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ANALYSIS OF SKID-RESISTANT RUNWAY PAVEMENT SURFACE ON YOGYAKARTA INTERNATIONAL AIRPORT WITH MU-METER TEST METHOD

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Abstract: One of the factors of an airplane accident is that a runway is not feasible because a lack of surface friction can cause it due to slippery conditions caused by rubber tire residue on the pavement surface. The way to ensure this safety is by conducting a friction test on the runway, which aims to test the ability of the runway pavement surface to hold objects moving on that surface from slipping. This research was conducted on the runway of Yogyakarta International Airport using primary and secondary data. Then analyze the raw data about the existing friction test results, with a calculation using a percentage of 90%. One data value of the friction result is determined, representing all the data on the friction of the runway pavement surface. Then, the comparison between the latest and previous test results shows that the friction level will decrease as the runway is used. In addition, it is known that the value of the pavement surface friction of the Yogyakarta International Airport runway is 0.67, which means that the runway surface at this airport is still on the verge of ordinary above the minimum requirements, so the runway is still categorized as feasible.

Keywords: *Yogyakarta International Airport, Runway, Runway Pavement Surface, Runway Pavement Friction, Mu-Meter*

Introduction

One of the factors causing aircraft accidents according to research conducted by the Badan Litbang Perhubungan is the condition of the runway which is bumpy, slippery, and flooded. Plane Crashes often occur especially when landing. For example, the aircraft will continue to drive even off the runway due to the lack of friction due to slippery surfaces caused by stagnant water or *rubber deposit* factors (rubber tire residues on the pavement surface).

These accidents can possibly occur as aircraft movements at airports increase. Including Yogyakarta International Airport although this airport began operating in 2019, this airport has experienced a growth in aircraft movements. Due to the increasing number of passengers using Yogyakarta International Airport, flight safety is a must-pay. This is reinforced by the Peraturan Menteri Perhubungan Nomor 95 tahun 2021 tentang Peraturan

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Keselamatan Penerbangan Sipil Bagian 139 tentang *Aerodrome* which states that airport operators must ensure that the *Aerodrome* meets the safety requirements for aircraft operation.

The way to ensure this safety is by properly maintaining the airside facility's infrastructure. One way is to conduct a friction test on the runway, which aims to test the ability of the runway pavement surface to hold objects moving on the surface from slipping.

Literature Review

Maintenance of Pavement Surface Friction Level

According to KP 94 Tahun 2015 tentang Pedoman Teknis Operasional Peraturan Keselamatan Penerbangan Sipil Bagian 139-23 Pedoman Program Pemeliharaan Konstruksi Perkerasan Bandar Udara, many factors cause pavement surface friction to decrease over time. One of the main factors is the friction between aircraft tires and pavement surfaces when braking and when the aircraft is running which results in the accumulation of rubber residue on the pavement surface.

The evaluation depends on the traffic frequency, aircraft type, and weight. The more often the runway is used for aircraft movements, the more frequent evaluations are compared to airports with fewer flight frequencies. The following in Table 1 is presented the interval time of implementation of the surface friction test.

Table 1

Landing Frequency Per Day	Routine Checking
≤ 15	1 Year
16 – 30	6 Months
31 – 90	3 Months
91 – 150	1 Month
151 – 210	2 Weeks
≥ 210	1 Week

Evaluation and Maintenance Guide

Based on FAA AC regulation No. 150/ 5320-12C *Measurement, Construction, and Maintenance of Skid-Resistant Airport Pavement Surfaces*, equipment that can be used for health testing is recommended as briefly outlined in Table 2 below.

