Evolution of the Structural Condition Index of Airport Rigid Pavements

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Abstract

Increasingly air transport is used to facilitate the movement of people and goods. This increase leads to greater vigilance with regard to verification of the conditions of service of airport infrastructure.

To ensure the service levels that are required for the safety of aircraft, one of the necessary actions is the observation of the evolution of pavement conditions, mainly due to the actions of traffic and climate, which necessarily implies making with recurrent, an assessment state floor so timely schedule for interventions on them.

This dissertation studies the evolution of the structural condition index (SCI) in the aprons of two international portuguese airports in a period of three years and assesses the possibility of establishing a pavement condition forecast for the following years. This index is determined by the typical distress of rigid pavements, the level of severity associated with it and the number of observed slabs.

The methodology for determining the SCI provides for the assessment of pavement condition based on visual inspection, in particular the anomalies observed in the pavement. This pavement condition index is rated from 0 to 100, where 0 is the condition worse and 100 that represents the best deck state.

Aiming to find a trend in the evolution of SCI a relation was established between the deducted values of the most constraints pathologies (the evolution of the deducted values of the distresses over the three years), the number of aircraft over the three years and the value of the structural condition index of the pavement.

Key-Words: Structural Condition Index; Evolution of the pavement condition; Rigid Pavement; Distress; Severity Level

Introduction

The increase in the demand of air transport inevitably led to the technological development of aircraft, requiring at the same time to the infrastructure of support to the operation of these to give an appropriate response through good structural and functional conditions and safety.

Hence the need for methods of assessing the state of the pavement for his condition at any given time and make deductions on his lifespan or need for any intervention. To this end the structural and functional aspects are evaluated on the same drive (stretch, section, element, etc.) at intervals previously established. The data of these evaluations feed performance prediction models previously calibrated to the pavement, allowing estimating a performance curve and thereby predicting the future level of service.

With this estimate can be programmed maintenance operations and reconstruction of the pavement, keeping service levels above the acceptable minimum.

In this document and in the context of application of these concepts is presented a brief description of the analysis of the structural condition of rigid pavements (used in aprons) of two portuguese international airports (Airport 1 and Airport 2) using the analysis of the evolution of the index of the structural condition of airport rigid pavements.

Methodology for determine the value of the Structural Condition Index (SCI)

To determine the value of structural condition index is necessary to take into account various parameters, type of distress, its severity level and the number of slabs in which the distress is observed (ASTM, 2011).

The circular AC 150 / 5320-6E (FAA, 2009) defines the conditions that contribute to determining the value of the SCI, which are shown in Table 1, as well as their severity levels.

Table 1 – Distresses and Severity Levels

Distress	Severity Levels
Corner Break (2)	Low, Moderate e High
Longitudinal, Transverse, and Diagonal Cracks (3)	Low, Moderate e High
Shattered Slab (12)	Low, Moderate e High
Shrinkage Cracks (13)	-
Joint Spalling (14)	Low, Moderate e High
Corner Spalling (15)	Low, Moderate e High

The description and how is measured the number of slabs in which each distress is present, are described below according to the norm D5430 (ASTM, 2011).

- **Corner Break**

This type of cracks occurs in the vicinity of slab corners and are characterized for intersecting the joints that delimit the corners. The distance between the joint and the crack, measured from the corner, should be less than half the length of the slab.

This type of distress may occur due to excessive repetition of loads acting on the pavement and the loss of carrying capacity in that part of the slab.

This condition differs from the corner spalling appearing on the slab corner, because these cracks arise perpendicularly to the sides of the slab, while the spalling appear at a given angle of incidence.

The distress is registered as present in a slab is: a single corner is broken; more than one corner is broken with a specific level of severity; two or more corners are broken with different levels of severity.

If two or more corners in the slab are broken it must be registered the highest level of severity.

- **Longitudinal, Transverse, and Diagonal Cracks**

This type of cracks is characterized by dividing the slab into two or more elements. The cracks extend along the length of the slab, i.e., from one end to another or to find other crack.

