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THE RUBBER ACCUMULATION IN THE TOUCHDOWN ZONE, THE FRICTION AND THE ROUGHNESS IN THE SAFETY OF THE LANDING AND TAKE-OFF OPERATIONS

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ABSTRACT

The enlargement and modernization of Brazil’s Airport Terminal Buildings are fomenting the repressed demand of passenger as part as a function to reflect the need of to adapt the movement area (runway, taxiway and apron) to the new reality, due to the new traffic’s level (landing gear configuration, load and movement number).

This work shows that the necessary synergy between the operational area, the passenger movement and cargo as your fundamental role in way to allow the safety of the landing and take-off operations influenced by the rubber accumulated in the touchdown zone, the friction and the roughness.

The main objective of this paper is to call attention of the airports administrators and aircraft pilots regarding the importance of to have actualized information about the rubber accumulated in the touchdown zone, the friction and the roughness.

There are two imports considerations regarding the safety of the landing and take-off operations. First of then is concerned the roughness considering the APR Consultancy proposal end the second is the relationship between the intensity of water precipitation and the skin-deep water in the pavement surface that has relationship with the friction and the rubber accumulated in the touchdown zone

As important as the capacity of structural pavement’s support at the new level of traffic generated by the enlargement and modernization of the airport terminal buildings is the necessity to accompany the performance of the pavement implanted under the aspect of rubber accumulate in the touch down zone, the friction and the roughness.

KEY WORDS: Runway, touchdown zone rubber accumulate, friction, roughness

INTRODUCTION

Interventions in runways, maintenance and recovery in the sense "Lato sensu" is a necessity and the airport administration has appropriate tools to increase the useful life of the pavements without affecting the environment, in way to allow safety landing and take-off operations.

Over the point of administrator view one of the most important aspect regarding the safety operations is the relationship between intensity of water precipitation / skin-deep water in the pavement surface and, in consequence, the *aquaplaning* phenomenon.

Airports operating Instrument Landing System (ILS) equipment's facilitate the landing operations and automatically have Surface's Meteorological Station Class I (EMS-I) that, among others information, register the intensity of water precipitation each hour and instantly in the flight controller's screen.

That type of information can be filed or printed in the paper whenever the flight controllers like this wanting. Therefore becomes possible to define parameters where can relate intensity of water precipitation / skin-deep water in the pavement surface, rubber accumulation in the touchdown zone, friction and roughness.

That monitoring can aid the local flight control, so that it comes to allow or not the continuity of the landing and take-off activities in functions, for instance, the intensity of water precipitation.

Besides that direct action of the airport administration separately or together with the local flight control (TWR), the pilot of the aircraft has your on role.

It can be mentioned as one of your actions, the effects of the reduction of speed regarding the reverse action of the turbine in landing and take-offs conditions that it can not be considered.

The braking effects of thrust reverses for jets or reverse pitch of props is mandatory do not consider on a take-off and landing conditions. The pilot might find himself where the additional braking abilities are not available (system failure, engine out, etc). These facts can cause accidents independent of the runway operational conditions.

The safer landing distances are calculated based on standard pilot techniques for minimum landing distance from 50 feets (around 15 meters), including a stabilized approach at *Vref* on a glideslope of 3° to 50 feets(around 15 meters) or lower. A firm touchdown, minimum time to lowering the nose to the runway, minimum time to development of lift dumping devices (spoilers) and application of brakes at sustained minimum antiskid ability until actually stopped is require.

Extensive procedures have been produced using a lot of kinds of measurements devices to determine the runway length required to a given attribute value as a friction, when comparing to wet and dry pavement.

For heavier aircraft, and high performance aircraft, another factor becomes more important than for light aircraft – the runway length required for an aborted take-off.

The frictions attribute used to determine the runway length frictions effect on take-offs is very important. If all goes well on a take-off, the aircraft accelerates, rotates and lifts off. This not requires much runway, especially for a light aircraft.