Table 2

Jenis Alat Uji	65 km/h (40 mph)			95 km/h (60 mph)		
	Minimal	*Perawatan*	*Konstruksi Baru*	*Minimal*	*Perawatan*	*Konstruksi Baru*
mu(myu)- *Meter*	0.42	0.52	0.72	0.26	0.34	0.66
Dynatest Consulting, Inc. Runway Friction Tester	0.50	0.60	0.82	0.41	0.54	0.72
Airport Equipment Co. Skiddometer	0.50	0.60	0.82	0.34	0.47	0.74
Airport Surface Friction Tester	0.50	0.60	0.82	0.34	0.47	0.74
Airport Technology USA Safegate Friction Tester	0.43	0.60	0.82	0.34	0.47	0.74
Findlay, Irvine, Ltd. Griptester Friction Meter	0.48	0.53	0.74	0.24	0.36	0.64
Tatra Friction Tester	0.48	0.57	0.76	0.42	0.52	0.67
Norsemeter RUNAR (operated at fixed 16% slip)	0.45	0.52	0.69	0.32	0.42	0.63

Mu-Meter Test Equipment

The Mu-meter tool consists of a trailer as shown in Figure 1 pulled by a towing vehicle or combined into the vehicle and includes two tester wheels that rotate freely and are loaded with static loads.

Figure 11

The Mu-meter device is operated at a vehicle speed of 65 km/h. The speed of the tester vehicle is recorded with the help of the instruments contained in the device. Water splashed in front of the testing vehicle tires onto the pavement surface. Sideway friction or friction force between the test tire and the pavement surface will be recorded as a graph showing the amount

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of SFC (*side force coefficient*) value on the measuring instrument. The relationship between the friction/SFC value and the surface condition of the GG. Giles version of the pavement is attached to Table 3 below.

Table 3

Nilai SFC	Resiko Yang Terjadi
> 0,60	Kemungkinan kecelakaan sangat kecil, permukaan perkerasan dapat dikatakan kasar.
0,55 – 0,60	Kemungkinan kecelakaan akan mulai terjadi, permukaan perkerasan masih dalam kondisi kasar.
0,40 – 0,55	Kecelakaan terjadi dan resikoko fatal, terjadi dalam bentuk slip

Runway friction testing is carried out on the runway surface and is divided into five segments which are carried out back and forth, namely:

1. *Centerline Runway*
2. 3 Meters to the Right from *Centerline (3 m Right)*
3. 3 Meters to the Left from *Centerline (3 m Left)*
4. 6 Meters to the Right from *Centerline (6 m Right)*
5. 6 Meters to the Left from *centerline (6 m Left)*

The friction test in the segment above was carried out in the area where the landing gear landed such as *narrow body* aircraft (Boeing 737 and Airbus A320) which have a *wheel track* of about 3 meters from *the centerline*, and *wide body* aircraft such as Boeing 777 has a wheel track of about 6 meters from the centerline. So testing was also carried out at 3 and 6 meters from the *centerline runway*.

Method

This research took place from April 2022 to July 2022 on the Runway of Yogyakarta International Airport, Kulonprogo. This study uses primary and secondary data. Primary data is based on the results of observations in the field and secondary data is in the form of the results of existing reports, applicable regulations, and Airport Standard Operating Procedures in the Aerodrome Manual. This research is quantitative because there are calculations to determine the analysis of the results of the *runway* health test to obtain conclusions from the research results.

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In research to test the friction of the runway, using a method with a Mu-Meter test tool based on the provisions of SNI 6748:2008 tentang Cara Uji Kekesatan pada Permukaan Perkerasan menggunakan alat Mu-Meter.

Test preparation procedure

a) Make sure the pressure of the two tester tires is by the provisions and Check the condition of the suspension eligibility or per.
b) Before the implementation, operate the test vehicle at a normal speed of at least 8 kilometers.
c) Install the test wheel in the raised position (toe-out) and the rear wheel in the position below.
d) Make sure the tester wheel is free to rotate and lock when the tire position is lifted.
e) The rear wheels should be able to be moved up and down and only restrained by their springs.

