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Threshold value of skid resistance and texture depth for Malaysia road

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Abstract. Skid resistance is an important pavement characteristic for roads, which determines the friction between the road surface and vehicle tyres. The level of friction is largely influenced by the pavement surface aggregates micro texture, macro texture, and drainage attributes. The objective of this paper is to present the findings of the research and analysis conducted on Skid Resistance Value (SRV), Mean Texture Depth (MTD) and Skid Number (SN) obtained from the data collected on federal roads over the years since 2008. This research also attempted to determine the appropriate limiting values for SRV (microtexture), MTD (macrotexture) and SN for the federal roads. The result of analysis indicated that the average value of SRV at the locations of wet surface accident is 52.31 ± 8.54 . While for MTD, the accident risk is higher when MTD value is below the average of 0.45 ± 0.025 . The SRV and MTD results were correlated to each other and it can be concluded that accident risk increases significantly when SN value is below the average value of 31.49 ± 7.87 . Based on these findings, it is concluded that the minimum desirable values for SRV and SN for Malaysia's Federal roads to be 55 and 30 respectively.

1. Introduction

Road accident is a serious issue and a major concern to any road authorities and public at large. Accident statistics from the Malaysia Royal Police (PDRM) showed that the number of road accidents increased almost every year from 328,264 cases in year 2005 to 489,606 cases in 2015. About 1.3 - 1.8 % of the road accident are fatal accidents.

An important aspect of safety during travel using road transport is the interaction between vehicle tyres and the road surface. Two main factors that have high influence in this case are the skid resistance between the tyre and the road surface, and the texture depth of the pavement.

Skid resistance is the friction force developed when a tyre that is fully or partially prevented from rolling slides along a pavement surface under lubricated conditions. Friction is developed with the close contact between the tyre and the pavement aggregates.

On wet road surfaces, the capability to drain off the surface water between the tyre treads and pavement surface is another significant property required for the pavement wearing course. It is attributed to the aggregate size and amount of filler that filled up the spaces and voids within the aggregate matrix hence forming the residual texture depth of the pavement surface. Both skid resistance and texture depth have great impact over the tyre-pavement friction interaction mechanism and determined the safe vehicle operations on pavements [16].



1.1. Objective

The main objective of this study is to analyse the data on Skid Resistance Value (SRV) and Mean Texture Depth (MTD) collected for Federal Roads. The study will also review the effect on the Skid Number (SN) and the risk of skidding accident. This study also included the determination of appropriate threshold values of SRV and MTD. These threshold values shall provide some guide for key performance measures and intervention levels for Road Asset Management System. Hence, sufficient fund shall be allocated for the maintenance needs and thus, preserving the required safety level of the highway system.

1.2. Skid Resistance

Skid resistance is described as a movement resistance of two surfaces in at their contact location. It is characterized by the road pavement aggregates, pavement surface roughness and the friction forces developed when the pavement is exposed to the wheel load. Friction is expressed via friction coefficient which is a sum value of two acting forces, one is parallel to contact surface between two bodies and opposite to their movement direction (friction force), other acting force is perpendicular to the contact surface (normal force) [13].

The skid resistance properties also determine the distance travelled during emergency braking process to a stopping point. For safety requirements there is a minimum amount of skid resistance required based of the type of road locations. Transport and Road Research Laboratory (TRRL) (1969) has suggested the following requirements for skid resistance as shown in Table 1.

Table 1. TRRL (1969) requirements for skid resistance.

Category	Type of site	Minimum skid resistance
A	Roundabout, gradient, bends, approach	65
B	Heavily trafficked roads, urban	55
C	All other sites	45

Skid resistance has two major components: adhesion and hysteresis. Adhesion results from the shearing of molecular bonds formed when the tire rubber is pressed into close contact with pavement surface particles. Hysteresis results from energy dissipation when the tire rubber is deformed when passing across the asperities of a rough surface pavement. These two components of skid resistance are respectively related to the two key properties of asphalt pavement surfaces, that is micro-texture and macro-texture as presented in Figure 1.