While any pilot should consider this, many pilots fly light aircraft out of airports with excessively long runways for their types, and therefore this consideration generally gets glossed over, even forgotten about.

A pilot must consider the length of runway required accelerating to take-off speed and aborting the take-off successfully without overrunning the end of the runway.

Since this maneuver requires deceleration, runway friction plays an important role this aspect as well. For a high performance aircraft like a jet, even water on the runway can make the difference between go and no-go since water alone acts like a lubricant, effecting braking.

Therefore, the aircraft's "*mix*" is a very important component in the definition of that length.

The *climb* or reason of ascent of the aircraft is that defines the initial length of a runway as a function of the load, the temperature and local altitude. Unhappily that parameter has not been considered in the design of the pavements concerning the Take-off weight (TOW). All pilots, obligatorily, when developing the manifest of the aircraft defines the necessary runway length to the take-off, function of a specific weight, considering the *climb* of the aircraft. Therefore it's a date available to the designers just to be used in the definition of the pavement structure concerning the TOW.

Another, not less important than the water precipitation / skin-deep water in the pavement surface and, in consequence, the *aquaplaning* phenomenon, is the rubber accumulation in the touchdown zone of aircrafts, the friction and the roughness. Every runway for jet aircraft should be evaluated at least once each year.

Depending on traffic's level on the runways, evaluations will be frequently, with the most heavily used runways as needing evaluation as often as weekly, as rubber deposits build up.

Runway friction measurements take time, and while tests are being conducted, the runway will be unusable by aircraft. Since this testing is not timed critical, a period should be selected which minimizes disruption of air traffic. Airport operations management should work closely with air traffic control.

Scheduling runway friction surveys must be based on an average traffic level of turbojet aircraft operating. Most aircraft landing on the runway are narrow body, such as B-737 line.

When any runway end has 20 percent or more wide body aircraft as B-747, DC-10, MD-11, B767, etc, of the total aircraft it is recommended that the airport operator should select the next higher level of aircraft operations and determine the minimum survey frequency.

Regarding the roughness, airport operators accumulate data on the rate of change of runway roughness under "*mix*" traffic conditions. The scheduling of roughness surveys may be adjusted to ensure that evaluators will detect and predict marginal roughness conditions in time to take preventive actions.

Therefore visual evaluations of pavement roughness are not reliable, according recentelly researchs. Visual inspections are essential, however to note other surface condition inadequacies such as drainage problems, including ponding and groove deterioration and structural deficiencies.

Import information about the runway is the aircraft ride quality that does not get assessed on several standard components of a typical Pavement Management System (PMS). Pavement Condition Index, structural integrity evaluation and load bearing capacity tests, are some of the most common components of a PMS.

Therefore, referring evaluations the roughness should be led in function of the rate of variation of these, about several conditions of aircraft "*mix*", in enough time for the necessary corrections as a form to avoid accidents.

CONSIDERATIONS ON RUNWAYS SURFACES

Deterioration of the pavement skid-resistance, a reduction in friction - a problem for aircraft tires to grab and safely stop the aircraft and, the runway roughness under various traffic conditions and runoff event are the main causes of ground-based accidents.

There are several factors that contribute to surface friction deterioration, since the type of aggregate used until the touchdown zone rubber accumulates.

The ground-based accidents are linked normally to the wet runway (*aquaplaning*), small macrotexture and lower values of microtexture. The skid resistance that means the amount of friction derived from the top of pavement surface is divided in two interrelated components that are the macrotexture and the microtexture.

The macrotexture or superficial texture of a pavement either can be classified in closed or open using a volumetric technique, as the Sand Spot method. The measurement of macrotexture is made through the rehearsal of stain of sand. The texture is measured in millimeters and it should place if between 1,0 and 0,5mm. Smaller textures than 0,4mm are considered closed and they affect the stop effectiveness.

The British Pendulum Tester measure the microtexture. The ASTM E-303-93 [1] show de procedures.

According Aps [2] values of adherence can already be quantified, in highways, through a denominated composed International Friction Index (IFI) based on friction measures and texture, being used of any equipments of the norm ASTM E-1960-98 [3].

