DESIGN OF ASPHALT RUBBER OVERLAYS FOR PCC PAVEMENTS IN AIRPORT RUNWAYS. THE CASE OF THE AIRPORT OF VITORIA, SPAIN.

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ABSTRACT. *Asphalt mixes with asphalt rubber have been widely employed in highway pavements. However, their use is much less common in airport runways. This paper proposes a design method for rehabilitation of PCC airport pavements with asphalt rubber overlays.*

In the case of the Foronda Airport in Vitoria, Spain, the runway is 3.5 km long and its pavement is constructed from PCC slabs. There are partial breaks in some of the slabs and signs of fatigue have appeared around the contact points. The region has a intermediate climate, with temperatures as low as -1 ºC in the winter.

Several alternatives were suggested for use as the overlay. In the end, 10 cm of bituminous mixes with asphalt rubber were added. This article presents an overlay design procedure

based on the FAARFIELD (Federal Aviation Administration Rigid and Flexible Iterative Elastic Layered Design) program, combined with a method of thickness reduction previously applied only to highways. The application of this methodology generated a thickness of 10 cm, which corresponds to the thickness of the overlay with which the runway was actually reinforced, making the Vitoria airport an important case study.

KEYWORDS: *Asphalt rubber, rehabilitation, airport runway*

1. Introduction

The Foronda Airport in Vitoria, Spain, identified as LEVT by the ICAO, was inaugurated in 1980 and most of its pavements date back to this time. The airport has one runway 04/22 that is 3,500 metres long and 45 metres wide. The runway offers an ILS that allows it to operate in meteorological conditions with limited visibility. For many years, the airport has specialised in freight traffic, with an insignificant amount of passenger traffic.

The airport receives a fleet of airplanes that includes B-747, A-300, MD-83, and BAe-146 airplanes, among other large aircraft. A variety of general aviation aircraft also make use of the airport. It is also notable that the runway has been used by the largest airplane in service, the Antonov-225.

In 2010, the airport decided to carry out a rehabilitation of the runway pavement, made up of concrete slabs, as roughness defects had been observed as well as a series of concrete slabs with signs of structural damage.

In the field of aviation, and more specifically that of airport pavements, the design methods of the Federal Aviation Administration (FAA) are deeply rooted. The Advisory Circular AC-150/5320-6E [1] offers the latest version of the design for new pavements and the rehabilitation of existing ones.

Unfortunately, this AC does not explicitly consider bituminous mixes with asphalt rubber in the special techniques for prevention of reflection cracking in section 405.5, *Overlays of existing rigid pavements: Reflection cracking in hot mix asphalt overlays*. Thus, it is not easy to apply thickness reductions to airport overlays as there is no existing methodology specifically designed for airport pavements that focuses on the resistance to reflection cracking offered by asphalt rubber mixes.

However, it has been clearly demonstrated that the resistance to aging and cracking are greater in asphalt rubber mixes, including in airport pavements [2]. This paper proposes that a method normally employed for the rehabilitation of highway pavements be applied to airport pavements, using the rehabilitation of the Vitoria airport pavement as an example.

At the time of the rehabilitation, the design of the overlay was justified by means of a formula based on the old Load Classification Number (LCN) method; this study, however, proposes the same design of the overlay, this time obtained by means of the latest version of the AC-150/5320-6E. The thickness for the conventional bituminous mix overlay provided by the FAARFIELD caluculations is subsequently reduced to adjust for the resistance to reflection cracking offered by asphalt rubber mixes. This constitutes the true innovation of this article.

2. Brief description of AC-150/5320-6E. Overlays of existing rigid pavements.

The FAA Advisory Circular AC-150/5320-6E [1] is used for the design of new airport pavements and for the rehabilitation of old ones that exhibit damage. This AC employs a finite elements method for rigid pavements; to facilitate the calculations for its users, it is accompanied by a software called FAARFIELD (Federal Aviation Administration Rigid and Flexible Iterative Elastic Layered Design).

The FAARFIELD program is easy to use. In the case of a rigid pavement rehabilitation, the user inputs the thickness of the existing layers: concrete slabs, cement-treated base courses and granular layers, as well as the modulus of each.

