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Estimating the Potential of Skid Incident at Airport Runway – A Case Study

(Menganggar Potensi Kejadian Tergelincir di Landasan Kapal Terbang – Satu Kajian Kes)

Ng Choy Peng[a,*], Faridah Hanim Khairuddin[a], Wan Mohamed Syafuan Wan Mohamed Sabri[a], Zawil Mohd Yusoff[a], Yit Hong Yee[b] & Marzuki Ramli[b]

[a]*Department of Civil Engineering, Faculty of Engineering, National Defense University of Malaysia, Sg. Besi Camp, Kuala Lumpur, Malaysia*

[b]*Air Accident Investigation Bureau, Ministry of Transport Malaysia, Malaysia*

**Corresponding author: cpng@upnm.edu.my*

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ABSTRACT

Skid resistance or friction on airport pavement plays an essential role in runway safety to ensure safe stopping distance. It also provides safety margins during take off and landing of aircraft especially in directional control by reducing the occurrence of overrun and veer-off incidents. The friction between pavement and tire is related to multiple factors such as pavement surface characteristics (microtexture and macrotexture), material intruded between tire and pavement surface (water, snow, and contaminants), tire conditions (types, wear, and inflation pressure), and vehicle operating conditions (vehicle speed and whether the wheel is rolling or locked). Skid incidents due to wet pavement surface at airport runway is a major concern especially in regions of wet-tropical climate countries such as Malaysia. Thus, this study was undertaken to measure the potential of skid incident at airport runway by collecting data on pavement surface characteristics. Field data collection on pavement surface microtexture was conducted using the British Pendulum Tester at a local airport runway to obtain data for the estimation of the skid number (SN). Due to constraints, pavement surface macrotexture test was unable to be conducted at site. However, the pavement surface macrotexture was able to be estimated based on previous research. The potential of the skid incident was estimated by calculating the SN using the aircraft's touch down speed at the airport runway, varies from 50 to 70 knots (57.5 – 80.6 mph or 92.6 – 129.6 km/h). The results of the estimation indicated that the possibility of the skid incident occurrence was high. This study provides useful insights for airport authority to investigate the potential of overrun and veer-off incidents of aircraft at the airport runway.

Keywords: Skid resistance; microtexture, macrotexture; skid number; runway

ABSTRAK

Ketahanan gelinciran atau geseran di turapan lapangan terbang memainkan peranan yang penting dalam keselamatan landasan untuk memastikan jarak berhenti yang selamat. Ia juga memberi margin keselamatan kepada pesawat terutamanya dalam kawalan arah bagi mengurangkan kejadian terlepas dan menyimpang semasa berlepas dan mendarat. Geseran antara turapan dan tayar dipengaruhi oleh beberapa faktor seperti ciri permukaan turapan (mikrotekstur dan makrotekstur), bahan yang wujud di antara permukaan tayar dan turapan (air, salji, dan bahan pencemaran), keadaan tayar (jenis, kehausan, dan tekanan), dan keadaan operasi kenderaan (kelajuan kenderaan dan sama ada roda berpusing atau terkunci). Kejadian tergelincir akibat permukaan turapan yang basah di landasan lapangan terbang menjadi perhatian utama terutamanya di negara-negara yang mempunyai iklim tropika seperti Malaysia. Oleh yang demikian, kajian ini telah dilaksanakan untuk menganggar potensi terjadinya kejadian tergelincir di landasan lapangan terbang dengan mengumpul data mengenai ciri permukaan turapan. Pengumpulan data mikrotekstur pada permukaan turapan telah dilakukan dengan menggunakan British Pendulum Tester di salah satu landasan lapangan terbang tempatan untuk mendapatkan data bagi pengiraan nombor skid (SN). Disebabkan kekangan, *ujian makrotekstur pada permukaan turapan tidak dapat dijalankan di lokasi pengumpalan data. Walau bagaimanapun, makrotekstur permukaan turapan dapat dianggar berdasarkan kajian literatur. Potensi kejadian tergelincir telah dianggarkan dengan pengiraan SN menggunakan kelajuan mendarat kapal terbang di landasan lapangan terbang yang bervariasi dari 50 hingga 70 knot (57.5 - 80.6 batu per jam atau 92.6 - 129.6 km/j). Keputusan kajian ini menunjukkan bahawa kejadian tergelincir yang berlaku di landasan lapangan terbang adalah tinggi. Kajian ini memberi pandangan yang berguna kepada pihak berkuasa lapangan terbang untuk menyiasat potensi berlakunya kejadian pesawat terlepas dan menyimpang di landasan lapangan terbang.*

