapting existing pavements to heavy aircraft traffic consists in adding a 0.12 m-thick layer of High Modulus Asphalt binder (HMA) and a 0.06 m-thick Aeronautical Asphalt Concrete (AAC) wearing course. This is true of the Paris airports (runways 1 and 2 at Roissy and runway 4 at Orly), and runway 2 of the Toulouse airport.

This solution was considered too expensive, and it required the refitting of the entire runway including its connection ways. So, the Toulouse Airport engineering department was looking for an optimized solution at acceptable costs.

The technical analysis of the existing runway, and the results of the experiments on roads carried out by Colas, Airbus and the Toulouse Airport in 2001, enabled the team to validate a reinforcement solution that was significantly more economical and also quicker to implement.
In fact, costs were cut by more than 50%, compared to the solution initially considered.

Because of financial concerns, and to reduce the closing time of the runway, the client decided not to overlay the shoulders, which were in relatively good condition. The savings on the shoulders are far from negligible, 30% of the overall reinforcement cost, including the removal and reinstallation of the side beaconing.

The reinforcement solution retained is as follows:

1. To overlay only the 45 m-wide central strip of the runway, which well allows for the passage area of the landing gears of all aircrafts.
2. To mill the diurnal beaconing marks to ensure excellent fixation on the entire existing pavement.
3. To overlay a new 0.07 m-thick layer of Aeronautical Asphalt Concrete ”AAC” to the 45 m-wide central strip.

In addition to large savings, these choices also had a considerable impact on the environment since they reduce by more than half the overall greenhouse gas emissions (including emissions caused by manufacturing, implementation and transport).

V. VERIFICATION OF THE STRUCTURE DESIGN AFTER REINFORCEMENT

The verification of the structure was carried out by two different methods, the CBR method and the rational method ELSA developed by the Colas Group.

CBR METHOD

The method used in France to check the structures design of aeronautical pavement is the one recommended by the STAC:
"Technical Instruction 1999 - General Direction of Civil Aviation - Technical Service of the Civil Aviation"

It is based on the CBR index and the equivalence coefficients of materials.

The difficulty in using this empirical method lies in the estimate of the equivalence coefficients of the existing, old pavement materials, as well as those of special materials. It gives a theoretical total equivalent thickness depending on the traffic and on the bearing pressure of the ground support, which makes it possible to determine the technical layer thicknesses.

According to the STAC optimized dimensioning method, the minimum equivalent total thickness required to support the total traffic official statement (as previously detailed) and with a CBR 5 subgrade is **1.18 m**.

The equivalent thickness of the structure obtained in our basic solution is as follows:

Layers	Thickness (m)	Equivalence Coefficient	Equivalent thickness (m)
Aeronautical Asphalt Concrete wearing course (standard NF P 98 131)	0.07	2	**0.14**
Asphalt Concrete laid in 1992 (In relatively bad condition and fatigued)	0.06	1.5	**0.17**
Asphalt Concrete laid in 1983	0.10	1.5	**0.15**
Dense Graded Mix carried out into 1965	0,16	1,5	**0.24**
Unbound gravel 0/20	0.14	1	**0.14**
Unbound limestone gravel	0.50	1	**0.50**
Equivalent total thickness (m)			***1.26***

The equivalent total thickness of the structure after reinforcement is **1.26 m.**

The equivalent total thickness is 1.26 m. It is thicker than the necessary 1.18 m., thus meeting the dimensioning conditions of the STAC optimized method.

Rational method ELSA

We then compared these results for the third pavement to those obtained using the ELSA method (French acronym for Limit States of Acceptable Service).

The working principle of ELSA is to determine the maximum stresses and strains in the layers at the various stages of the structure's evolution, and to compare them with the acceptable limits of the structure's constitutive materials. Runway designing then takes into account the probabilistic combination of all the mechanisms of possible operation and loading that may be encountered during the working life of the structure.

The procedure for the design study of flexible pavements consists in:

- modelling the existing structure according to its thicknesses and to its constitutive materials rigidity moduli and Poisson ratios,
- calculating the strains throughout the different layers, using the reference of the most aggressive landing gear,
- determining the acceptable strain limit for each of the materials according to its particular mechanical characteristics (laws of material fatigue) and to the cumulated traffic,
- checking to see if the calculated strains are lower than the previously given acceptable limits.