In the same way, the program must be supplied with some parametres that indicate the structural condition of the pavement to be rehabilitated. There are two parametres:

- CDFU: Cumulative Damage Factor Used, which defines the amount of structural life that has been used by the existing pavement up to the time of the overlay.
- SCI: Structural Condition Index, derived from the Pavement Condition Index (PCI), using just 6 modes of distress: corner break; longitudinal, transverse and diagonal cracking; shattered slab; shrinkage cracks; joint spalling; and corner spalling. An SCI of 80 is the FAA definition of structural failure of a rigid pavement and is consistent with 50% of slabs in the traffic area exhibiting structural cracks.

The FAARFIELD program also requires information regarding the fleet of airplanes which the airport will receive. To facilitate the introduction of the fleet, with the departure frequency and projected annual growth rate, the program offers a library from which to select the most common aircraft models. For each model, the number of annual departures is introduced as well as the annual growth expected in the coming years.

Finally, the design life of the project must by introduced; this is usually established at 20 years.

Based on this data and on the modulus of the overlay, the program calculates by successive iterations the necessary thickness of conventional bituminous mixes for the pavement overlay.

3. The case of the Vitoria airport: designing an overlay with FAARFIELD.

The runway of the Vitoria airport is not composed of homogenous pavements. The soil modulus of subgrade reaction varies from section to section between 30 and 130 MN/m^3, and the thickness of crushed stone + PCC slab also varies between 32 + 25 cm with weaker subgrades and 22 + 15 cm with the subgrades with the highest modulus of subgrade reaction.

In order to use a section that is representative of the entire runway, the following section was chosen and used in the FAARFIELD calculations:

- 30 cm of PCC slab, with a flexural strength equal to 5.0 MPa
- 20 cm of crushed aggregate, with a modulus of 477 MPa
- Modulus of subgrade reaction equal to 80 MN/m^3

An “undefined” material was chosen for the overlay, as this enabled the modulus to be established at 5,500 MPa. As this is not a standard FAA material, the FAARFIELD results displayed a “non-standard structure” warning.

As for the structural state of the Vitoria airport, the CDFU was established at 100, as the airport opened to traffic 30 years ago. This is a conservative hypothesis as it supposes that the pavement has consumed 100% of the structural life for which it was designed.

It was also observed that a high percentage of the slabs, around 40%, exhibited structural cracks, although the state of the pavement is acceptable and its main problem is surface regularity. From this data, its SCI was estimated to be around 85.

The FAARFIELD program requires fleet and annual departure frequency data to calculate the overlay. According to the statistical data available from the Vitoria airport, the entire mix of aircraft was grouped into four types, represented by the most common aircraft of each type:

- B747-400ER Freighter: 2,049 annual departures, 3% annual growth
- A300-600 LB: 4,474 annual departures, 3% annual growth
- MD83: 17,207 annual departures, 3% annual growth
- BAe 146: 10,324 annual departures, 3% annual growth

The use of an aircraft that is representative of a group is not common practice with the AC-150/5320-6E, but it was necessary as more concrete data regarding the

distribution among the different models within each group of airplanes was not available.

The design life of the project has been established at 20 years, common practice in this type of airport pavement project.

Figures 1 and 2 show screenshots of the combination of aircraft and pavement characteristics that were introduced to the program. Figure 2 also shows the results of the calculation: the recommended overlay thickness is 168.4 mm.

