Evaluation of the Runway at the Eduardo Gomes International Airport in Manaus

Alexandre da Silva Leocádio
Grupo de Geotecnia – PPG - ENGRAM
UFAM / INFRAERO
Manaus, Brazil
alexandre_leocadio@infraero.gov.br

Consuelo Alves da Frota
Grupo de Geotecnia – PPG - ENGRAM
Universidade Federal do Amazonas - UFAM
Manaus, Brazil
cafrota@ufam.edu.br

***Abstract*—Air transport is one of the most dynamic sectors of the world economy, as growing commercial demand stimulates the aeronautical industry to produce larger aircraft with greater capacity for transporting both passengers and cargo, resulting in faster and safer transportation. This development has had a direct impact on the tire-pavement interaction on airport runways, since landing and take-off operations are the most critical flight procedures in terms of safety. To this end, the maintenance of these structures is of the utmost importance in order to avoid accidents. One of the means of monitoring and conserving these pavements is through the measurement of friction and macrotexture. The information presented here was gathered from the runway at the Eduardo Gomes International Airport in Manaus, Amazonas, Brazil. The data indicated that, in spite of the high demand that leads to more intense air traffic, friction indices and macrotexture remained at a level considered safe. This result was due to regular maintenance procedures, such as rubber removal and layer rehabilitation.**

Keywords — airport; friction measuring; macrotexture; runway

I. Introduction

Air transport has occupied an increasingly prominent position in the global economy. Its greatest evolution occurred shortly after World War II, when the search for better technology was focused on overcoming the enemy, which led to rapid aeronautical development and transformed the airplane into one of the most important means of transport in the world.

This sector has contributed substantially to reducing distances between the main commercial centers, besides providing comfort and safety for the airport population. Aviation has become one of the most dynamic sectors of the world economy in the face of increasing commercial demand, which has stimulated the aeronautics industry to produce ever larger aircraft capable of transporting a growing number of passengers and cargo with major improvements in cost, speed and safety.

Bielschowsky (2011) states that in Brazil, the most significant expansion of demand in this sector occurred between the 1920s and 1960s, due to the diversification and growth of the Brazilian economy. He also points out that, after a period of crisis, it has been expanding since 2003, as a result of (1) the intense growth of the companies responsible for the sector, (2) high commercial demand and (3) profitability protected by market regulation.

Since 2000, improvements in macroeconomic conditions have led to the expansion of this sector in Brazil. Traditional Brazilian companies have used product differentiation strategies forming alliances with foreign companies, in order to increase the airway network, a phenomenon that has led to an increase in air traffic.

Airports are designed to provide loading and unloading services for goods and persons, using specific structures. The runway is the main connecting element between flights and embarkation and debarcation procedures and demands strict maintenance, in order to prevent deterioration and in so doing prevent accidents and incidents. Landings and take-offs are considered the most critical flight operations. Therefore, a pavement intended for contact with aircraft must have three basic characteristics: (1) adequate support, (2) good ride quality and (3) appropriate surface friction characteristics (GONZAGA et al., 2010).

The Brazilian Airport Infrastructure Authority (INFRAERO), besides managing most Brazilian airports, is also responsible for runway analysis, verification and control, based on the procedures and requirements of the National Civil Aviation Agency (ANAC). This agency, in turn, is responsible for overseeing all civil aviation activities as well as the country's aeronautical and airport infrastructure.

In this study, the macrostructure and the Average Friction Index of the runway at the Eduardo Gomes International Airport, in Manaus, is examined, in the light of current legislation, in order to provide information that may contribute to the improvement of the structure's maintenance program.

II. Review of the Literature

A. *Friction Measurement*

At the beginning of the twentieth century most runway surfaces were grass; only a few had a rigid pavement surface. Le Bourget Airport in Paris (Figure 1) was one of the first to have a paved runway, and at that time, friction measurement was not a priority. A skid test was considered adequate: if the surface was too slippery, a ban on airport use was issued. The disturbing number of accidents, however, pointed to the need to develop more efficacious methodologies.