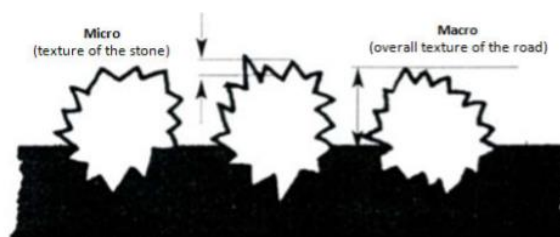


Figure 1. Illustration of Macro and Micro texture of a pavement surface [5].

1.3. Wet Weather Accidents

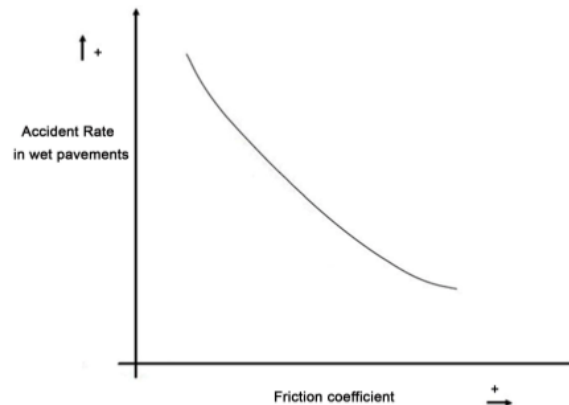


Figure 2. Relationship between accident rate in wet weather conditions and pavement surface friction [25].

Wambold et al. [27] reported that wet-weather accidents have a significant relationship with the skid numbers measured with a skid trailer. The effect of wet weather conditions on road safety was also demonstrated by a study conducted in Germany, where the proportion of wet crashes was compared to pavement surface friction, as shown in Figure 2. Friction in this study was measured at a speed of 80 km/hr. This figure clearly shows a significant decrease in wet pavement accidents as the pavement friction increases [25]. The relationship between pavement skid resistance and crash rates and the effect of pavement friction improvement on these crash rates is also demonstrated by several researchers [4, 10, 14, 17, 25].

1.4. Pavement texture

Road pavement texture can be divided into several categories. The Committee on Surface Characteristics of the World Road Association (Permanent International Association of Road Congresses (PIARC) 1995) has proposed a texture classification based on the wavelength range for each category as shown in Table 2.

Table 2. Texture classifications according to wavelength, PIARC (1995).

Texture classification	Relative wavelength
Microtexture	$\lambda < 0.5 \text{ mm}$
Macrotexture	$0.5 \text{ mm} < \lambda < 50 \text{ mm}$
Megatexture	$50 \text{ mm} < \lambda < 500 \text{ mm}$
Roughness	$0.5 \text{ m} < \lambda < 50 \text{ m}$

In the interaction between the vehicle tyres and the road surface, there are two main categories of surface texture that played very significant role in safety against skidding especially during wet conditions. They are the microtexture and macrotexture

With the wavelength of $< 0.5\text{mm}$, microtexture of individual aggregates contributed to the skid resistance at all speeds [6, 22, 24], and provides a greater contribution than macrotexture where vehicle operating speeds are low ($< 50\text{km/hr}$) [11, 19, 23]. It contributes to the coefficient of friction through the creation of adhesion forces, which occur as a result of the tyre interlocking with the road surface [22] and molecular bonds being sheared as the rubber of tyres pass over the road surface [19]. Macrotexture refers to the overall texture of the road surface ($0.5\text{mm} - 50\text{mm}$) [7], that being the surface irregularities caused by the size, shape and spacing of stone chips in the pavement [2]. Macrotexture primarily contributes to the coefficient of friction through the dry contact with the

aggregates and allowing water to drain through the texture spaces, thereby reducing the risk of aquaplaning especially at high speed.