Possible causes for its appearance are the repetition of acting loads and shrinkage stresses.

After the identification of the distress severity level it is registered as present in a single slab. They must be recorded only the cracks detected in current inspections and not others recorded in previous inspections which have been subject to repair by replacing the original pavement material replacement material (patches).

- **Shattered Slab**

The shattered slab occurs when a high number of cracks joins and divide the slab into four or more elements.

This condition may occur due to high traffic on the pavement and insufficient foundation support capacity.

In the case of a shattered slab with a high or medium severity level should not be considered the existence of spalling, durability cracks or scaling, even if they exist, because it would substantially affect the slab classification. The shrinkage cracks should not be taken into account when the slab is shattered in four or more elements.

- **Shrinkage Cracks**

Such cracks are smaller than the cracks already discussed, once it does not traverse the slab throughout their length. Occur in laying and curing of the concrete due to retraction, forming surface cracks.

If there are one or more shrinkage cracks in a slab this is counted as one slab with shrinkage cracks.

- **Joint Spalling**

It consists of the breakdown or breakage of the slab joints. This type of distress generally occurs about 0.6 m of the joint forming an angle with the joint.

This type of distress may occur due to excessive stresses on the pavement, the cracks having therein incompressible material, or even because it is a weaker zone of the slab where very high loads are acting.

If the spalling is located along the slab joints counts as a slab. If the spalling is located in more than one slab joint, the one with the greatest severity level defines the severity level of the slab displaying the distress. The appearance of spalling can occur between two adjacent slabs. In this case each slab is counted as having the distress.

- **Corner Spalling**

It consists of the breakdown or breakage of the slab corners. This type of distress generally occurs about 0.6 m from the corner forming an angle with the joints.

This type of distress may occur due to excessive stresses on the pavement, the cracks having therein incompressible material, or even because it is a weaker zone of the slab where very high loads are acting.

If there is spalling in one or more corners of the slab, and these have the same level of severity, the slab is recorded as having spalling the corner. If it has more than a severity level is accounted that the slab has the highest severity level checked.

The parameters mentioned above are determined using visual inspection, which is performed by a specialist who performs the inspection on foot or in a vehicle and uses its own software for the registration of necessary elements (distress, severity levels and counting the number of slabs) for the determination of the value of SCI.

With the distress, the severity levels and the number of slabs, is possible to determine the density of each distress. Knowing the density you can determine the deduct value (DV) that each distress have in the subsection under review. For such abacuses contained in D5430 standard are used (ASTM, 2011) that allow to relate the density of each distress with the severity level they have. Knowing the deduct value of each distress is performed "a filter", by which all deducted values that are below 5 are deleted. After the "filtering" the significant deduct values for analysis (which are equal to or greater than 5) are added, determining the Total Deduct Value (TDV). With this value and using the abacus that relates TDV with the number of distress that have a deduct value equal to or greater than 5, D5430 standard (ASTM 2011), it’s possible to determine the Corrected Deduct Value (CDV). This corrected value is subtracted from 100 thereby yielding the value of structural pavement condition index (Equation 1).

$$SCI = 100 - a\sum_{i=1}^{ms}\sum_{j=1}^{nj} f\left(T_i; S_j; D_{ij}\right) \qquad (1)$$

a – adjustment factor

ms – Total number of distress type related to the pavement structural failure

nj – total number of severity levels for the ith distress

$f(T_i; S_j; D_{ij})$ – deduct value for distress type T_i, at the severity level S_j, existing at density D_{ij}.

This process was carried out for all subsections of all aprons.

Evaluation of the evolution of the Structural Condition Index

Knowing the value of the structural condition index of each subsection of each apron is determined the value of the structural condition index (SCI) of these aprons over three years of analysis. The SCI values of each apron are reached by calculating the average of the values of structural condition index of each subsection.