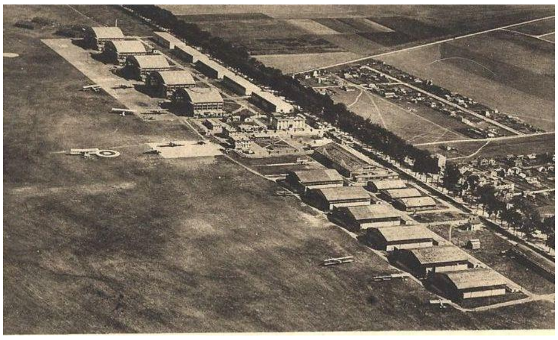


Fig 2- *Aeroporto de Le Bourget – Paris*

In 1946 the Scandinavian Airlines System (SAS) began operating with the Douglas DC-4 aircraft. For maintenance reasons, they occasionally had to land at Oslo Fornebu Airport, whose runway was only 1200 meters long with steep slopes at both ends. In an effort to avoid air accidents on snow- and ice-covered runways, the airport administrator, Ottar Kollerud, developed his own method. The Kollerud Method consisted of recording the time or distance traveled up to the total stop of a truck loaded with sand at a speed of 30 km/h. This test found that DC-4 deceleration was roughly twice that of the truck. Subsequent tests led to the conclusion that the same relation was valid for many different types of aircraft. The Kollerud method is still adopted by the International Civil Aviation Organization (ICAO), detailed in Doc 9137-AN / 898 (Airport Service Manual, 1991). Some modifications have been introduced, such as the adoption of the coefficient of friction μ.
In the late 1940s and early 1950s the problem of airport runway friction was not recognized internationally, but SAS began requesting information on runway friction conditions at airports in Sweden, Denmark and Norway. The director of Bromma airport in Stockholm, Bertil Florman, used the Kollerud method at Fornebu Airport, concluding that it was suitable for that airport, due to the low frequency of DC-4 landings. However, in Bromma, where traffic was very heavy, the procedure was not found suitable since it was time-consuming and caused very rapid wear of truck tires and brakes. Florman replaced it with the Tapley meter (Figure 2), a decelerometer, an instrument easily installed in any vehicle. The procedure consisted of accelerating the vehicle to a certain speed and then braking hard enough to lock the wheels. The subsequent skid was registered on a meter. There was no need to brake the vehicle to a complete stop, thus avoiding deterioration of the tires and brakes. The friction was usually measured at nine points along three lines, along the centerline and along lines 5 meters on each side of the centerline. This instrument represented a major advance in friction measurement techniques (Gunnar, 1997).

Fig 1 - *Tapley Airfield Friction Meter*

Later, at Florman's request, Kullberg, Chief Engineer at the Swedish Road Research Insitute, developed the so-called Skiddometer, which measures friction continuously along the runway. It was tested at Bromma airport in the early 1950s and led to the development of the trailer-based Skiddometer, the BV2. SAS believed that the instruments should be heavy enough to represent the aircraft of the time. They decided that during measurement, a load of 1000 kg would be required on the wheel, and that the equipment should weigh about 3000 kg, as well as having three wheels on the same axle with devices which allowed the center wheel (measuring wheel) to have a smaller diameter, so as to result in a slippage of around 17%.

Another advantage of the Skiddometer method was that 80 to 85% of the braking energy could be fed back to the other wheels as a propelling force, aiding in the transport of the trailer. As the experiments advanced, it was found that measurements could be taken with lower loads. Currently the load on the measuring wheel is only 105 kg, so the equipment is lighter, as in the current version, the BV-11. In the late 1960s the Swedish vehicle manufacturer Svenska Aeroplan AB (SAAB) developed a friction meter, a car with a fifth wheel that allowed the measurement data to be collected. This device was named SAAB Surface Friction Tester (SFT). Its main advantage was speed of data collection and the runway's immediate release to traffic without impacting landing and take-off operations. This instrument proved to be extremely useful in very busy airports (Gunnar, 1997).
Subsequently, SAS and the operators of Sweden's domestic airports developed a new method based on the premise that during landing, the friction properties of the middle and final portions of the runway are more important. The runway was thus divided into three parts (three thirds), for the purpose of reporting on pavement conditions. The thirds were assigned designations "A", "B" and "C", with the "A" always being the friction information corresponding to the lower runway designation number. Thus, for example, on a runway designated 11/29, an approaching pilot at runway end 29 would receive the information in the sequence C, B and A (Gunnar, 1997). This information was easily understood by Swedish airport operators. However, the numbers were not clear to

foreign pilots. Because of this, the expressions *Good*, *Medium* and *Poor* were introduced in order to describe pavement conditions.