2. Methodology

This research is based on evidence collected from most accident cases investigated by the JKR's Road Safety investigation team. The investigation procedures involved conducting several tests which included collecting data on skid resistance values and the texture depths of the pavement surface at the accident locations under investigation. Prior to the site investigation, basic information such as POL27 reports, accident and maintenance records are collected from the respective road authorities and agencies including the media.

2.1. British Pendulum Test (ASTM E303)

The British Pendulum Test (BPT) is a portable device that is widely used due to its simplicity, low cost and large historical database. It utilizes the loss in momentum of a swinging pendulum to measure pavement frictional properties. A rubber slider is attached to the end of the pendulum arm, which is raised parallel to the pavement surface prior to each test. Once released, the arm swings down and the slider travels across the pavement surface. The greater the friction of the surface, the greater the loss of momentum of the arm and the less amount of "backswing." A pointer follows the arm after the slider has left the pavement surface and measures the resulting Skid Resistance Value (SRV) or British Pendulum Number (BPN). This method is sometimes considered a surrogate for estimating effect of the microtexture.



Figure 3. British Pendulum Tester.

2.2. Sand Patch Method (ASTM E965)

One of the oldest, most often used and relied on methods for measuring macrotexture of pavement surface is the Sand Patch Method [1]. Even today most other tests are referenced to the sand patch method. This test method determines the average depth of pavement textured surface over a region by smoothing an area with a known quantity of sand. The method is designed to provide an average depth value of only the pavement macrotexture and is considered insensitive to pavement microtexture characteristics. The average depth between the bottom of the pavement surface voids and the top of surface aggregate particles can be calculated using the following:

$$MTD = \frac{4V}{\pi D^2} \quad (1)$$

Where: V = Sampling volume (cm³)
D = Average diameter of the area covered by the sand (mm)



Figure 4. Measuring texture depth using the Sand Patch Method.

3. Result and analysis

Data from accident investigation are being collected since 2008 and filtered for accident due to skidding of vehicles. Most of these accidents involved run-off vehicle cases but there are also other types of accidents that have been reported to be due to vehicles that are out-of-control. However, all these accidents have a common trend that is they had occurred on wet pavement surfaces. Table 3 shows the statistical analysis of data collected through the investigation on 37 wet surface accidents.

Table 3. Summary of the statistical analysis on wet surface accident data.

	Skid Resistance Value (SRV)	Mean Texture Depth (MTD)	Skid Number (SN)
Arithmetic Mean	52.31	0.45	31.49
Variance	72.87	0.0006	61.94
Standard Deviation	8.54	0.025	7.87

Based on the analysis, it can be concluded that the mean value of SRV and MTD are 52.31 ± 8.54 (43.77, 60.85) and 0.45 ± 0.025 (0.425, 0.475) respectively. By inserting these values in the Skid Number equation 2 [15], the mean value for SN is equal to 31.49 ± 7.87 (23.62, 39.36). SN is the Skid Number (Coefficient of Pavement Friction * 100) and SN₀ is the Skid Number at zero speed. SN₀ has been shown to be highly correlated to pavement microtexture which depends on the surface of aggregate asperities with its magnitude ranging from 1 to 500 mm (0.5 mm).

$$SN = SN_0 \exp \left[\frac{-(PNG) V}{100} \right] \quad (2)$$

Where: SN = Skid Number
SN₀ = $-31 + 1.38BPN$; Skid Number at zero speed
PNG = $0.45 (MTD)^{-0.47}$; Percent Normalized Gradient
V = Vehicle Speed (assumed constant urban street velocity of 60 km/hr)

3.1. MTD and SRV

According to the general principles and available literature, Microtexture and macrotexture are both necessary for the provision of adequate skid resistance. Thus, any measures available should be taken to increase the values of both parameters.

Increase in SRV may be achieved by reducing the aggregate particle size as well as the distance between particles, yet both of these adjustments to a mixture would create a decrease in MTD. Increase in MTD are beneficial to the overall skid resistance at high speeds, and this may be increased by coarsening the aggregate structure and extending the separation between particles. Greater MTD generates larger void spaces at the surface of the pavement, which reduces the effective contact area of the vehicle tire with the roadway – causing a reduction in SRV.