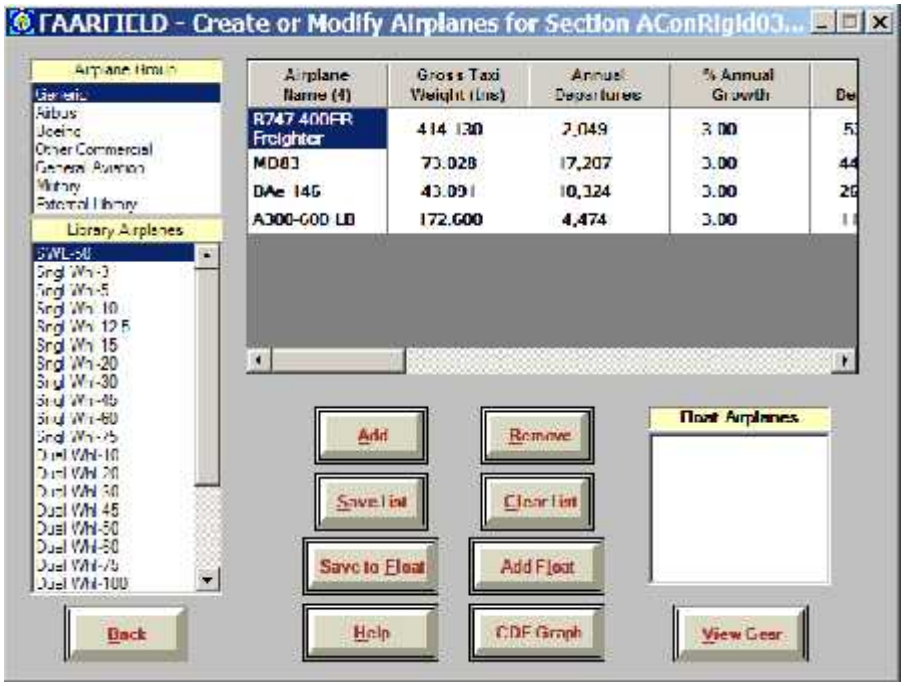

Figure 1. *FAARFIELD screenshot: combination of airplanes at the Vitoria airport.*

The AC-150-5320-6E admits that reflection cracking is often a problem in hot mix asphalt overlays, particularly in rigid pavement overlays. The thickness generated by FAARFIELD, however, does not address reflection cracking. The AC suggests several techniques that have been tested in an attempt to address this problem, to varying degrees of success: coarse aggregate binders, rubblisation of the existing PCC pavement, engineering fabrics, asphalt reinforcement with high tensile strength and low strain capacity, etc.

As the technique of using asphalt rubber mixes to resist reflective cracking is not recognized as a valuable strategy in the latest AC, this paper suggests the application of a highway-based method to reduce the thickness of the asphalt mix overlay in order to properly control the problem of reflective cracking.

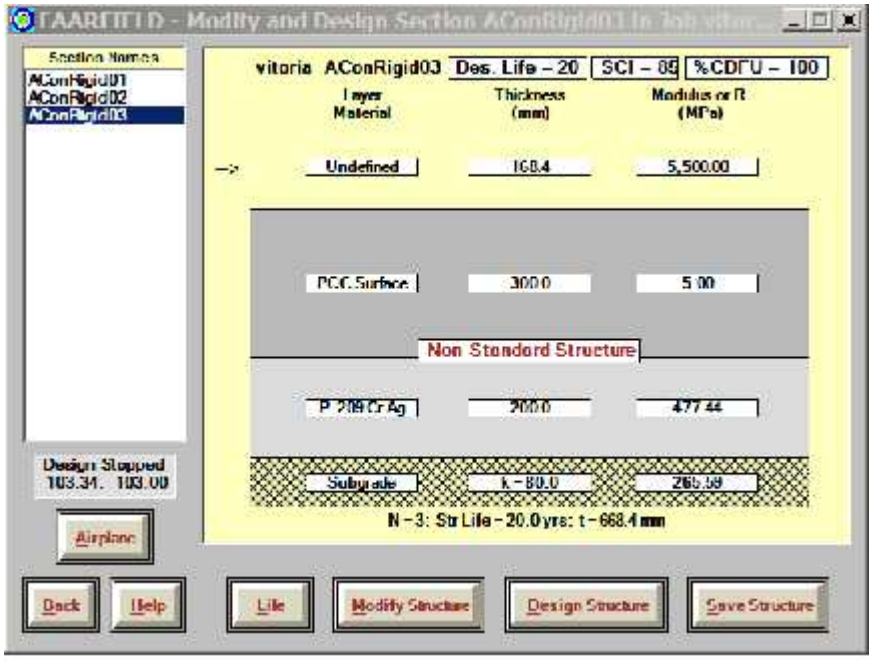

Figure 2. *Existing pavement and overlay calculated with FAARFIELD.*

4. Reducing overlay thickness with asphalt rubber mixes

Various methods exist to estimate the thickness equivalent between conventional bituminous mixes and bituminous mixes with asphalt rubber, in an attempt to control the problem of reflective cracking. These methods come from highway engineering, a field of study in which asphalt rubber mixes have often been applied with the goal of controlling reflective cracking. This article will consider the mechanistic-empirical overlay design method for reflective cracking proposed by Sousa et al. [3]. This method is based on follow-up from real cases of 150 in-service highways in Portugal, Arizona and California, as well as on laboratory tests and modelling with finite elements.