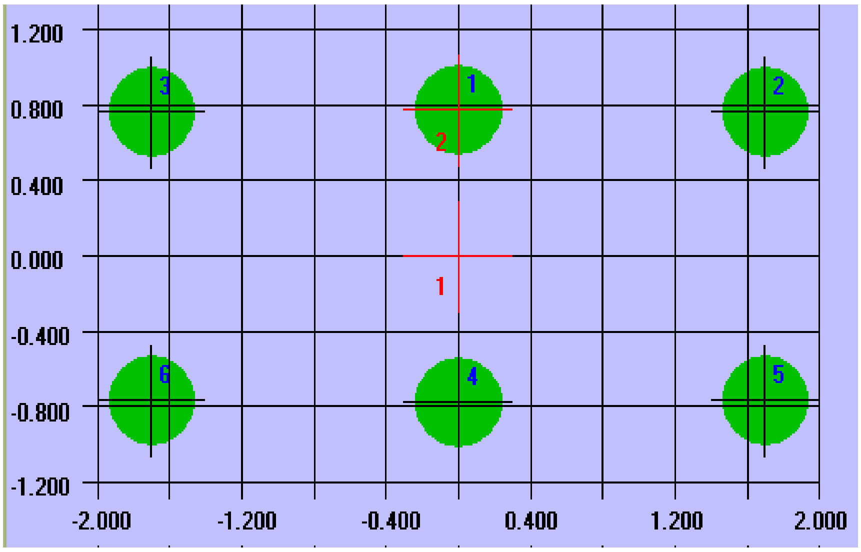
In our case, the critical element in designing is the plastic (irreversible) vertical strain at the surface of the layers made out of unbound materials, in particular at that of the subgrade. This strain is proportional to the stress intensity generated under the passage of the landing gears and to the cumulated number of movements.

Calculation of the stress and strain maxima

The pavement structure modelling can be done using an analytical program such as Alizé (by the French Laboratoire Central des Ponts et Chaussées). The use of finite element software is not necessary for the flexible pavements.

Photo 2: Airbus A380 with 6-whell landing gear

We retain as reference loading, the A380 plane with a 6-wheel landing gear (Photo 2) described in figure 1.



Total load: 156 tons per 6 wheels bogie

Contact pressure: 1.5 MPa

Figure 1: Modelling of the 6-wheel landing gear of the A380 Airbus

There is a direct relationship between the stress and vertical strain generated at the ground support surface under the passage of a load, and the plastic deformation of the ground.

For example, figure 2 shows the vertical strain at ground support surface under the passage of a A380 6 -wheel landing gear obtained with Alizé.

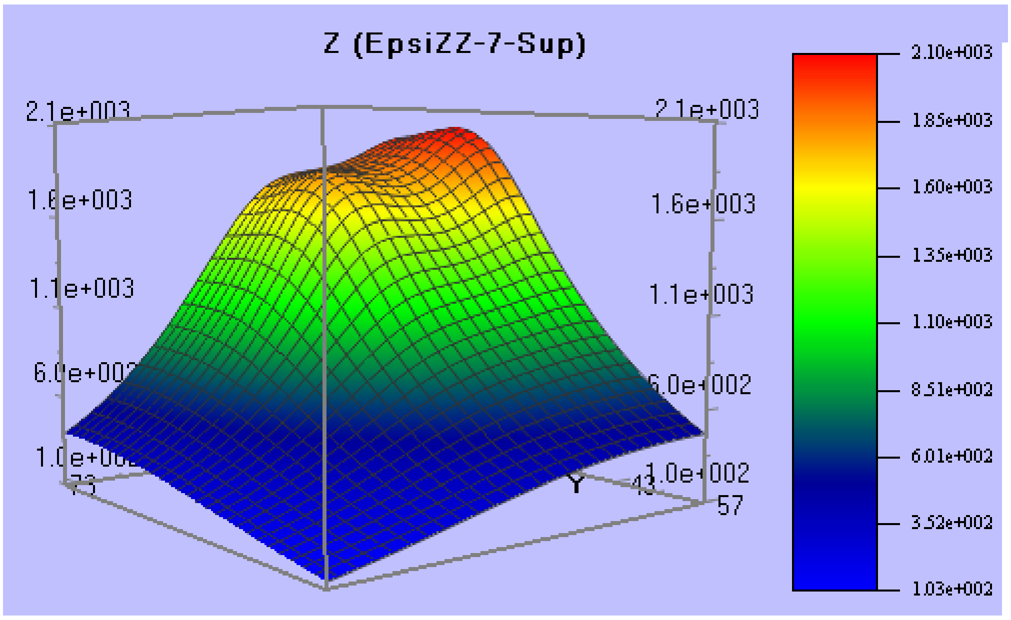


Figure 2: Vertical strain at ground support surface under an A380 main landing gear as calculated with Alizé