SAS also prepared a questionnaire for about 3,000 pilots to evaluate aircraft control conditions in crosswind situations and on snow- and ice-covered runways. The responses showed that for coefficients of friction of 0.40 and above, there was no problem. But there were reports of difficulties at 0.25 and below. This study led to the introduction of a standardized form of reporting information about runway conditions, which associated descriptive terms with friction levels measured on pavements. This form is still in use today by ICAO, as shown in Annex-14 on snow- and ice-covered paved surfaces (Table 1).

Table 1 – Friction characteristics on snow- and ice-covered paved surfaces.

Measured Friction	Estimated Braking Action	Code
0.40 and above	Good	5
0.39 to 0.36	Medium to Good	4
0.35 to 0.30	Medium	3
0.29 to 0.26	Medium to Poor	2
0.25 and below	Poor	1

In 1952 the International Air Transport Association (IATA) held a meeting where SAS had the opportunity to present the Scandinavian experience on evaluation and dissemination of airport runway friction information. As a result, IATA decided on the operational necessity of having reliable and uniform information regarding the peculiarities of ice- or snow-covered runways. A representative of the National Aeronautics and Space Administration (NASA) was present at that meeting, and the cooperation between SAS and NASA technicians established at that meeting for the investigation of the friction profile of airport runways (Gunnar, 1997) has lasted to this day. Also in 1952, during the fifth meeting of ICAO's Airports and Ground Assistance Division, IATA's demands were considered and included in a document called ICAO Annex 14, which contains the standards and recommendations for the design and operation of Aerodromes.

International recognition of Scandinavian procedures for measurement of friction characteristics at airports occurred when the Flight Safety Foundation awarded the SAS spokesman and the Swedish Civil Aviation Administration the Admiral Louis de Florez Flight Safety award. Scandinavia was thus recognized as the pioneer region in the development of friction measurement methods and equipment (Gunnar, 1997).

B. Coeficient of Friction

A runway's coefficient of friction is one of the main factors to be considered with regard to airway safety, since it is a determining factor in landing and take-off operations. The frictional characteristics of airport pavements, especially runways, affect the safety of aircraft operations. Depending on the conditions found in these layers, a poor level of friction can cause serious incidents with fatal injuries (Oliveira, 2009). It is a dimensionless magnitude and can be thus differentiated: dynamic coefficient of friction (μ_d), present from the moment of displacement of the body; and static coefficient of friction (μ_e), when movement of the body is imminent, that is, as the external force begins to act.

Mossmann (2002) states that the value of the static coefficient of friction can vary between zero and a certain maximum value, that is, the body oscillates between relative rest and the maximum static condition. During the initial displacement, the kinetic or dynamic coefficient of friction is obtained, which indicates the loss of tension between the surfaces, for example, the skidding of a vehicle on a highway. The values of the maximum static coefficient of friction depend on the individual characteristics of the surfaces in contact. Clearly, however, the dynamic coefficient of friction is of greater importance, as the relevance of this parameter can be verified only in the presence of movement, during landing and take-off operations, that is, in the imminence of the aircraft skidding. According to the NCHRP (2009), 'pavement–tire friction is the force that resists the relative motion between a vehicle tire and a pavement surface'. This resistive force is generated as the tire rolls or slides over the pavement surface (Figure 3).