The Directory of Aeronautical Engineering (DIRENG) developed a methodology establishing the roughness quality conditions of aircrafts through pilots of aircraft commercial subjective correlations to turbojet and of regional aviation.

The objective is to measure the roughness settling down the conditions of softness, similar highways, using the roughness quotient (QI - counting/km), for each third part of a runway in function of the medium value of roughness readings (LI) starting from the calibration equation, QI = 17,3138 + 0,7648 (LI).

The roughness readings being used of the equipment integrator IPR/USP, along 3 (three) longitudinal alignments. One in the axis and the other ones two distant of this 3m to the left and the right. To the speed of 65km/h, readings are taken to each 80m. The table 1 below establishes this relationship.

Table 1 - Attribute Aircraft ride quality function of the Roughness Quotient (QI)

Attribute Aircraft ride quality condition	Commercial Jet aircrafts QI (Count./km)	Commercial aircrafts from Regional segment-QI(Count./km)
Very Good	13 - 22	26 - 36
Good	22 - 32	36 – 46
Fair	32 - 41	46 – 57
Poor	41 - 51	57 – 67
Very Poor	51 - 60	67 – 77

NOTE: Adapted from DIRENG Brazilian report airports database – Santos Dumont airport, Rio de Janeiro / RJ, maio/91.

On the other hand, instead evaluate the Aircraft ride quality by the Roughness Quotient (QI) is mandatory to evaluate the pilot’s seating (PSA) and at the aircraft’s center of gravity (CGA) regarding to prevent accidents.

Therefore, ride quality is an important attribute used to measure the vertical accelerations or “g’s” experienced at the pilot’s seat (PSA) and at the aircraft’s center of gravity (CGA). If the vertical acceleration exceeds ± 0.4g, the ride quality is considered to be in the area of human discomfort.

For simulation, the speed is increased to 25 knots (around 12,86 m/s) and the same section of pavement is evaluated at that speed. Once again, the peak accelerations are stored for later use. This process is continued in 5-knot (around 2,57m/s) increments until the aircraft’s rotation velocity is reached. .

Once obtained the speed for the cycle of the homogeneous section and the acceleration vertical pick for the pilot's certain position and center of gravity, the figure 2 can be generated, shown below, being obtained the critical speed where the aircraft in subject enters in resonance. When entering in resonance, the pilot can lose the aircraft control or such resonance can, for instance, not to allow to the pilot to lift the nose of the aircraft in a take-off operation as vineyard happening in the runway of Santa Cruz's air base, when being used by military aircrafts F-5, according CARDOSO [4].

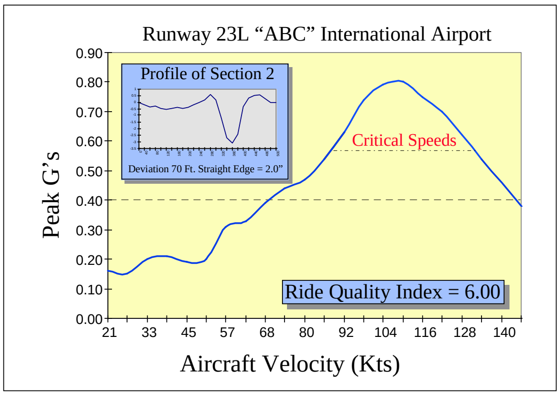

Figure 1 - Aircraft resonance Critical Speed
NOTE: Adapted of APR Consultancy [5]

The value of this type of plot is that it immediately points out the aircraft velocities that cause resonance between the natural frequencies of the aircraft and the bumps and dips in that section of the pavement. The peak center of gravity response curve will reflect the speeds, which excite the aircraft’s heave mode of vibration for the bumps and dips on that section of pavement. The pilot’s station response will reflect those that excite the aircraft’s pitch mode of vibration.

This process could be used as a criterion for determining when rehabilitation is needed, and as acceptance criteria for new and rehabilitated pavements.