Kata kunci: Ketahanan gelinciran; mikrotekstur; makrotekstur; nombor skid; landasan

INTRODUCTION

Appropriate surface friction or skid resistance must be provided on airport pavement so that loss of control does not occur during take off and landing of the aircraft when the pavement is wet. Skid accidents are accidents related to wet pavement. It is possible to distinguish between three different events of wet pavements that can cause loss of control: (a) damp (water film thickness less than 0.1 mm), (b) viscoplaning (water film thickness between 0.1 and 0.5 mm) and (c) hydroplaning or aquaplaning (water film thickness more than 0.5 mm).

Pavement surface texture has a huge effect on skid resistance especially in wet surface conditions. Macrotexture refers to aggregate properties such as the types, size (especially the maximum aggregate size), and gradation, together with the properties of asphalt mixtures such as binder content, mix design, and air voids (Hall et al. 2009; Leandri & Losa, 2015; Kogbara et al. 2016). Microtexture refers to the coarse aggregates' type and the abrasion resistance of the aggregates subjected to dynamic loading of traffic and environmental factors. Smooth macrotexture, which indicate insufficient channels to facilitate the flow of excess water on the runway and polished aggregate with smooth microtexture, which reduces skid resistance between the aggregate and the tire, are two major causes of skid incident. Figure 1 shows the illustration of pavement surface texture. Usually, macrotexture depths varying between 0.2 to 3 mm whereas microtexture depth of the aggregate ranging from 0 to 0.2 mm control the pavement-tire contact.

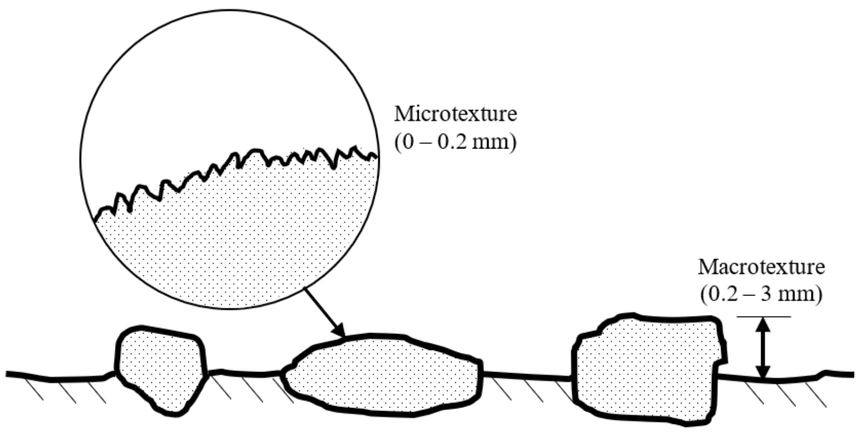

FIGURE 1. Illustration of pavement surface texture
Source: Modified from Hass (1997), Flintsch et al. (2003) and Tighe (2013)

(ICAO 2002; Cairney 2006; Pulugurtha et al. 2007; Mayora & Pina 2008; Srirangam et al. 2014; ICAO 2018) indicated that skid accident decreases with an increase in both macrotexture and microtexture depth. Microtexture plays a vital role in the pavement-tire contact especially during wet condition as the size of microasperities has a significant trace in overcoming the thin water film. Squeezing and overcoming the thin water film present in the pavement-tire contact area and generating friction forces requires the existence of microtexture (Do et al. 2000).