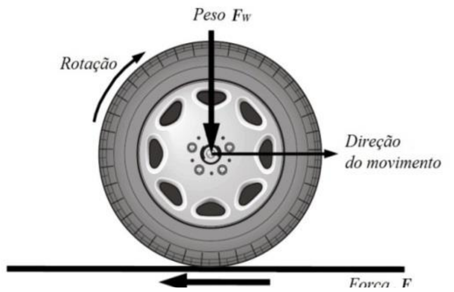


Fig 3 - *Simplified diagram of the forces acting on a moving wheel*

According to the *Runway Surface Condition Assessment, Measurement and Reporting* (ICAO, 2011), the coefficient of friction is a response system generated by a dynamic system composed of: pavement surface, tire (airplane), contaminants (between tire and pavement) and atmospheric conditions (temperature, radiation). According to Lopez (1995), the coefficient of friction is dependent on the equipment used to perform the test, which can be done using a structure with wheels that spin free or are locked during the experiment. These parameters are: a) longitudinal coefficient of friction, associated with the development of the force in the tire-pavement contact interface, when dragging a locked wheel. It simulates resistance to slip during emergency braking or when a vehicle is braked, accelerated or decelerated in the longitudinal direction; and b) transverse coefficient of friction, related to the development of the force in the tire-pavement contact interface, perpendicular to the wheel's plane of rotation, when it rotates at an angle with respect to its direction of rotation (tangential forces). It shows the transverse slip resistance required to maintain a vehicle on bends or while skidding.

C. *International Friction Index (IFI)*

As technology progressed, several friction meters with a good level of precision were developed; however, methods varied according to the country of origin. This made it difficult to compare parameters between countries. In order to harmonize these values, PIARC (currently World Road Association) began research in 16 countries. Various types of measuring equipment were tested under different conditions of friction, texture, and speed, as well as on different types of road and airfield surfaces. In 1995 an international reference scale was presented, proposing a universal standard for evaluating pavement surfaces. This scale, the International Friction Index (IFI), allows comparison of results produced by different devices, thus constituting a common evaluation index of surface texture and friction. The IFI relates friction and slip speed; it estimates the reference constant for speed (Sp) and friction at 60 km/h (F60) of a pavement. This pair of values, Sp and F60, expresses the IFI value of a pavement and calculates the friction value, F (S), at any slip speed (equation 1).

$$FR(60) = FR(S) * \text{and} (S-60) / Sp \quad (1)$$

Where:
FR (60) = Friction Related at 60 km/h
FR (S) = Friction Related by measurement of slip speed
S = Slip speed, in km/h
Sp = Speed Constant, in km/h
60 = standard speed - km/h

Aps (2006) proposes a classification of the IFI in intervals, in which the friction index is composed of measurements made with a portable device (Table 2). She goes on to explain that it is of fundamental importance to verify the methodology applied in determining the friction parameters, since portable equipment makes discrete evaluations, while the others, such as the Griptester, take continuous measurements. She also affirms that the indices collected through discrete or continuous measurements can make substantial contributions to the study of accidents, evaluation of pavement management systems, and airport runway maintenance.

Table 2 - Classification of friction index.
Source: Aps, 2006.

Limits (IFI)	Classification
IFI <0.05	Very Poor
0.06 <0.08	Poor
0.09 <0.11	Marginal
0.12 <0.14	Regular
0.15 <0.21	Good
0.22 <0.35	Very Good
IFI> 0.35	Excellent

D. *Texture and Friction Measurements*

Methods for macrotexture testing can be divided into: a) volumetric or Mean Profile Depth (MPD), the most common being the Sand Patch and the Grease Patch; b) profilometer or Root Mean Square of Texture Profile (RMS). These can be of three types, laser, photosection and contact water, of which the most widely used is the laser type; and c) an outflow meter, which measures drainage time of water contained in a transparent plastic cylinder, in contact with the pavement surface. Friction meters can be of four types: static (British Pendulum, Dynamic FrictionTest - DFT), oblique sideslip angle equipment (*Mu-Meter*); equipment with locked wheels (Adhera, Mader), and equipment with partially locked wheels (ASFT T-10, *Skiddometer* BV-11, *Griptester*). INFRAERO currently uses four devices: the *Skiddometer* BV-11, the *Mu-Meter* MK-6, the ASFT T-10 and the *Griptester*.

III. MATERIALS AND METHODS

This study was carried out on the runway of the Eduardo Gomes International Airport, Manaus (SBEG). The aerodrome is located 14 km from the city center, specifically at coordinates 3^{o}02'08.83"S 60^{o}02'59.17"W. It has a single runway (runway thresholds 11/29) for landings and take-offs, as shown in Figure 4, with a coating of asphalt concrete (AC). It is identified as SBEG or MAO by ICAO and IATA, respectively. The runway was evaluated using macrotexture tests (sand patch) and surface friction measurement (*Griptester*)

Fig 4 - *SBEG Runway*

A. Materials

For the macrotexture test the following materials were used: sand, with particle size contained between the #50 and #100 sieves, i.e. passing the 50 mesh sieve and retained on the 100 mesh sieve; metal ruler for measuring the sand patch diameter; protective device against wind effects; and a stamp, to contain the volume of sand (24 cm³) and spread this material on the pavement (Figure 5). Obtaining the runway's friction data involved the use of: the *GripTester* friction measurement device; a van, used to tow the meter trailer; a computer for data collection. The computer hardware contains the *Airbase* program responsible for processing all information obtained by the *GripTester* (Figure 6).