The next step is to quantify the rideability of that section of pavement in a consistent manner that will permit comparison from year-to-year and section-to-section. This is done by calculating a normalized root mean square (RMS) of the peak pilot and center of gravity vertical accelerations and combining them resulting in a single number. This single number is called the Ride Quality Index (RQI). The enterprise APR Consultancy [5] it developed a software capable to evaluate RQI in a simple way and it aims at, once it is had the irregularity data and of the “*mix* “of aircrafts in operation in a runway.

The microtexture, linked to the adherence, you can feel for the touch of the hand to the surface of the pavements and for your time is related with the roughness. The effects of the texture on the friction, considering the speed of the aircraft is shown below in the figure 2.

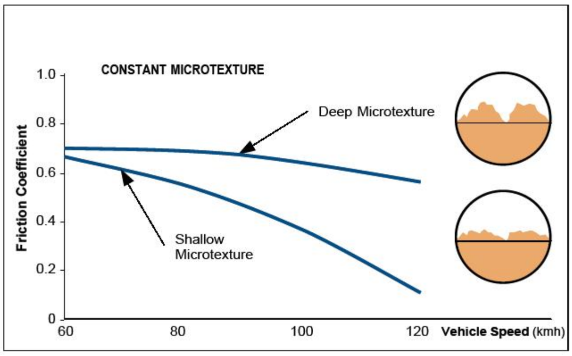

Figure 2 - Effects of the texture on the friction
NOTE: Adapted of OLIVER [6]

Rubber deposits, linked to the adherence are another important element to be observed and considered. However the question is: How many ever had to deal with removal of rubber deposits from a runway?

First of all is necessary to remember the origin of the rubber deposits. The origin is the friction and heat between the tires under thousands of pounds of pressure on the pavement surface in a take-off or landing of an aircraft.

The heat created causes a polymerization of the rubber or a chemical reaction, turning it into a very hard material that is spread on the surface in a thin layer

According SPEIDEL [7], "seven hundred grams of rubber or about 1.4 pounds are deposited per tire per landing of each large aircraft, such as a 747 or an L-011. With repeated landings of aircraft, this hardened rubber fills the microtexture of the pavement giving it a smooth, almost glass like surface that can make landing the aircraft and stopping difficult, or even dangerous, particularly when the pavement is wet. It will also begin to fill the macrotexture of the pavement surface, which will diminish the ability of the grooves to adequately drain the water during a rain event, increasing the likelihood of *aquaplaning"*.

The figure 3, below, presents the typical effects of the rubber accumulation being used of the equipment GRIPTESTING, considering the parameters of planning reference and maintenance established by the administration of any airport, in comparison with the parameters of the International Civil Aviation Organization (ICAO).

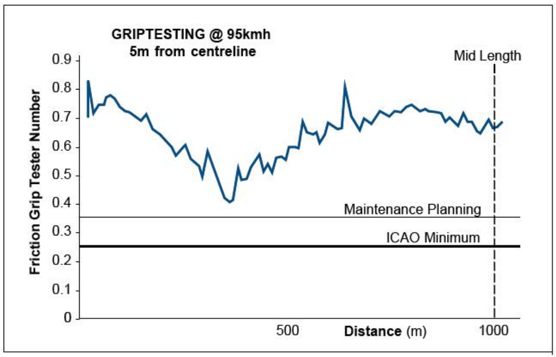

Figure 3 - Typical effect of rubber build-up
NOTE: Adapted from OPUS [8]

Federal Aviation Administration (FAA) has been the reference to the airport pavement design in Brazil, through Advisory Circular (AC) 150/5320-6D.

The AC 150/5320-12C, "*Measurement, Construction, and Maintenance of Skid-Resistant Airport Pavement Surfaces*", has procedures on how to recover areas where the friction is below the performance values recommended, involving evaluations of modern techniques of retreat the rubber accumulation in the touchdown zone.