After obtaining the values of the SCI for the three years of data was possible to carry out a review of its evolution in each apron. From there, it was possible to make a comprehensive analysis for each airport (Airport 1 and Airport 2) of the value of the SCI. To allow the assessment of the variation or dispersion of the SCI values from the average the standard deviation was calculated for each apron for the three years under review. This measure indicates that if the value is low, the values determined for the SCI for each subsection tend to be close to the average, if it is high the values are scattered. In addition it was determined the coefficient of variation indicating the accuracy of the data analyzed, i.e., the lower its value greater accuracy.

For Airport 1 were analyzed nine aprons and for Airport 2 were analyzed seven. In this abstract we present the analysis of one of the studied aprons, because it is the one that best evidences the relationship to be studied between the evolution of the structural condition index, the critical distresses existing in the aprons and the traffic in them. Thus, it describes the analysis done for apron designated by 14 APRON of Airport 1, done similarly for the remaining plates.

- **APRON 14**

On the apron called APRON 14 (Figure 1) it is found that there is a decrease in the value of the structural condition index in the three years under review, more pronounced in 2012 and 2013. It is noted that in 2011 there are three distinct types of distresses (linear cracks; joint spalling and corner spalling), which even with high deduct values do not cause a decrease in the value of the structural condition index. Nevertheless, these conditions should be monitored, since the loads acting with their level of severity or its density may increase, becoming significant for analysis.

In 2012 and 2013 there was a decrease in the value of structural condition index of the pavement, inferring an increase of its degradation. In 2012 the reduction of SCI may be due to the emergence of a new distress (corner break) or increase of the deducted value from corner spalling and linear cracks.

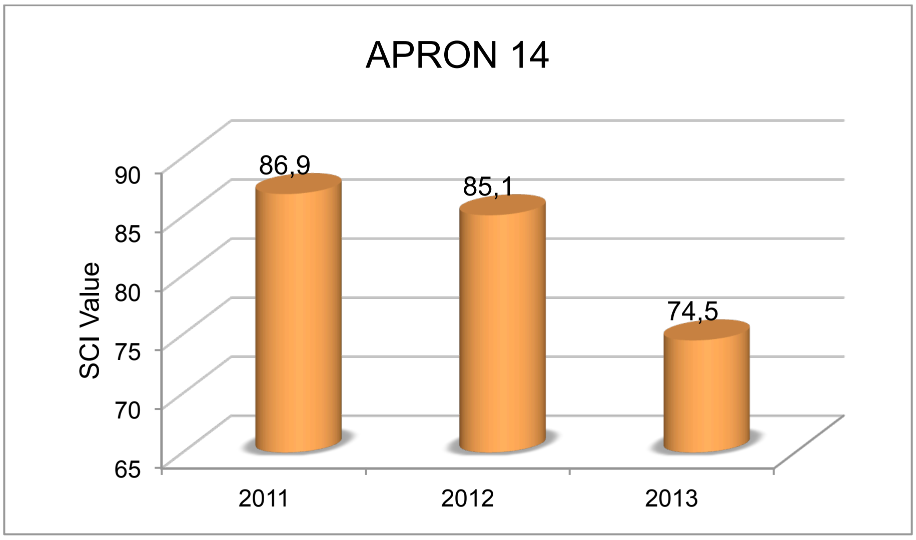

Figure 1 – Evolution of the SCI for APRON 14

In 2013 the decrease in the value of the structural condition index is not justified as easily as the previous year. It is observed that there is a decrease in the deducted value from distresses. It can be understood that there is lack of information, since it is only known the deduced values from two of the four distresses recorded during previous years. It refers, however, that the two registered distresses (Figure 2) are critical, since the SCI value is below 80, below which the infrastructure manager must consider rehabilitating pavement.

The average value of the coefficient of variation for the three years in question is 4.2 %, and in 2013 the value is null.