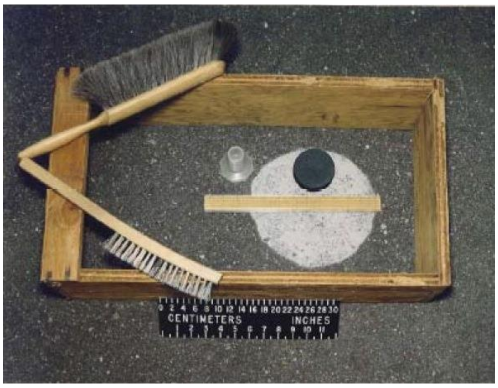


Fig5 - *Materials for the Sand Patch test*

Fig 6 - *Friction meter assembly (reservoir detail and Airbase software)*

B. Methods

Experimental methodology was in accordance with ANAC Resolution Nº 236/2012. In particular, macrotexture was measured on the whole operational extension of the runway, with the first measuring point at the start of the runway (point zero), in areas of the pavement with no grooving, in areas three meters from the runway axis, and alternately every 100 meters to the left and to the right of the axis, with at least three measurements for each area (Figure 7).

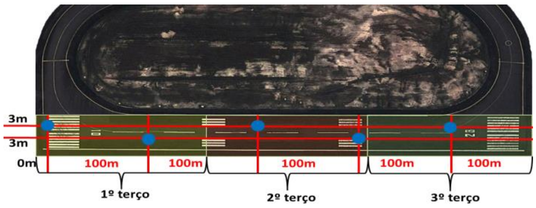


Fig 7 – *Lease of Test points for Macrotextura*

In order to perform the macrotexture test, the metal cylinder was completely filled with sand. Subsequently, the contents of the cylinder were poured at chosen points on the pavement and spread uniformly, forming a familiar geometric figure, generally a circle. The parameters of the spreading area were measured in four directions (Figure 8). Average macrotexture depth on a runway should be not less than 0,60 mm (RA Nº 236/2012 ANAC).

Fig 7 - *Sequence of the Sand Patch test*

Before initiating friction measurement, the equipment and the software were calibrated and configured. After this check, the GripTester should be positioned at the threshold with the highest number of landings, in this case at threshold A. The operator then switched on the system and started the route along the runway in one millimeter of water. Data collection will begin as soon as the equipment reaches 65 km/h. The vehicle traveled both directions in parallel lines three and six meters apart on either side of the axis (Figure 9). Upon completion, the data acquired was sent via Bluetooth to the notebook and processed by the Airbase software.

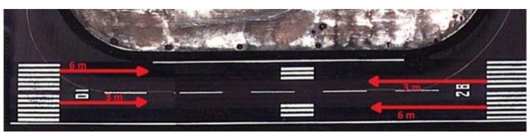


Fig 8 - Travel distance during friction measurement

The minimum parameters related to the friction measurement, ie the friction values determined by the GripTester, are classified as: new surface - μ> 0.74; safe unsupervised runway - 0.53 <μ <0.74; safe supervised runway - 0.43 <μ <0.53 and unsafe runway - 0.43> μ (RA Nº 236/2012 ANAC) (Table 3). Friction indices below 0.24, will cause the runway to be considered unsafe for aircraft operations. This will generate a Notice to Airmen (NOTAM), in order to disseminate, in advance, all aeronautical information of direct and immediate interest to safety. According to RA 236, there is a 2.5% tolerance on values calculated for the coefficient of friction.