The touchdown zone measurement must be at least 80% the value of the clean pavement to be considered having a sufficient friction. If the measurement falls below the 80% value, then the cause of the drop in friction must be determined and measures must be taken to restore the friction to acceptable levels.

The most common cause for a reduction in friction quotient is rubber accumulation. It is easy to recognize, simple to correct and relatively inexpensive do to when we are talking about human being. The Rubber removal techniques are high-pressure waterblasting, ultra-high pressure waterblasting, chemical removal, high velocity impact removal (*shotblasting*) and mechanical removal.

THE INFLUENCE OF THE RUBBER ACCUMULATION IN THE TOUCHDOWN ZONE, THE FRICTION AND THE ROUGHNESS IN THE SAFETY OF THE LANDING AND TAKE-OFF OPERATIONS

Information regarding the attribute friction, roughness, rubber accumulation in the touchdown zone, your correlation with the Intensity of water precipitation and the Pavement Classification Number (PCN) is extremely important to the pilot, to the administration of the airport and to the Air Traffic Control, in way to allow landing operations and take-off, with safety.

The friction's effect on take-off, considering the runway length required for an aborted take-off without overrunning the end of the runway my become an import element that can make difference between go and no-go since water alone acts like a lubricant, affecting braking.

Countless variables that take in consideration the requested distance of stop after acceleration exist (*accelerate-stop distances*) that are not of average publication. The obtained data are considered valid for landing and tail wind or crossed wind, but, information don't still exist published in relation to the take-off.

Spite of this is necessary to consider the factor affecting measured friction. One the must important factor is the data obtained in the runway, according TOAN [9]. First of all, the friction data is only relevant when "averaged over a distance of 100 - 150m, which is commensurate with the speed of landing aircraft (around 250 km/h) even though, spot measurements over 10 m are routinely taken".

According CENEK *et al* [10], the time elapsed between the last rain and the long dry period have an influence on the results of the friction measurement due to the effects of the accumulated dust on the pavement surface.

According BENNIS *et al* [11] "after such periods of dry weather, friction could become for a short period (0, 5 to 1, 0 hour) dramatically reduced in heavy rain".

The figure 4 below, disposes the alterations in the friction values due to pollution variations and climatic conditions.

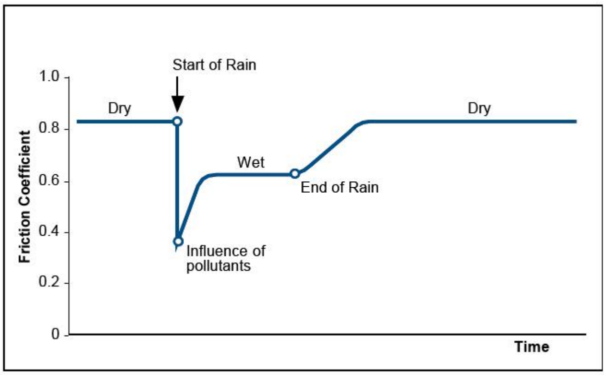

Figure 4- Influence of Pollution on Friction
NOTE: Adapted from BENNIS et al [11]

The administration of the airport owes, disposal on line, information on the attribute friction, roughness, rubber accumulation in the touchdown zone, your correlation with the Intensity of water precipitation and the PCN, when the pilot prepares your Flight Plan at the Aeronautical Information Service (AIS)

The relationship between the intensity of water precipitation / skin-deep water in the pavement can be obtained through collected data in the field. The intensity of water precipitation usually is from the EMS I and the skin-deep water in the pavement can be obtained from the device "*Water Surface Depth Instrument*".

Unhappily important, same airports don't dispose given such on line and usually these don't represent the field reality when they are made the Flight Plan.

In spite of that fact, in relation to the capacity of support of the pavement, expressed through PCN, according MOTTA and RODRIGUES FILHO [12] the aircrafts don't use of the runway with your Maximum Take-off Weight. However, the relationship among friction, roughness, rubber accumulation in the touchdown zone with the water Intensity of precipitation would be fundamental to be available *on line* when the pilot comes to make your Flight Plan.