The study considers two types of mixes: the first, a dense asphalt mix, with 5% bitumen; the second, a gap-graded mix with 8% asphalt rubber. The model incorporates corrections for the aging of the materials and for the temperatures that the overlay will suffer throughout the year. It is valid for asphalt pavements as well as for PCC pavements.

It also requires the introduction of the thickness of the existing pavement layers, their moduli and the percentage of reflective cracking after 10 years in service. This method offers an estimation of the evolution of reflective cracking with two

different materials: dense-graded asphalt mix and gap-graded asphalt rubber mix. The result is a graph in which the equivalent thickness is established between the conventional bituminous mix and the asphalt rubber mix for the same pavement conditions, yearly temperature range and traffic load.

It is important to mention that the temperatures are calculated from the statistical data. The mean annual air temperature is defined according to the Shell design method [4]. This temperature is a weighted temperature; the weight factor (w-factor) is a function of the mean monthly air temperature (MMAT) and can be obtained by the equation (1):

$$w - factor = 0.0723e^{0.1296MMAT} \quad (1)$$

Thus, the mean annual air temperature (w-MAAT), as proposed by the Shell design method, can be calculated using the equation (2):

$$w - MAAT = 7.7068 \cdot Ln(w - factor) + 20.257 \quad (2)$$

where the w-factor is the average of the w-factors calculated for all 12 months of the year and MMAT is the mean monthly air temperature.

In the case of the Vitoria airport, the following values were introduced:

- Cracking at end of design life: 5%
- Maximum air temperature: 28.1 ºC
- Mean monthly air temperature: 13.2 ºC
- Minimum air temperature: -1ºC
- PCC moduli: 25,000 MPa
- Slab thickness: 30 cm
- Granular layer elastic modulus: 477 MPa
- Granular layer thickness: 20 cm
- Subgrade elastic modulus: 265 MPa

Figure 3 shows the results obtained by this method. It can be observed that the approximate thickness of 160 mm of conventional mixes, obtained by the FAARFIELD program, is equivalent to 90 mm of mixes with asphalt rubber.

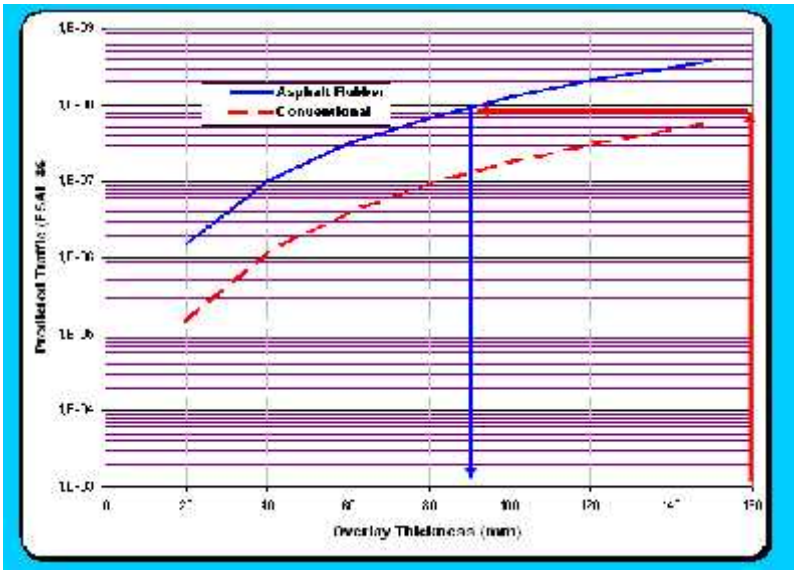

Figure 3. ***Thickness equivalent of overlay with conventional and asphalt rubber mixes.***

Thus, with a view to controlling reflection cracking, a 160 mm overlay of conventional bituminous mixes would offer the same protection to the pavement as 90 mm of gap-graded asphalt rubber mixes.

Nonetheless, one should be aware of the limitations of this method: it is a highway-based method, calibrated on the basis of highway observations, where the vehicles have an equivalent single axle load (ESAL) of 86 kN. It is obvious that the loads transmitted to pavements by aircraft are much higher, especially in the case of large aircraft.