Terms of the speed of the tester vehicle

a) The implementation is carried out at a vehicle speed of 65 ± 0.8 km / h with a tolerance of ± 1.5 km / h.
b) If testing is carried out at speeds other than 65 km/h, note Mu-N with a significant speed in lowercase under the value of Mu-N (For example, MuN50 if the speed is 50 km/h).

The procedure for conducting the test

Operate the test equipment at the vehicle speed as above. Before the test begins, remove the water on the test tire for approximately 1 second. Perform the test to completion. Stop giving water approximately 1 second after the test is completed. Mark the initial and final limits of the test on graph paper in the note-taking box.

Discussion and Result

***Raw data* test of runway friction**

The data from the measurement test came out in the form of a graph between the intended mileage, the average speed of the towing car per 50

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meters, and the Mu-Number per 50 meters. Each test segment produces a different graph.

A summary of *the raw data* of the results of the runway friction test is presented in **Table 4**.

Table 4

Sta	Cl 11-29	Cl 29-11	3M L 29-11	3M L 11-29	3M R 11-29	3M R 29-11	6M L 11-29	6M L 29-11	6M R 11-29	6M R 29-11
50	0,52	0,50	0,59	0,65	0,57	0,59	0,77	0,88	0,81	0,75
100	0,62	0,55	0,64	0,67	0,58	0,59	0,80	0,89	0,85	0,78
150	0,62	0,56	0,67	0,67	0,58	0,61	0,81	0,89	0,87	0,79
200	0,63	0,56	0,67	0,68	0,59	0,62	0,84	0,91	0,88	0,80
250	0,64	0,58	0,68	0,68	0,60	0,62	0,85	0,91	0,89	0,81
300	0,64	0,59	0,68	0,69	0,61	0,64	0,85	0,91	0,89	0,81
350	0,65	0,59	0,70	0,69	0,61	0,64	0,85	0,92	0,90	0,84
400	0,66	0,59	0,71	0,69	0,61	0,65	0,87	0,92	0,90	0,85
450	0,66	0,60	0,72	0,69	0,62	0,65	0,89	0,92	0,91	0,85
500	0,68	0,60	0,74	0,71	0,62	0,69	0,89	0,93	0,91	0,86
550	0,68	0,60	0,74	0,71	0,62	0,69	0,89	0,93	0,91	0,86
600	0,68	0,60	0,74	0,73	0,63	0,71	0,90	0,93	0,91	0,87
650	0,69	0,61	0,74	0,75	0,65	0,72	0,92	0,94	0,91	0,88
700	0,72	0,61	0,75	0,75	0,66	0,73	0,92	0,94	0,91	0,89
750	0,72	0,62	0,75	0,77	0,68	0,74	0,92	0,94	0,92	0,90
800	0,72	0,63	0,75	0,77	0,68	0,74	0,92	0,94	0,92	0,90
850	0,72	0,63	0,75	0,77	0,68	0,75	0,92	0,94	0,92	0,90
900	0,72	0,64	0,76	0,77	0,69	0,75	0,92	0,94	0,92	0,90
950	0,73	0,64	0,76	0,78	0,69	0,75	0,93	0,94	0,92	0,91
1000	0,74	0,64	0,76	0,78	0,69	0,76	0,93	0,95	0,92	0,91
1050	0,74	0,64	0,76	0,78	0,70	0,76	0,93	0,95	0,93	0,91
1100	0,74	0,65	0,76	0,78	0,70	0,77	0,93	0,95	0,93	0,92
1150	0,74	0,65	0,77	0,78	0,70	0,77	0,93	0,95	0,93	0,92
1200	0,74	0,66	0,77	0,78	0,71	0,77	0,93	0,95	0,93	0,92
1250	0,75	0,67	0,78	0,79	0,71	0,78	0,93	0,95	0,93	0,93
1300	0,75	0,68	0,78	0,79	0,71	0,78	0,94	0,95	0,93	0,93
1350	0,76	0,68	0,78	0,79	0,71	0,78	0,94	0,95	0,93	0,93
1400	0,77	0,68	0,79	0,79	0,72	0,78	0,94	0,96	0,93	0,93
1450	0,77	0,69	0,79	0,80	0,72	0,79	0,94	0,96	0,93	0,93
1500	0,77	0,70	0,80	0,80	0,72	0,79	0,94	0,96	0,93	0,93
1550	0,77	0,70	0,80	0,80	0,73	0,79	0,94	0,96	0,93	0,93
1600	0,77	0,71	0,80	0,80	0,73	0,79	0,94	0,96	0,93	0,93
1650	0,78	0,71	0,80	0,81	0,73	0,80	0,95	0,96	0,93	0,93