Table 1 – Parameters for coefficient of friction, by type of measuring equipment. Source: Resolution Nº 236 – ANAC, 2012

Ground Test Vehicle	Tire		Test Speed (km/h)	Water Depth (mm)	Minimum Coefficient of Friction		
	Type	Inflation Pressure (kPa)			New Pavements	Maintenance level	Acceptable level
MuMeter	A	70	65	1,0	0,72	0,52	0,42
	A	70	95	1,0	0,66	0,38	0,26
Skiddometer	B	210	65	1,0	0,82	0,6	0,5
	B	210	95	1,0	0,74	0,47	0,34
Surface Friction Tester Vehicle	B	210	65	1,0	0,82	0,6	0,5
	B	210	95	1,0	0,74	0,47	0,34
Runway Friction Tester Vehicle	B	210	65	1,0	0,82	0,6	0,5
	B	210	95	1,0	0,74	0,54	0,41
TATRA	B	210	65	1,0	0,76	0,57	0,48
	B	210	95	1,0	0,67	0,52	0,42
Griptester	C	140	65	1,0	0,74	0,53	0,43
	C	140	95	1,0	0,64	0,36	0,24

IV. Discussion of Results

Tests were carried out from 8:00 a.m. to 11:40 a.m., over the period spanning April 2012 to July 2014. The morning was chosen for the tests due to the low frequency of landings and take-offs during this period. In both experiments climatic conditions oscillated between sunny and cloudy and the ambient temperature between 25°C and 31.4°C. For better precision and illustration, a thermal imager was used to detect temperatures around 49.6°C and 31.5°C in the pavement and the environment, respectively (Figure 10). It is important to point out that these experiments (friction and macrotexture) cannot be carried out during rainfall.

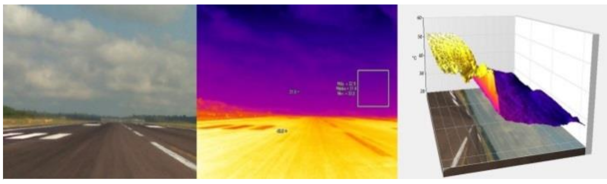


Fig 10 - Temperature collection using thermal imaging device.

A. Macrotexture

The set of longitudinal profiles for 2012 (Figure 11) show similar behavior in the three tests. This is due to the rubber deposited in the area between 150 and 800 meters. This area is defined as the touchdown zone - indicated for landings, and therefore with a higher number of landings and take-offs (predominant threshold). It should be emphasized that in September, repairs, which included milling and rehabilitation of asphalt layer, were carried out on runway threshold 11, over the section starting at 270 meters (540 x 14 meters). Despite the new coating, there was no substantial improvement in the following month. This result is believed to be due to the coating showing type III characteristics, ie with tightly closed macrotexture and fairly rough microtexture, a structure characteristic of newly constructed pavements. However, over time the texture tends to fit into type I, which means good quality macro- and microtexture.

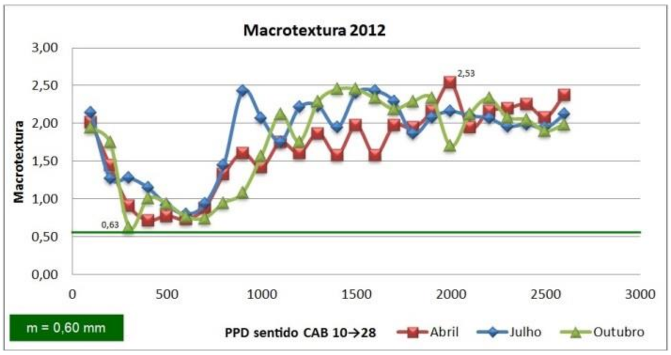


Fig 9 - Consolidated longitudinal profile for April, July and October/2012.

Transferring the 2013 tests to the same graph (Figure 12) exhibits a performance similar to that of 2012, with only minor alterations. Isolated values below the tolerated level were observed for October and July, and the remaining values at the same depth interval along the runway. Note that in August further repairs were carried out on runway thresholds 11 and 29, with the coating being renewed on the first third of the runway, starting at 100 meters (direction 11/29), with an area of 165m by 14m, and on the last third (direction 29/11), following the 100 meters (200m by 23m). For this reason, these revitalized areas provided low macrotexture depths, following the same principle as the 2012 repairs (type III pavement with more tightly closed texture). As a consequence, the depth at some points was close to 0.60mm or below; for example, at 200 meters where depth was only 0.59mm. Once again, note that, with the increase in traffic, texture tends to change gradually through the removal of fine material close to the surface.