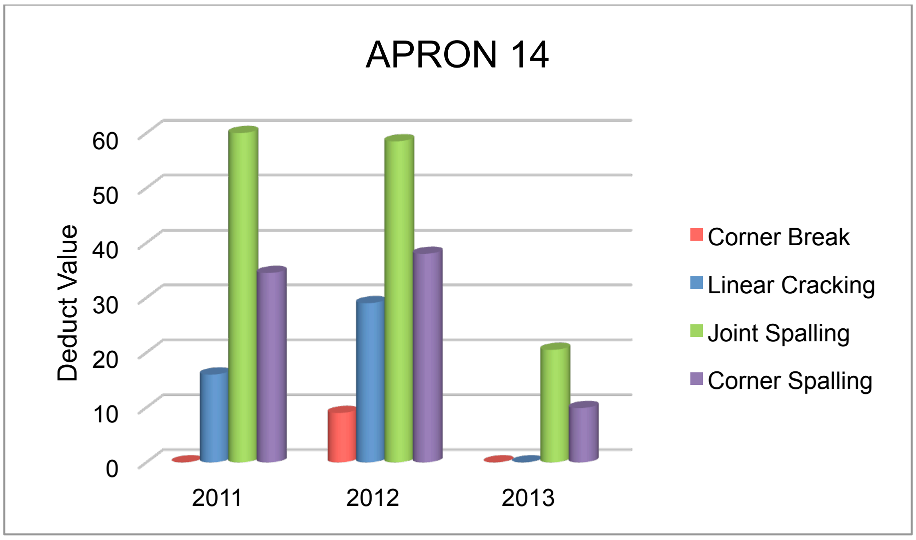

Figure 2 – Deduct Values of the distresses of the APRON 14

Regarding the traffic it verifies that family 5 (long-haul aircraft) shows an increase in 2012 compared to 2011, which may explain the decrease in the value of structural pavement condition index in 2012 (Figure 3). In 2013, although there is a decrease in the number of aircrafts of the two families operating on the apron the fact that they are aircrafts with significant weights that can lead to progressive degradation over the years, even when reducing their number.

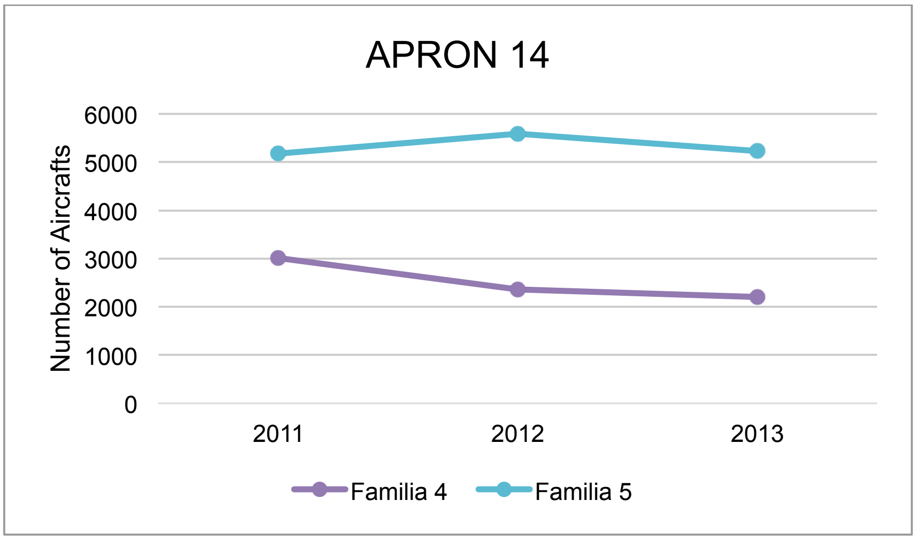

Figure 3 – Aircrafts of APRON 14

For Airport 1 and 2 Airport was made a global analysis based on the value of SCI, the standard deviation (SD) and coefficient of variation (Coeff. Var.). For Airport 1 were obtained the values shown in Table 2 and the Airport 2 the values shown in Table 3.