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1700	0,78	0,71	0,80	0,81	0,73	0,80	0,95	0,96	0,93	0,93
1750	0,78	0,72	0,80	0,81	0,73	0,80	0,95	0,96	0,94	0,93
1800	0,78	0,74	0,81	0,81	0,74	0,80	0,95	0,96	0,94	0,93
1850	0,78	0,78	0,81	0,81	0,74	0,80	0,95	0,96	0,94	0,94
1900	0,78	0,78	0,81	0,81	0,74	0,81	0,95	0,96	0,94	0,94
1950	0,79	0,78	0,81	0,82	0,74	0,81	0,95	0,97	0,94	0,94
2000	0,79	0,80	0,81	0,82	0,74	0,81	0,95	0,97	0,94	0,94
2050	0,79	0,80	0,81	0,82	0,74	0,81	0,95	0,97	0,94	0,94
2100	0,80	0,80	0,81	0,82	0,74	0,81	0,95	0,97	0,94	0,94
2150	0,80	0,81	0,81	0,82	0,74	0,81	0,96	0,97	0,94	0,95
2200	0,80	0,81	0,81	0,82	0,74	0,81	0,96	0,97	0,94	0,95
2250	0,82	0,82	0,81	0,82	0,75	0,82	0,96	0,97	0,94	0,95
2300	0,82	0,82	0,81	0,83	0,75	0,82	0,96	0,97	0,95	0,95
2350	0,82	0,83	0,82	0,83	0,75	0,82	0,96	0,97	0,95	0,95
2400	0,83	0,83	0,82	0,83	0,75	0,82	0,96	0,97	0,95	0,95
2450	0,83	0,83	0,82	0,83	0,75	0,82	0,96	0,98	0,95	0,95
2500	0,84	0,84	0,83	0,83	0,75	0,83	0,96	0,98	0,95	0,96
2550	0,84	0,84	0,83	0,84	0,75	0,83	0,96	0,98	0,95	0,96
2600	0,84	0,84	0,83	0,84	0,76	0,85	0,96	0,98	0,95	0,96
2650	0,84	0,84	0,83	0,84	0,76	0,85	0,96	0,98	0,95	0,96
2700	0,85	0,85	0,83	0,86	0,76	0,85	0,96	0,98	0,95	0,96
2750	0,86	0,86	0,85	0,86	0,79	0,86	0,96	0,98	0,95	0,96
2800	0,87	0,87	0,85	0,86	0,80	0,86	0,97	0,99	0,96	0,97
2850	0,88	0,89	0,87	0,88	0,82	0,87	0,97	0,99	0,96	0,97
2900	0,89	0,92	0,88	0,90	0,83	0,88	0,97	0,99	0,96	0,97
2950	0,90	0,92	0,89	0,90	0,84	0,89	0,97	0,99	0,96	0,97
3000	0,90	0,92	0,97	0,91	0,91	0,89	0,97	0,99	0,96	0,97
3050	0,91	0,94	0,98	0,92	0,91	0,89	0,97	1,00	0,96	0,97
3100	0,91	0,97		0,93		0,89	0,97		0,98	0,98
3150				0,93		0,90	0,98			0,99
Average	**0,77**	**0,72**	**0,79**	**0,80**	**0,72**	**0,78**	**0,93**	**0,95**	**0,93**	**0,92**

Comparison between Current Data and Previous Data

The runway friction testing data at Yogyakarta International Airport was previously tested in November 2021 and was carried out before the implementation of the 2021 Rubber Deposit began. The comparison between the two data is presented in **Table 5** below.