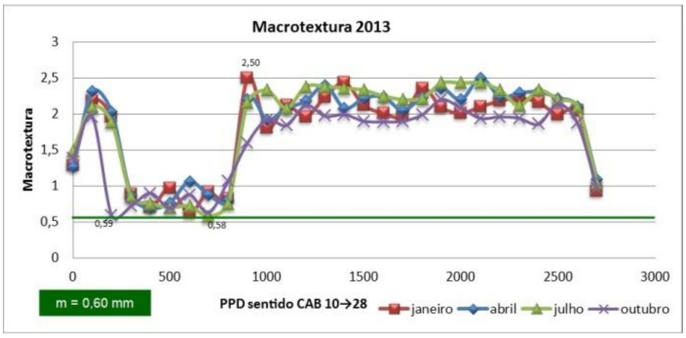
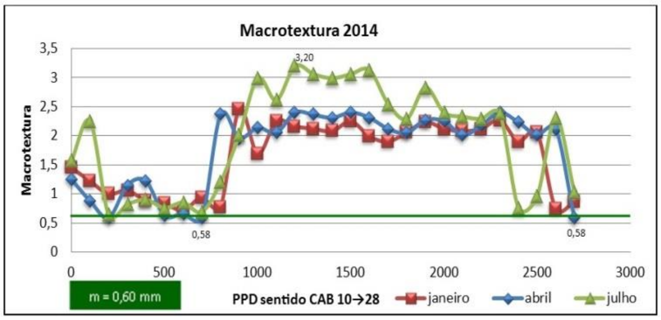


Fig 11 - Consolidated longitudinal profile for January, April, July and October/2013.

In 2014 there was a slight change in the threshold area of runway 11. This was the result of the most recent repairs. However, the other months showed an average lower than that of January. This behavior can be credited to the situation of the new pavement combined with the rubber deposits in the area. Also in July, the variation in depth is most evident, with both the lowest (0.58 mm) and the highest (3.20 mm) values for macrotexture, as shown in the consolidated profile presented in Figure 13.



Figa 12 - Consolidated longitudinal profile for January, April and July/2014.

B. *Friction Measurement*

Inserting all the tests in one year and in the same graph (Figure 14) causes a considerable improvement in the friction indices of the third third of the runway (runway threshold 29) for 2012. This result is believed to stem from rubber removal, part of the residue generated by the landing gear, which settles into the gaps between the aggregates, making for a more tightly closed texture (Type III pavement). There is also an increase in the indices for October and a reasonable improvement at runway threshold 11. In particular, in the area beginning at 300 meters up to near 800 meters, there was rehabilitation of the asphalt layer. However, the increase in friction was not large, since new coatings exhibit type III pavement characteristics, that is, closed macrotexture and high microtexture, thus improving friction by adherence on dry surfaces.

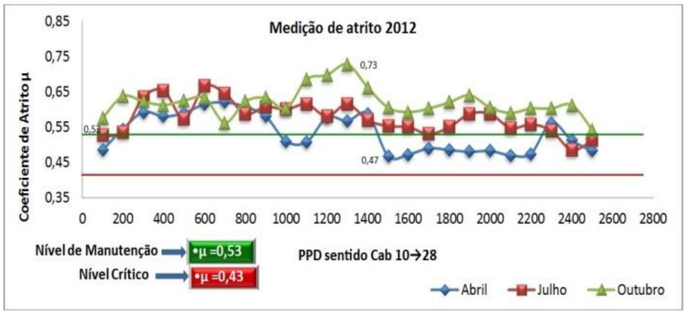


Fig 14 - Consolidated longitudinal profile, friction indices for April, July and October/2012

The tests done in 2013 (Figure 15) give a clear picture, especially in the first third, of variation in profile behavior. On runway threshold 11, in April and July, µ is below 0.53, whereas in October friction levels reach a high average. These levels stood out from the others, due to the work done in August on the asphalt coating. The repairs began at the 100 meters mark of runway thresholds 11 and 29, covering an area of 165x14 meters and 200x23 meters, respectively. Also in the first third, the data collected were superior to the rest. It is important to emphasize that rubber removal contributed to improved friction.