In Figure 5, MTD is plotted against SRV. The result shows weak correlation between MTD and SRV for wet surface accidents. Although a small amount of scatter was present in the data, the general trend of decreasing texture depth with increasing SRV was evident. Thus, maximizing both parameters is not advisable. A balanced approach is more appropriate.

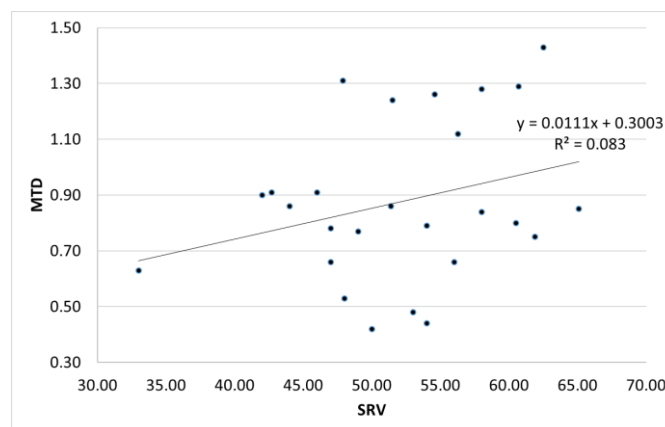


Figure 5. Mean Texture Depth vs. Skid Resistance Value.

3.2. Threshold value for SRV

Previously, in the absence of locally collected data, the minimum limiting value for SRV used by JKR is based on research conducted by TRRL on skid resistance in the United Kingdom (UK). A limiting value of 45 SRV (based on Category C, TRRL 1969) is being adopted as a guide for the minimum skid resistance value for all federal roads.

However, based on the results of the statistical analysis on the collected data, the mean value of SRV is 52.31 ± 8.54 (43.77, 60.85). It turns out that this finding is within the TRRL acceptable limits for roads in Malaysia (heavily trafficked roads). Hence, it is proposed that the minimum value of SRV for safe riding condition on Malaysian roads is 55 SRV.

3.3. Threshold value for SN

Page and Butas [21] claimed that the accident rate is low and uniform for pavements with SN of 26 and higher. However, the mean value computed from this analysis is 31.49 ± 7.87 (23.62, 39.36). Thus, it is proposed that the SN value of 30 to be used as a minimum threshold value.

4. Conclusions

The results of this analysis on the entire data relating to wet surface accidents are as follows:

- Minimum threshold value of SRV is 52.31 ± 8.54 (43.77, 60.85)
- Minimum threshold value of MTD is 0.45 ± 0.025 (0.425, 0.475)
- Risk of accident is higher when the SN value less than 31.49 ± 7.87 (23.62, 39.36)

This study recommended that the minimum SRV value for Malaysian Federal roads to be 55 SRV, minimum value of MTD to be 0.50 mm and minimum value of SN to be SN30.