However, it can be observed that in this instance, an estimation of the number of airplanes that could use the runway was not attempted; instead, this study sought to establish an approximate equivalent between the thickness of an overlay made of a conventional bituminous mix and one made of a gap-graded asphalt rubber mix, when submitted to the same temperature conditions – those of Vitoria – and the same traffic load.

Considering that the mechanisms that generate reflection cracking must be very similar in highway and airport pavements, the contribution of this paper is a first step toward a methodology that should be fully applicable to airports. Continued research will be necessary, however, in order to adapt this methodology to airport

pavements. The involvement of airport authorities would be very valuable to new research projects.

This is an important field of application for asphalt rubber, as PCC pavements are very common among airport surfaces: runways, taxiways, parking areas, etc. They often have an adequate structural capacity and only require correction of surface irregularities (roughness). What is more, routine maintenance of concrete slabs is expensive, which is why in many cases it is preferable to apply an overlay, which can be of reduced thickness if gap-graded asphalt rubber mixes are used.

5. The rehabilitation project at the Vitoria airport.

In the summer of 2010, the rehabilitation of the airport runway pavement was carried out. 10 cm of gap-graded asphalt rubber mixes were laid in two layers: the first of 6 cm and the second of 4 cm.

The asphalt rubber for the project was supplied by the Asfaltómeros S.A. company, the project was carried out by the Vías y Obras S.A. construction company and the technical assistance was provided by Conelsan, which specialises in airport works. The Spanish airport management group AENA (Spanish Airports and Air Navigation) accepted the use of this material, although the thickness of 10 cm had not been reached by means of the procedure proposed in this paper, which is a combination of the FAARFIELD program and a method used to reduce the thickness of overlays for highway surfaces, considering the special the resistance to reflective-cracking properties demonstrated by asphalt rubber mixes.

Follow-up is currently being done to monitor the behaviour of the asphalt rubber overlay. Some years will be necessary to evaluate its behaviour in the mid- to long-term.

6. Conclusions.

The most important points of this study can be summarised as follows:

- A method was proposed, based on the FAARFIELD (Federal Aviation Administration Rigid and Flexible Iterative Elastic Layered Design) program and on a method used for highway pavements, for the estimation of reduced thickness overlays in airport pavements with asphalt rubber and for controlling the phenomenon of reflection cracking.
- For the application of this method, an estimation of the number of airplanes that could use the runway was not attempted; instead, this study sought to establish an approximate equivalent between the thickness of an overlay of a conventional bituminous mix and one

made of a gap-graded asphalt rubber mix, when submitted to the same temperature conditions and the same traffic load.

- The thickness obtained by this procedure for the airport in Vitoria, Spain, is the same as was installed on the runway 04/22 in the summer of 2010, making it a case study that could contribute to the possible validation of the methodology described here.
- It is clearly important to continue this research in order to calibrate the procedure for thickness reduction of asphalt rubber overlays for application to airport pavements.
- Given that PCC pavements are very common in airport surfaces and that these surfaces often have an acceptable structural capacity, but that they require improvements to their regularity and continual work to maintain the PCC slabs, it may be preferable to apply a reduced thickness overlay of asphalt rubber mixes, as these mixes offer greater resistance to reflective cracking, one of the main problems with overlays on existing PCC airport pavements.

7. Bibliography

[1] *Advisory Circular AC-150-5320-6E: Airport Pavement Design and Evaluation*. Federal Aviation Administration. U.S. Department of Transportation: 2009.

[2] Saboundjian, S., Knopke, T. and Raad, L. *Field Aging Effects of Asphalt Rubber Mixes and Conventional Mixes for Runway Surface Applications.* FAA Worldwide Airport Technology Transfer Conference. Atlantic City, New Jersey: 2004.

[3] Sousa, J.B., Pais, J.C., Saim, R., Way, G.B. and Stubstad, R.N. *Mechanistic-Empirical Overlay Design Method for reflective Cracking.* Transportation Research Record 1809. Washington, D.C.: 2002.

[4] Claussen, A.I.M., Edwards, J.M., Sommer, P. and Ugé, P. *Asphalt Pavement Design. The Shell Method.* Proceedings: Fourth International Conference on the Structural Design of Asphalt Pavements, Vol. I, 39-74. Ann Arbor: 1977.