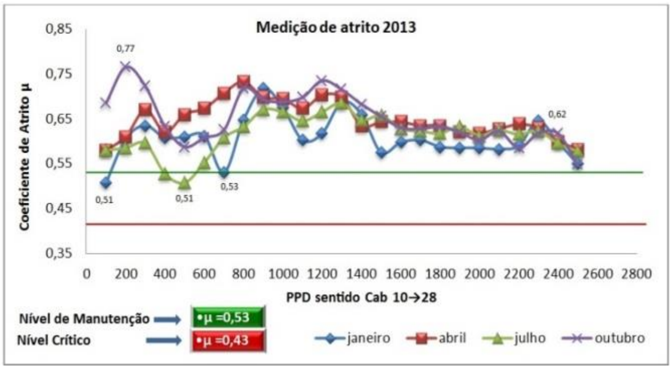


Fig 13 - Consolidated longitudinal profile, friction indices for January, April, July and October/2013.

The consolidated graph for the year 2014 (Figure 16) exhibits clear differences in performance between the longitudinal profiles. While in January the average friction index, was high, in April it hit its lowest point, with most of the values at the maintenance level limit. The findings for January that pointed to high value data reflect the repairs to the bituminous coating concreted the previous year, since in the October 2013 profile, the same performance was obtained. In the following months there was a substantial drop, reaching worrying levels, especially in April. This result was attributed to the substantial rubber deposits caused by the large volume of take-off and landing operations stimulated by the holiday season. However, the month of July already indicated a considerable improvement in its average friction index, with the removal of rubber deposits contributing significantly to the final result.

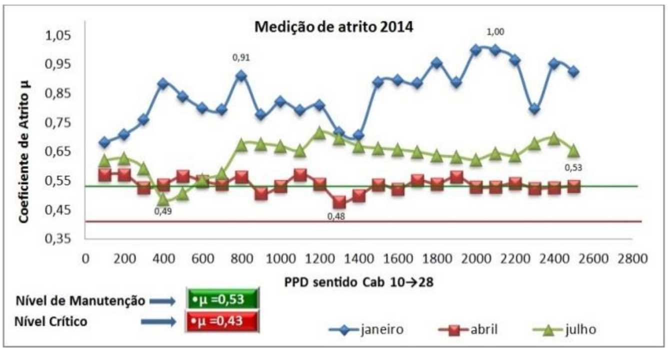


Fig 15 - Consolidated longitudinal profile, friction indexes for January, April and July/2014.

V. Conclusion

A. Macrotexture

Year 2012 - Low values were observed on the first third of the runway (runway 11/29), rising from the second third on and maintaining the same level up to the end of the runway. The initial results were due to rubber deposits, since runway threshold 11 is in the first third, the predominant site (about 98%) for landing and take-off operations. However, even with this deficit in the first third, these values can be seen as satisfactory, since they remained above what is considered tolerable (m = 0.60mm).

Year 2013 – The results were found to be similar, in general, to those of 2012. There were only two points with indices below what is permitted, explained by the presence of a new asphalt layer with tightly closed macrotexture. This situation leads to a sand patch with a larger diameter, as compared to the previous one, since the gaps, which should be filled by the sand, are occupied by the elements of the asphalt composite.

Year 2014 - No differently from the previous year, the results repeated the performance of the decrease on runway threshold 11 and the increase of the macrotexture from the second third on. It should be noted that the first third of the track presented the best indices in January. As in 2012, this behavior is due to a recently applied coating.

B. Friction Measurement

Year 2012 – April and October presented different behavior, registering, respectively, the lowest and highest average friction indices. Rubber removal improved the friction levels for July, which evolved from supervised safe (maintenance) to unsupervised safe. For October, these numbers were higher, as a consequence of the rubber removal and asphalt layer rehabilitation carried out in August on runway thresholds 11 and 29.

Year 2013 - The results obtained for the first third of the runway exhibited a different behavior, while the remaining stretches showed similar values, practically in the same friction range. October and April produced the highest average friction index. Overall, most values were above μ = 0.53, which characterized an unsupervised safe condition, and only four indices were positioned in the supervised safe situation.

Year 2014 - Low indices were observed in April and high values in January. Results are highest for the period April 2012-July 2014. The first test in 2014, which produced a high average friction index, reflected the rehabilitation of the asphalt coating and rubber removal implemented at the end of 2013. The low indices in April and the subsequent maintenance condition were caused by the presence of a large quantity of rubber due to the breakdown of the rubber removal equipment.

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