This study was undertaken to identify the performance of pavement surface texture and the potential of skid incident at the airport runway. With the help from Malaysia Airport Holdings Berhad (MAHB), the Royal Malaysia Police (RMP) and the Air Accident Investigation Bureau (AAIB), Ministry of Transport, data collection for measuring the pavement surface texture of this project was conducted on 21 August 2020 at a local airport located at Long Seridan, Sarawak. This paper presents the findings from the data collection at the runway and the estimation of the skid number (SN) would provide useful information for the airport authority to take action with respect to the pavement surface condition.

PAVEMENT SURFACE TEXTURE, FRICTION AND SKID NUMBER

Many methods have been used for measuring macrotexture. The most frequently used is the sand patch method specified as ASTM E965 Standard Test Method for Measuring Surface Depth using Sand Volumetric Technique. No practical method has been developed to measure microtexture directly, however, a commonly used substitute is to measure low-speed friction by the British Pendulum Tester, as specified in ASTM E303 Standard Method for Measuring Surface Friction Properties using the British Pendulum Tester.

Surface friction is defined as the force developed when a tire that is preventing from rotating slides along the pavement surface (as indicated in Figure 2). Surface friction can be computed as:

$$F = \mu W \tag{1}$$

where F = tractive force applied to the tire at the tire-pavement contact
μ = coefficient of friction
W = dynamic vertical load on the tire

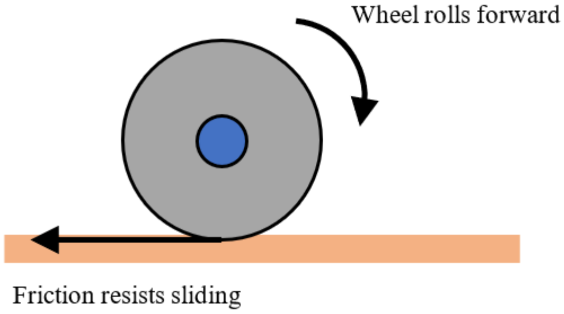

FIGURE 2. Surface friction

Skid number (SN) is computed by multiplying coefficient of friction by 100.

$$SN = 100\mu = 100\left(\frac{F}{W}\right) \tag{2}$$

The relationship between skid number (SN) and speed (V) was expressed by Leu & Henry (1978).

$$SN = SN_0 e^{-\left(\frac{PNG}{100}\right)V} \tag{3}$$

where SN_0 = skid number at zero speed
PNG = percent normalized gradient of the SN versus V curve in mile/h

The relationship between the skid number at zero speed, SN0 and the British Pendulum Number, BPN and the relationship between percent normalized gradient, PNG and mean texture depth, MTD were expressed by Meyer (1991).

$$SN_0 = 1.32BPN - 34.9 \tag{4}$$

$$PNG = 0.157MTD^{-0.47} \tag{5}$$

where BPN = British Pendulum Number
MTD = mean texture depth in inches

Table 1 shows the typical skid number and the indications of the requirements of pavement maintenance and rehabilitation to increase the pavement safety level.

TABLE 1. Typical skid number and indication

SN	Remarks
< 31	Take measures to correct the pavement texture
≥ 30	Acceptable for low volume of traffic
31 – 34	Monitor the pavement frequently
> 35	Acceptable for high volume of traffic

Source: Wambold et al. (1990); Jayawickrama et al. (1996)

METHODOLOGY

STUDY LOCATION

The study location selected for this research was the Long Seridan Airport's Runway in Sarawak. This is a public airport located at Ulu Tutoh, Baram, Long Seridan serving the community in Long Seridan, Sarawak. The airport is located at 03°58'34" N and 115°04'02.2" E and the runway was built in December 2000 and was paved with asphaltic concrete pavement instead of concrete pavement due to low air traffic volume. The last resurfacing works was conducted in December 2012. The length of the runway is 548 m and the width of the runway varies between 18-19 m, at 9-9.5 m per direction. No proper paved shoulder was constructed at both sides of the runway. Natural earth drain was located at approximately 5 m from the edge of the runway on both sides. The short runway of 548 m can only handle small aircrafts with capacity of not more than 25 passengers such as the de Havilland Canada DHC-6 Twin Otter and helicopters.