To evaluate the ride quality of an aircraft implicates in working not only with the quotient of roughness - QI (Counting/km). Is necessary to use the "*mix*" of aircraft in simulations speeds of the aircraft that causes resonance between the natural frequency and the holes, roughness and existent depressions in the homogeneous section of the pavement.

In fact, when you increase the passenger number you will increase the use of a runway. So, is mandatory to take care with the rubber accumulation in the touchdown zone, the friction and the roughness in the safety of the landing and take-off operations.

The difference between the passenger number before the enlargement and modernization of Brazil's Airport Terminal Buildings and the actual passenger number considering 5(five) important airport are showed in the table 2 below. January was chose because is a vacation month and, normally, there is an increasing passenger flow.

Table 2 - Historical data considering passenger and aircraft demand

Airport Month/year	Aircraft(Unit.)			Passenger(Unt.)		
	Domestic	International	Total	Domestic	International	Total
SBBE-Inter. Belém						
JAN./2003	2809	117	2926	98077	4166	102243
JAN./2004	2669	130	2799	115572	3331	118903
JAN./2005	2508	282	2790	130266	5695	135961
JAN./2006	2934	136	3070	142022	3817	145839
SBCT-Inter.Curitiba						
JAN./2003	5146	155	5301	172.807	3.572	176.379
JAN./2004	3752	356	4108	178009	6052	184061
JAN./2005	4044	193	4237	229090	3669	232759
JAN./2006	4927	249	5176	252764	4706	257470
SBFZ-Inter. Fortaleza						
JAN./2003	3751	162	3913	205708	13566	219274
JAN./2004	3184	274	3458	218706	25218	243924
JAN./2005	3773	432	4205	273601	33431	307032
JAN./2006	3737	295	4032	309074	28612	337686
SBRJ-S.Dumont/RJ						
JAN./2003	8223	9	8232	391687	0	391687
JAN./2004	7254	42	7296	417287	60	417347
JAN./2005	4304	15	4319	240134	0	240134
JAN./2006	5559	5	5564	265042	0	265042
SBSP-Inter.Congonhas						
JAN./2003	18753	0	18753	846710	0	846710
JAN./2004	17845	0	17845	1014849	0	1014849
JAN./2005	16863	0	16863	1250651	0	1250651
JAN./2006	20018	0	20018	1498198	0	1498198

NOTE: Passenger : departure + arrival

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Airports / aircrafts	2003	2004	2005	2206	Variation(%)
SBBE-Inter. Belém	2926	2799	2790	3070	4,92
SBCT-Inter. Curitiba	5301	4108	4327	5176	-2,36
SBFZ-Inter. Fortaleza	3913	3458	4205	4032	3,04
SBRJ-S.Duomont/RJ	8232	7296	4319	5564	-32,41*
SBSP-Inter.Congonhas	18753	17845	16863	20018	6,75

NOTE: (*) Reduction considering the traffic transference

CONCLUSION AND SUGGESTION

Was showed the necessity to adapt the movement area (runway, taxiway and apron) to the new reality, due to the new traffic's level. This fact engage modern equipment, modern's technology regarding to keep safe the landing and take-off operations.

Considering the table 2 is possible to observe the demand increment as a function of the enlargement and modernization of Brazil's Airport Terminal Buildings and that According SPEIDEL [7], the interval of runway observation and monitoring must be reduced to avoid the corrective intervention than preventive, even considering the studies of MOTTA and RODRIGUES FILHO [12].

The attribute friction, roughness, rubber accumulation in the touchdown zone, your correlation with the Intensity of water precipitation and the value of the Pavement Classification Number (PCN) actualized, must be the concern of the airport administrators, considering the damage caused by the aircraft's accidents.

As a suggestion, after adjust the problems regarding roughness, according APR Consultancy [4] proposal, is to adapt the following alternatives to improve the friction: "grooving", friction porous layer, asphalt microsurfacing or yet, a surface retexturization.

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