Design Traffic

The designing method ELSA calculates the cumulated total fatigue damage caused by the passage of all planes. However, since the bogie loadings are different for each plane, we must compare the damage caused by any given plane with that of a reference plane, thus calculating an "Aggressiveness factor" according to the configuration of its structure and landing gear. The aggressiveness factor makes it possible to express the partial damage caused by a plane compared to the damage caused by the passage of the reference plane, which in our case is the A380 Airbus.

NB: Various simulations highlighted the absence of interaction between the bogies of the A380 plane. However, it is necessary to remain cautious and not generalize this result to rigid pavements.

The following table summarises the aggressiveness factors of different planes and their equivalent number of movements per annum, in terms of A380 planes.

Type of plane	**Movements (per annum)**	**Aggressiveness of the plane compared to A380**	**Movements in A380 equivalence**
Airbus A380	50	1	50
Boeing B747-400	160	0,60	96
Airbus A340-600	50	0,46	23
McDonnell Douglas DC-10	810	0,45	365
Airbus A320 and Boeing B737	40 000	0,04	1600
Overall movements per annum in terms of equivalent A380 planes			2134

For example, the aggressiveness of an A320 Airbus compared to that of an A380 Airbus is 0.04. This means that one passage of an A380 causes as much structural damage as the passage of 25 A320s.

It is also necessary take into account the transverse distribution of the passages of planes, that is, the covering rate which corresponds to the real passage of the landing gears at a given point of the pavement. According to statistics, this covering rate is between 3 and 4. The French Civil Aviation gives a value of 3.65. Thus, for a total number of movements of 2134 per annum, the traffic to be retained for the checking of the pavement will be 585 movements per annum.

For a 10- year design life, the total traffic cumulated in equivalence of A380 planes will be 5850 movements.

Figure 3 shows the total plastic strain of the pavement (W) according to the cumulated total number of plane passages, given in terms of equivalent A380 planes.

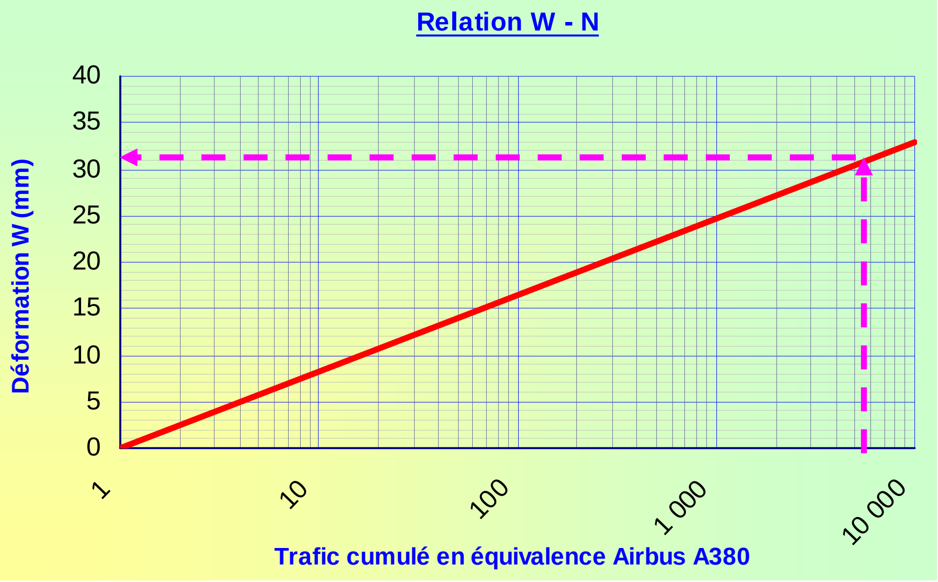


Figure 3: Total plastic strain of the pavement according to the total number of movement equivalent to A380 planes

For a cumulated total traffic of 5850 equivalent A380 movements, the total deformation of the subway will be 31 mm.

It is advisable to see if this total deflection of approximately 3 cm is acceptable in terms of constraints of operating of the runway.