Table 2 – Values of SCI, Standard Deviation and Coefficient of Variation for Airport 1

	2011	2012	2013
SCI	88,7	87,9	89,7
DP	5,1	5,6	5,8
Coeff. Var.	6,2	6,6	6,6

Table 3 – Values of SCI, Standard Deviation and Coefficient of Variation for Airport 2

	2011	2012	2013
SCI	89,9	88,2	88,1
DP	5,2	3,2	5,3
Coeff. Var.	5,7	3,6	6,0

It is noted that the average structural condition index of Airport 1 has no significant variations between 2011 and 2013. Assuming a normal distribution of the sample values it can be said that the probability of having values inferior to 79 (2011), 77 (2012) and 78 (2013) is 5%, which is an indicator for the infrastructure manager that still have some leeway when it comes to programming a more widespread intervention in the aprons.

Assuming the same as in the Airport 1, a normal distribution of the sample values in Airport 2 it can be said that the probability of having values inferior to 80 (2011), 81 (2012) and 78 (2013) is 5%, which, as mentioned above, is an indicator for the infrastructure manager that still have some leeway when it comes to programming a more widespread intervention in the aprons.

Conclusion

The airport infrastructure must have always minimum service levels that respond to operations that were designed, through structural, functional and appropriate safety features. To secure these service levels in all airport pavements there is a need, through evaluation methods of the state of pavements, to determine the condition of the same at any given time.

To assess the state of rigid pavements, commonly used in aprons, contributes the analysis of the evolution of the structural condition index (SCI), since it allows the infrastructure manager to know whether or not to rehabilitate the pavement in a given time and in a certain place, and also establish management plans of conservation of airport infrastructure.

The SCI analysis is based on data obtained by visual inspection. The latter is associated with some subjectivity that depends of the perception of the operator who makes the records during the survey. The inspection also depends on the weather and time of day when the data is recorded. These are usually held at night, which may hinder the detection of the distress and its severity level correctly. For instance, if the inspection is conducted during hot days (even at night time) the concrete slabs dilate which can hide the cracks and their size.

In this context, the present work aimed to analyze the evolution of the structural condition index of the aprons of two international Portuguese airports in three successive years and also assess whether it can predict the evolution of the behavior of pavements in the following years.

The value of the SCI for each subsection, obtained using the deduct value, ranges from 0 to 100, corresponding the last value to the better structural condition of the pavement.

In the study of the aprons of the two airports, as regards the analysis of the evolution of the structural condition index can be concluded that it is not possible to establish a general relationship between the evolution of SCI, the state of evolution of the distress and the traffic operating on the aprons for a so small number of years of data, although in some aprons it has been possible to establish specific relationships (with logic) between the three parameters analyzed, for example on the apron designated APRON 14 in which the value of SCI decrease between 2011 and 2012 accompanied by an increase in the deduct value of the existing distress and as well as the traffic operating on that board.

In spite of the difficulties described, including the random selection of the sections to be inspected (according to D5340 Standard (ASTM, 2011)) it was showed that most of the aprons have good structural conditions, i.e., the value of the structural condition index is greater than 80, showing no major changes over the three years of analysis, as would expected in a framework of aprons relatively young.

The method that is based on the application of structural condition index in pavement condition assessment proves to be suitable enough, because despite the analysis of this index has been made in only three successive years, it seems to work as a good indicator for the definition of immediate action of conservation. As for the definition of a medium-term conservation strategy it requires a greater period of observation (at least 10 consecutive years) and also a different collection strategy, to allow it to have a consistent set of information that enables establishing trust relationships between the variables involved (SCI and traffic) in order to be able to model the evolution of the aprons degradation.

In that sense, it is suggested that from each apron it must always be collected data of a small set of subsections (3, for example) strategically defined in the more stressed areas and whose course of the degradation can be monitored consistently in order to be able to establish a relationship between evolution of SCI and traffic. This will also have to be more reliably recorded under penalty of losing quality in understanding the evolution of degradation of pavements. Independently of using the strategy outlined in the D5340 standard (ASTM 2011) for other categories and thus be able to monitor the evolution of the apron degradation according to the formality currently used.

It is also necessary to establish inspection methodologies to enable its executions twice a year, as mentioned in the circular AC 150 / 5380-6C (FAA, 2014), to obtain more information on the conditions of the pavement and thus establish a more accurate evolution the structural condition index.

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