Figure 3 shows the aerial photograph of the airport. During the arrival at the airport, small aircrafts will first touch down at plane T_1T_3 then decelerate and travel along the left-hand side of the runway, making a U-turn before the end of the runway (approximately at the location of the 8th centreline) then travel at the opposite direction on the right-hand side of the runway towards plane T_4T_2, making another U-turn (approximately at the location before the 1st centreline), then the aircraft will be parked at the "blue star" location for passenger disembarkment. On the other hand, when the aircraft is ready for departure, the aircraft will first reverse to the location approximately at the location of the 1st centreline, waiting for control tower instructions, before starting to accelerate and the aircraft will take off once it reaches the take off plane on the left hand side approximately near location 7BL.

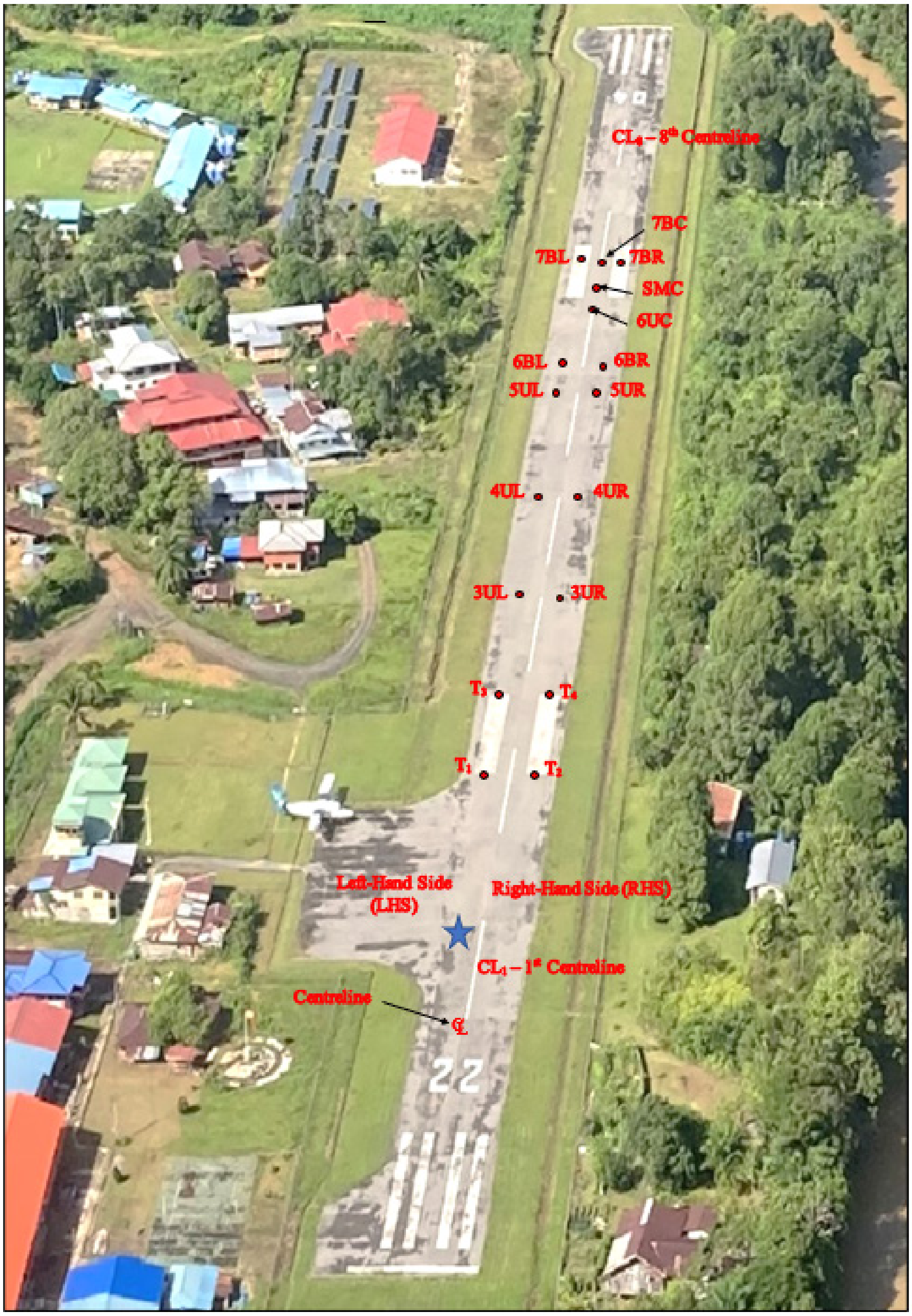

FIGURE 3. Aerial photograph and layout plan for the skid resistance tests

PAVEMENT SURFACE TEXTURE MEASUREMENT

The microtexture of the pavement surface or skid resistance at the runway was measured using the British Pendulum Tester following the standard testing procedure as specified in ASTM E303. A total of 17 points were identified and marked for the skid resistance tests. Figure 3 shows the points for the tests. The skid resistance tests were conducted by measuring the British Pendulum Number (BPN) at all points with a minimum of three to five readings taken at each point under two conditions, (a) dry condition and (b) wet condition.

The points for the skid resistance tests could be classified into 3 groups:

1.Group 1, located at the centreline of the runway which consists 3 points that act as controlled points (6UC, SMC and 7BC)

2.Group 2, located at the left-hand side of the runway which consists of 5 points situated 4.5 m from the centreline of the runway and 2 points at the midpoint of the touch down plane T1T3 (T1, T3, 3UL, 4UL, 5UL, 6BL and 7BL)