NB: This deformation does not include nor account for possible rutting.

6. PARTIAL ANALYSIS OF ENVIRONMENTAL IMPACT

In order to comply with the Kyoto protocol, the French government set up a national programme to fight climate change, based on the work entrusted to the Interdepartmental Mission of the Greenhouse Effect. One of the principal actions of this Mission is to stabilise the national greenhouse gas emissions over the period 2008-2012. The second environmental impact systematically evoked in Sustainable Development engagements is the optimization of natural resources, in particular the reduction of energy consumption. In the Toulouse runway renovation, we sought to apply this protocol in designing a solution.

To properly characterise the environmental aspects of runway renovation project, we carried out an analysis of the life cycle (LCA) of the basic structure (0.06 m AAC/0.12 m HMA) and the one carried out (0.07 m AAC). The LCA takes into account all consumption, from the extraction of raw materials to their use, including manufacturing, transportation, and all related operations (equipment and staff transport, equipment wear, etc.).

However, this analysis accounts only for the pavement construction in itself. Side effects of the traffic intended to circulate on the pavement, of the indication, safety equipments, etc. are not taken into account.

Figure 4 gives the overall energy consumption necessary to the realisation of one m² of pavement, from the extraction of the raw materials to their use on the building site. Energy is expressed in MJ (Megajoules) per m² of pavement.

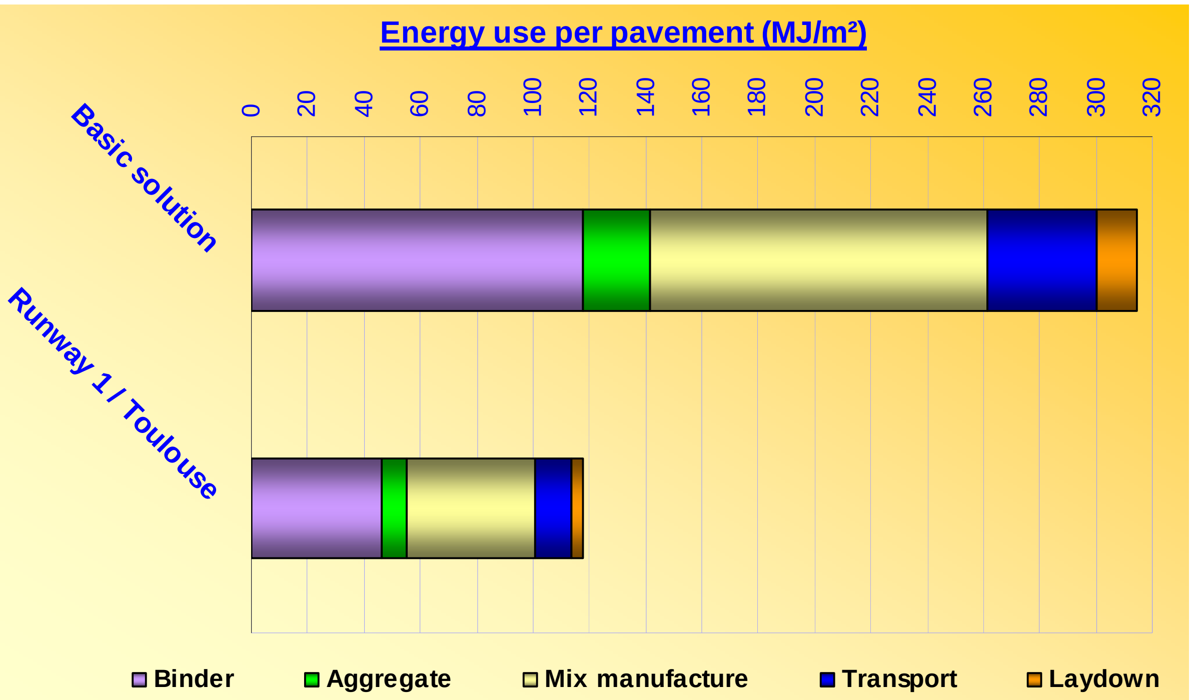


Figure 4: Overall energy consumption per m² of pavement, for each reinforcement solution

The main greenhouse gases produced in the field of road construction are carbon dioxide (CO_2), dinitrogen oxide (N_2O) and methane (CH_4).