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Table 5

No.	Location	Result		Comparison
		November 2021	Current (May 2022)	
1.	*Runway 11-29 Centerline*	0,75	0,77	Up ↑
2.	*Runway 11-29 3 M Right*	0,82	0,72	Down ↓
3.	*Runway 11-29 3 M Left*	0,85	0,80	Down ↓
4.	*Runway 11-29 6 M Right*	0,90	0,93	Up ↑
5.	*Runway 11-29 6 M Left*	0,91	0,93	Up ↑
6.	*Runway 29-11 Centerline*	0,71	0,72	Up ↑
7.	*Runway 29-11 3 M Right*	0,81	0,78	Down ↓
8.	*Runway 29-11 3 M Left*	0,88	0,79	Down ↓
9.	*Runway 29-11 6 M Right*	0,92	0,92	Up ↑
10.	*Runway 29-11 6 M Left*	0,92	0,95	Up ↑

Based on the comparison above, it can be concluded that after a Rubber Deposit Cleaning is carried out and within 6 (six) months, there is a decrease in the level of friction, especially in segments 3 (three) meters from the right and left of the runway centerline. This happens caused because the aircraft movement traffic that often operates is *narrow body* aircraft or 1 (one) crossroads for example, Boeing 737 and Airbus 320 which are used mainly by airlines operating at Yogyakarta International Airport.

In addition to the decrease, there is also an increase in the level of surface tightness, this can be caused by weather factors that can make the value of tightness rise because there is a natural factor, namely the rubber deposit that is lifted. In addition, due to the frequency of *wide-body* aircraft traffic that rarely operates at this airport, the level of tightness in the 6-meter segment of the *centerline* will gradually restore rise. The rear wheels of the aircraft became the first wheels to hit the surface and braking made the front wheels' performance less heavy than the work of the rear wheels. This resulted in the value of centerline friction, which recovered a little over time.

Based on this comparison, it was concluded that the more often the runway is used by aircraft operations, the more surface tightness will decrease over time.

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Test Data Analysis with a Percentage of 90%

Based on data from the field (**Table 4**), there are 621 Mu-Number values obtained along the runway. As for knowing the value of the Mu-Number, of course, not all of them are mentioned, but only take one piece of data can represent the entire segment of the runway. Analyzing this data using the 90 percent percentage method means taking data representing 90 percent of the data from all available data. Data analysis is available in **Table 6** below.

Table 66

DATA	FREQUENCY	DATA PASSED(N)	PERCENTAGE (N/621*100%)
0,50	1	621	100,00%
0,52	1	620	99,84%
0,55	1	619	99,68%
0,56	2	618	99,52%
0,57	1	616	99,19%
0,58	3	615	99,03%
0,59	7	612	98,55%
0,60	5	605	97,42%
0,61	6	600	96,62%
0,62	8	594	95,65%
0,63	4	586	94,36%
0,64	9	582	93,72%
0,65	7	573	92,27%
0,66	4	566	91,14%
0,67	**5**	**562**	**90,50%**
0,68	13	557	89,69%
0,69	11	544	87,60%
0,70	6	533	85,83%
0,71	11	527	84,86%
0,72	11	516	83,09%
0,73	8	505	81,32%
0,74	21	497	80,03%
0,75	19	476	76,65%
0,76	11	457	73,59%
0,77	15	446	71,82%
0,78	23	431	69,40%
0,79	15	408	65,70%
0,80	24	393	63,29%
0,81	30	369	59,42%
0,82	21	339	54,59%
0,83	18	318	51,21%
0,84	14	300	48,31%