3. Group 3, located at the right-hand side of the runway which consists of 5 points situated 4.5 m from the centreline of the runway and 2 points at the midpoint of the touch down plane T2T4 (T2, T4, 3UR, 4UR, 5UR, 6BR and 7BR).

The sand patch tests for measuring the macrotexture of the runway was not conducted at the site due to time constraints (there was an aircraft landing and the data collection had to stop for approximately 1.5 hours) and absence of the laboratory equipment.

RESULTS AND DISCUSSION

Descriptive Statistics

Table 2 shows the descriptive statistics of the dry and wet BPN readings for all groups where the skid resistance tests were performed.

TABLE 2. Descriptive statistics of the dry and wet BPN readings

Items	All		Centreline, CL (1)		Left-Hand Side, LHS (2)		Right-Hand Side, RHS (3)	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Count	17	17	3	3	7	7	7	7
Mean	82.68	75.34	79.58	70.67	84.22	77.76	82.48	74.91
Median	82.50	75.83	75.00	67.00	86.88	78.33	80.83	75.83
Mode	75.00	78.33	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Std. Dev.	6.84	7.46	9.04	6.64	6.60	6.05	6.80	8.89
Kurtosis	-1.66	-0.71	#N/A	#N/A	-1.52	-1.50	-0.94	-0.15
Skewness	-0.10	-0.13	1.69	1.73	-0.64	-0.15	0.03	-0.17
Range	19.00	26.75	16.25	11.67	16.25	15.50	19.00	26.75
Min.	72.50	61.25	73.75	66.67	75.00	70.00	72.50	61.25
Max.	91.50	88.00	90.00	78.33	91.25	85.50	91.50	88.00
Sum	1405.63	1280.71	238.75	212.00	589.54	544.33	577.33	524.38

The mean dry and wet BPN readings for all points were 82.68 and 75.34, respectively. Generally, the mean dry and wet BPN readings at the centreline were lower compared to the BPN readings at the LHS and RHS of the runway. The standard deviation for the dry BPN readings at the centreline were higher than other locations while the wet BPN on the right-hand side of the runway were higher than other locations. The values for the skewness and kurtosis between -2 and +2 were acceptable to prove that the BPN readings were normally distributed (George & Mallery 2010).