5. References

- [1] ASTM International 2015 *ASTM E965 Standard test method for measuring pavement macrotexture depth using a volumetric technique* (West Conshohocken: ASTM International).
- [2] Austroads 2005 *Guidelines for the management of road surface skid resistance* (Australia: Austroads)
- [3] Bonnot J and Ray M 1976 Rehabilitation of concrete pavements anti-skid properties *Transportation Research Record* **624** 72-81
- [4] Bray J 2002 The role of crash surveillance and program evaluation: Nysdot's skid accident reduction program (SKARP) *28th International Forum on Traffic Records and Highway Information Systems* Orlando, 4-8 August 2002
- [5] Bullas J C 2004 *Tyres, road surfaces and reducing accidents: A Review* (United Kingdom: AA Foundation for Road Safety Research).
- [6] Cenek P D, Henderson R J, Loader M and Locke N 2002 *Texture depth requirements for state highway asset management purposes* (Lower Hutt, New Zealand: Opus International Consultants).
- [7] Chelliah T, Stephanos P, Smith T and Kochen B 2002 *Developing a design policy to improve pavement surface characteristics* (Virginia, United States: Maryland State Highway Administration).
- [8] Data Collection Ltd 2006 *Road measurement data acquisition system - Roughness surveys* Retrieved on 28th August 2006 from <http://www.romdas.com/surveys/sur-rgh.htm>.
- [9] Giles C G, Sabey B E and Cardew K H F 1962 *Development and performance of the portable skid-Resistance tester* (United States: ASTM International)
- [10] Gothie M 1996 Relationship between surface characteristics and accidents *International Symposium on Pavement Surface Characteristics Christchurch* 3-4 September 1996.
- [11] Hall J W, Smith, K L, Titus-Glover L, Wambold J C, Yager T J and Rado Z 2009 *Guide for pavement friction* Available from http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w108.pdf.
- [12] Highway Agency 2004 *Design manual for roads and bridges-Pavement design and maintenance-Pavement maintenance assessment* (United Kingdom: Highways Agency)
- [13] Kane M and Scharnigg K 2009 *Report on different parameters influencing skid resistance, rolling resistance and noise emission* TyroSafe Project Deliverable D10, 95
- [14] Larson R 1999 *Consideration of tire/pavement friction/texture effects on pavement structural design and materials mix design* (HIPT: Office of Pavement Technology).
- [15] Leu M C and Henry J J 1978 *Prediction of Skid Resistance as a Function of Speed from Pavement Texture-Transportation Research Record* 666 (Washington DC: Transportation Research Board and National Research Council).
- [16] Fuentes L G 2009 *Investigation of the factors influencing skid resistance and the international friction index* (Doctoral dissertation, University of South Florida).
- [17] McLean J 1995 *The relationship between pavement conditions and road safety Load - Pavement Interaction Workshop* 1995 Newcastle, 5-6 July 1995
- [18] Shafii M A 2009 *Skid resistance and the effect of temperature* (Master Thesis, University Teknologi Malaysia).

- [19] Noyce D A, Bahia H U, Yambó J M and Kim G 2005 *Incorporating road safety into pavement management: Maximizing asphalt pavement surface friction for road safety improvements* (Wisconsin: Midwest Regional University Transportation Center - Traffic Operations and Safety (TOPS) Laboratory)
- [20] Ong G P and Fwa T F 2007 Prediction of wet-pavement skid resistance and hydroplaning potential *Journal of the Transportation Research Board* 160-71
- [21] Page B G and Butas L F 1986 *Evaluation of friction requirements for California State highways in terms of highways geometrics: Final report* (FHWA/CA-TL-86/01) (California Department of Transportation: Federal Highway Administration).
- [22] Roe P G, Parry A R and Viner H E 1998 *High and low speed skidding resistance: The influence of texture depth* (Crowthorne, Berkshire: Transport Research Laboratory).
- [23] Roe P G, Webster D C and West G 1991 *The relation between the surface texture of roads and accidents* (Crowthorne, Berkshire: Transport and Road Research Laboratory).
- [24] Rogers MP and Gargett T 1991 A skidding resistance standard for the national road network *Highways and Transportation* **38** 10-16
- [25] Schulze K, Gerbaldi A and Chavet J 1977 Skidding accidents, friction numbers, and the legal aspects involved report of the PIARC technical committee on slipperiness and evenness *Transportation Research Record* **623** 1-10
- [26] Titus-Glover L and Tayabji S 1999 *Assessment of LTPP friction data* (FHWA-RD-99-037) (McLean, Virginia: Federal Highway Administration).
- [27] Wambold J C, Henry J J and Hegmon R R 1986 *Skid resistance of wet-weather accident sites. The Tire Pavement Interface (ASTM STP 929)* (West Conshohocken: ASTM International) <http://dx.doi.org/10.1520/STP20001S>.