Since the greenhouse effect is different for each of these gases, it is appropriate to express their effect in GWP (Global Warming Potential) expressed in equivalent CO_2. It is agreed that the GWP of N_2O is 310 and that of CH_4 is 21, which means that one kg of N_2O contributes as much as 310 kg of CO_2 to global warming. The greenhouse gas emissions are thus expressed using a CO_2 equivalence.

Figure 5 presents the quantity of greenhouse gases released during the manufacturing and the realisation of one m² of pavement, from the extraction of the raw materials to their use on the construction worksite, expressed in CO_2-equivalent kg per m².

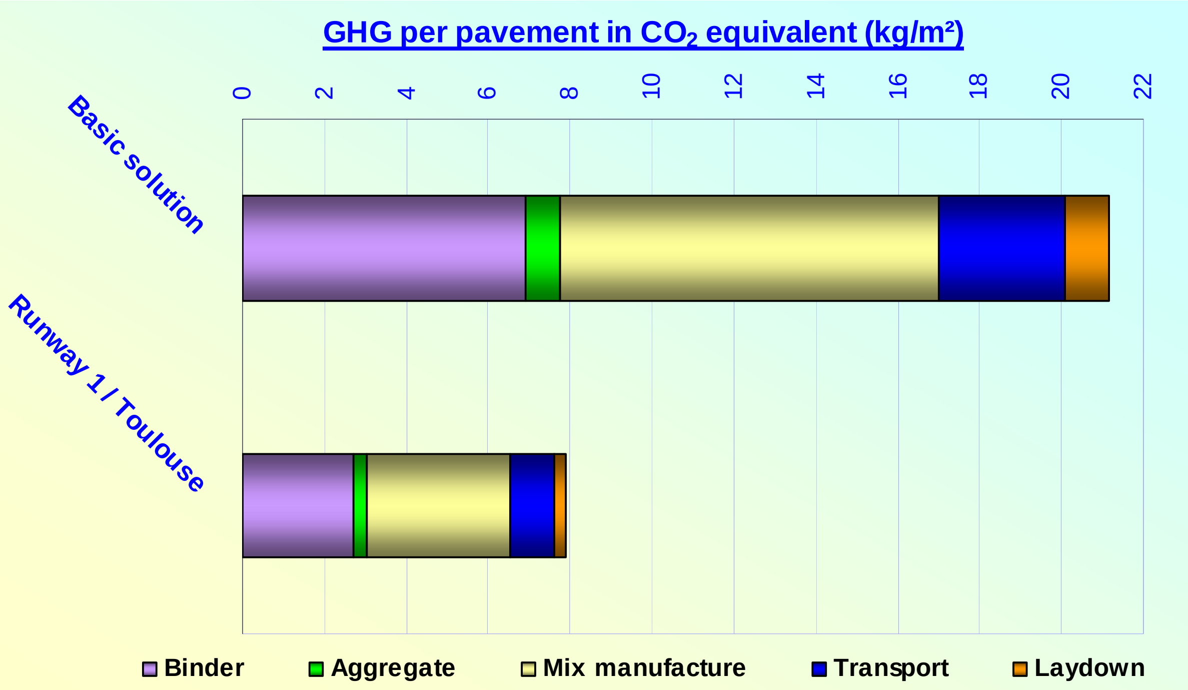


Figure 5: Greenhouse gas emissions for each reinforcement solution in kg of equivalent CO_2 per m² of pavement

7. CONCLUSION

It becomes clear, then, that the innovative technical solutions adopted for the Toulouse renovation also generated excellent results for the environment and significant savings for the client. However, in order to validate the overall approach to this operation (optimizing technical, economical and environmental requirements), the performance of the overlaid structure of runway 14L/32R must now be very carefully monitored

BIBLIOGRAPHICAL REFERENCES

J Bilal, "Design and dimensioning of the industrial grounds, ELSA an original approach", RGR n° 734, November 1995

J Bilal – Y. Gimenez – P. Beaulieu – P. Dessiaume, "High Performance Bitumen Binders for Reinforcement of Aeronautical Pavement - Experiments on the Toulouse-Blagnac Airport", RGR n° 808, July 2002

J Bilal – Ph. Rey, "Designing Airfield Pavement For Heavy Jumbo Jets" - 2004 FAA WORLDWIDE AIRPORT TECHNOLOGY TRANSFER CONFERENCE - Atlantic City, New Jersey, the USA April 2004

J - Bilal –M. Chappat, "The Ecological Road of the Future". Colas report/ratio, September 2003