ONE-WAY ANOVA ANALYSIS

One-way ANOVA test was used to compare whether the BPN readings measured under (a) dry and (b) wet condition for the three groups had significant difference from each other using a confidence level of 95% (significance level of 5%).

Tables 3 and 4 show the one-way ANOVA analysis for the mean dry and wet BPN readings, respectively.

Generally, as indicated in Table 3, the mean dry BPN readings for the three groups were not significantly different from each other at the significance level of 5%, F (2, 14)

=0.453, p = 0.645. Thus, this implied that the BPN readings at the centreline, left-hand side, and right-hand side of the runway were equal.

Similarly, the one-way ANOVA analysis as indicated in Table 4 also shows that the mean wet BPN readings for the three groups were not significantly different, F(2, 14) =0.964, p = 0.405, at the significance level of 5%. Again, the results implied that the wet BPN readings taken at all locations were equal.

Table 3. ANOVA test for dry BPN for various group

Dry BPN	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	45.549	2	22.775	0.453	0.645
Within Groups	703.549	14	50.253		
Total	749.098	16			

Table 4. ANOVA test for wet BPN for various group

Dry BPN	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	107.603	2	53.802	0.964	0.405
Within Groups	781.018	14	55.787		
Total	888.621	16			

INDEPENDENT SAMPLE T-TEST

To check whether the BPN readings measured under dry condition were significantly higher than the BPN readings measured under wet condition, an independent sample T-test was used to compare the results of the mean BPN readings measured at all locations using a confidence level of 95%. The results are shown in Table 5.

TABLE 5. Independent sample T-test

Items	Dry BPN	Wet BPN
Mean	82.68	75.34
Variance	46.76	55.63
Observations	17	17
Pooled Variance	51.20	
Hypothesized Mean Difference	0	
df	32	
t Stat	2.994	
P(T<=t) one-tail	0.003	
t Critical one-tail	1.694	
P(T<=t) two-tail	0.005	
t Critical two-tail	2.037	

The results of the independent sample T-test in Table 5 shows that the results were significant at the 5%, t = 2.994, p = 0.003, which conclude that the mean dry BPN readings were significantly higher than the mean wet BPN readings at all locations of the runway.

COMPUTATION OF SKID NUMBER (SN)

Skid number (SN) is an indication of the skid resistance by taking into consideration both the microtexture and macrotexture. The BPN readings obtained from the British Pendulum Tests, which associated with the microtexture could be used to calculate the skid number at zero speed as shown earlier. The mean wet BPN reading of 75.34 was used in the estimation associated to the ANOVA tests that showed the mean wet BPN readings at the three locations were not significantly different.

Even though the sand patch tests were not conducted at the site, the percent normalized gradient could be estimated based on the suggestions from Leu & Henry (1978) where good mean texture depth of 0.03 inches, average mean texture depth of 0.02 inches, poor mean texture depth of 0.01 inches, and very poor mean texture depth of 0.005 inches were used in the estimations.

The potential of skid incident is also associated with aircraft speed. Thus, for the estimation of SN, the landing speed of the aircraft, which varies between 50 to 70 knots (57.5 – 80.6 mph or 92.6 – 129.6 km/h) were used to simulate the possibility of the skid incident during wet conditions. These landing speeds are the usual landing speeds of small aircrafts approaching the touch down plane of T1T3 at Long Seridan. Tables 6-8 show the estimations of the SN at three different landing speeds of 50 knots (57.5 mph or 92.6 km/h), 60 knots (69.0 mph or 111.1 km/h), and 70 knots (80.6 mph or 129.6 km/h).