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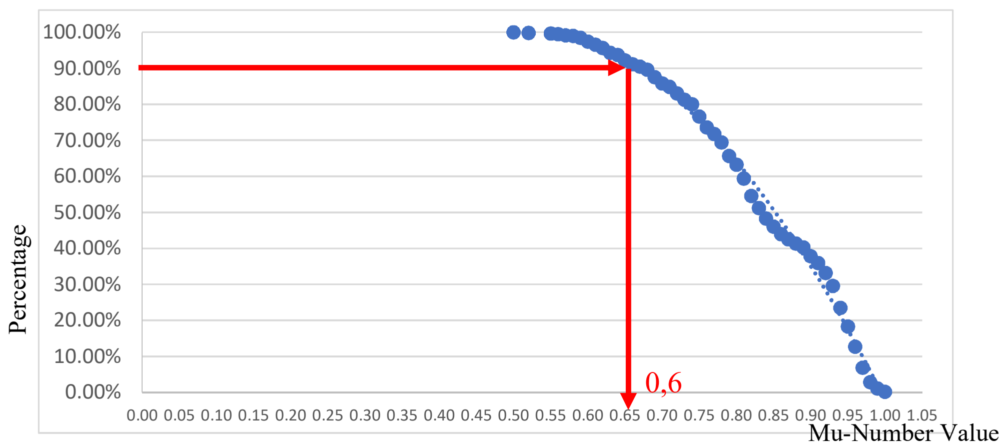
0,85	13	286	46,05%
0,86	9	273	43,96%
0,87	7	264	42,51%
0,88	7	257	41,38%
0,89	15	250	40,26%
0,90	12	235	37,84%
0,91	17	223	35,91%
0,92	22	206	33,17%
0,93	38	184	29,63%
0,94	32	146	23,51%
0,95	35	114	18,36%
0,96	36	79	12,72%
0,97	25	43	6,92%
0,98	11	18	2,90%
0,99	6	7	1,13%
1,00	1	1	0,16%

The data in the table above inserted into the graph becomes like **Picture 2** next.



Figures 2

Based on the Graph in **Figure 2** above, it can be concluded that 90% Percentage Data is contained in the value of 0.67. This led to the conclusion that the Mu-Number value on the pavement surface of the runway was 0.67.

In the regulation of the Direktur Jenderal Perhubungan Udara Nomor KP 94 Tahun 2015 tentang Pedoman Teknik Operasional Peraturan Keselamatan Penerbangan Sipil Bagian 139-23 Pedoman Program Pemeliharaan Konstruksi Perkerasan Bandar Udara, it is stated that there is a classification of the level of friction of the runway pavement surface for various measuring instruments as in **Table 2**. Moreover, it can be concluded

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that by using the Mu-Meter test equipment at a testing speed of 65 km / h, the minimum level of friction is at a value of 0.42, the maintenance is at a value of 0.53 and for new construction it is at 0.72. It can be concluded that the result of the value of the friction of the runway surface of 0.67 meets the minimum level and level of maintenance requirements.

In addition, based on the SFC values in **Table 3** above, it can be concluded that the value of 0.67 contains a minimal probability of an accident, and the pavement surface can be said to be rough. So, the runway at Yogyakarta International Airport has a tendency that is still feasible for flight operations.

Conclusion

Based on the research results above, it can be concluded that runway maintenance is a form of maintenance of airside facilities. One form of runway maintenance is testing the surface friction of the runway pavement. The runway is expected to have an excellent ability to operate the flight.

Based on comparisons with the previous year's data, it was found that the 3-meter segments from the left and right of the *centerline* experienced a decrease in the level of friction. This shows that the more often the runway is used by aircraft, the less friction will decrease over time.

Based on calculations with a percentage of 90%, it is determined that the result of the runway friction of Yogyakarta International Airport is worth 0.67, which means that according to regulations, a value of 0.67 is above the standard threshold above the minimum limit.

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