TABLE 6. Estimation of SN using wet BPN reading (Landing speed = 50 knots or 57.5 mph or 92.6 km/h)

Condition	Good	Average	Poor	V. Poor
British Pendulum Number, *BPN*	75.34	75.34	75.34	75.34
Speed of aircraft, *V* (*mph*)	57.5	57.5	57.5	57.5
Skid number at zero speed, $SN_0 = 1.32BPN - 34.9$	64.55	64.55	64.55	64.55
Mean texture depth, MTD (*inches*)	0.03	0.02	0.01	0.005
Percent normalized gradient, $PNG = 0.157MTD^{-0.47}$	0.82	0.99	1.37	1.89
Skid Number, $SN = SN_0 e^{-\left(\frac{PNG}{100}\right)V}$	40.38	36.59	29.40	21.72

TABLE 7. Estimation of SN using wet BPN reading (Landing speed = 60 knots or 69.0 mph or 111.1 km/h)

Condition	Good	Average	Poor	V. Poor
British Pendulum Number, *BPN*	75.34	75.34	75.34	75.34
Speed of aircraft, *V* (*mph*)	69.0	69.0	69.0	69.0
Skid number at zero speed, $SN_0 = 1.32BPN - 34.9$	64.55	64.55	64.55	64.55
Mean texture depth, MTD (*inches*)	0.03	0.02	0.01	0.005
Percent normalized gradient, $PNG = 0.157MTD^{-0.47}$	0.82	0.99	1.37	1.89
Skid Number, $SN = SN_0 e^{-\left(\frac{PNG}{100}\right)V}$	36.76	32.66	25.13	17.47

TABLE 8. Estimation of SN using wet BPN reading (Landing speed = 70 knots or 80.6 mph or 129.6 km/h)

Condition	Good	Average	Poor	V. Poor
British Pendulum Number, *BPN*	75.34	75.34	75.34	75.34
Speed of aircraft, *V* (*mph*)	80.6	80.6	80.6	80.6
Skid number at zero speed, $SN_0 = 1.32BPN - 34.9$	64.55	64.55	64.55	64.55

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Mean texture depth, MTD (*inches*)	0.03	0.02	0.01	0.005
Percent normalized gradient, $PNG = 0.157MTD^{-0.47}$	0.82	0.99	1.37	1.89
Skid Number, $SN = SN_0 e^{-\left(\frac{PNG}{100}\right)V}$	33.44	29.13	21.44	14.03

With respect to ICAO Annex 14, 8.3.10, the mean texture depth of a normal wet runway should be at least 0.25 mm or 0.01 inches to provide adequate drainage and friction qualities (ICAO 2018). However, the estimation in Tables 6-8 indicate that the SN estimated at 0.01 inches fail to provide adequate skid resistance during wet conditions, as the SN estimated were below 30, implying that the runway needs corrective and preventive measures to increase the pavement surface texture. The higher the landing speed of the aircraft, the likelihood of the skid incidents to occur will be greater especially during wet condition.

The results of this study provide useful insights for the airport authority to investigate the necessary maintenance and rehabilitation of other airport runways which have similar geometric characteristics like the Long Seridan Airport. Air transportation plays a vital role especially in large states such as Sarawak where majority of the terrain are mountainous. In Sarawak, small airports with short runway such as Ba'kelalan (549 m), Bario (670 m), Belaga (427 m), Kapit (427 m), Lawas (686 m), Long Akah (680 m), Long Banga (550 m), Long Lellang (426 m), Long Semado (487 m), Long Seridan (548 m), and Long Sukong (402 m) provides rural community the access to social, economic, education, and medical services. Thus, ensuring the safety of the runway is important as some rural community only reachable via air transportation.

CONCLUSIONS

This research shows that the potential of the skid incident at the Long Seridan airport runway is high. It is recommended that the Long Seridan Airport's runway to be resurfaced to improve the pavement microtexture and macrotexture. The maintenance and rehabilitation of runway could increase the skid resistance of the pavement and reduces the likelihood of skid incident. It is also suggested that the asphaltic concrete pavement design of the runway to follow the standards and specifications as indicated in Part 3 of the Aerodome Design Manual (ICAO 1983) and Annex 14, Volume 1 of the Aerodrome Design and Operations (ICAO 2018). In addition, the runway should also be maintained periodically despite of low traffic volume as pavement surface could deteriorate over the time due to weathering. For the runway maintenance, it is recommended that the standards and specifications as indicated in Part 2 of the Airport Services Manual (ICAO 2002) to be followed accordingly.

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DECLARATION OF COMPETING INTEREST

None

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