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Determination of Appropriate Method to Measure Mean Texture Depth (MTD) for Bicycle Lane Surface

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Abstract – *A bicycle is described as a two-wheel vehicle, propelled by pedals and steered by handlebars attached to the front wheel. In Malaysia, it is difficult to obtain the exact number of bicycles on the road because they are not registered with the authority. However, based on observation, it has seen a tremendous increase in the number of bicycle activities on the road. The increment was anticipated due to the government initiatives on green environment and reducing carbon monoxide from transportation. In supporting the initiatives, the government has also taken a proactive measure to provide more bicycle facilities on the road. In general, an optimal design of a bicycle facility must be capable of providing safety, comfort to road users, and high accessibility to the road network. Because of the lack of bicycle facility design standard available in Malaysia, various bicycle design was observed. Bicycle lane pavement is one of the dissimilarities observed. Since the quality of pavement surface is vital in ensuring safety, this study is aimed to investigate the skid resistance ability provided by a different type of bicycle lane pavement. Besides measuring the Skid Resistance Value (SRV), skid resistance can also be investigated by measuring the pavement Mean Texture Depth (MTD). This study utilized the Out Flow Meter Test and Sand Patch Test to measure the MTD value. Data collection was conducted at 20 locations including on-road and off-road bicycle lanes. It was found that there is a good correlation between the outflow meter test and the sand patch test for bicycle lane pavement.*

Keywords: Bicycle lane, Mean Texture Depth (MTD), Sand Patch Test, Outflow Meter Test

1.0 INTRODUCTION

Transportation system developments in Malaysia are now moving towards environmentally friendly and low carbon design which encourages people to use human-powered transport such as bicycles in daily life movement. Apart from a healthy lifestyle and other policy concerns, professionals and policymakers are looking at ways to increase the use of walking and bicycling for everyday travel (Dill, 2009; Wen & Rissel, 2008). While most of the focus on “active living” has been on walking, bicycling may have a greater potential to substitute for motorized vehicle trips because of its faster speed and ability to cover greater distances. In Malaysia, it is not a practice to register bicycle ownership with relevant authorities. Thus, the number of bicycle users may not be obtained. However, based on observation, a tremendous increase in the number of bicycle activities can be seen on the road. This is later proven by the crash records from the year 2012 to 2016 as shown in Figure 1 where the number of fatalities involving bicyclists has a steady rate increase from 156 fatalities in 2012 to 123 fatalities in 2016. Due to the increase in the number of bicycle activity on the road as well as fatalities involving bicyclists, the number of fatalities involving bicyclists is 669 and shows an identical trend each year since 2007.

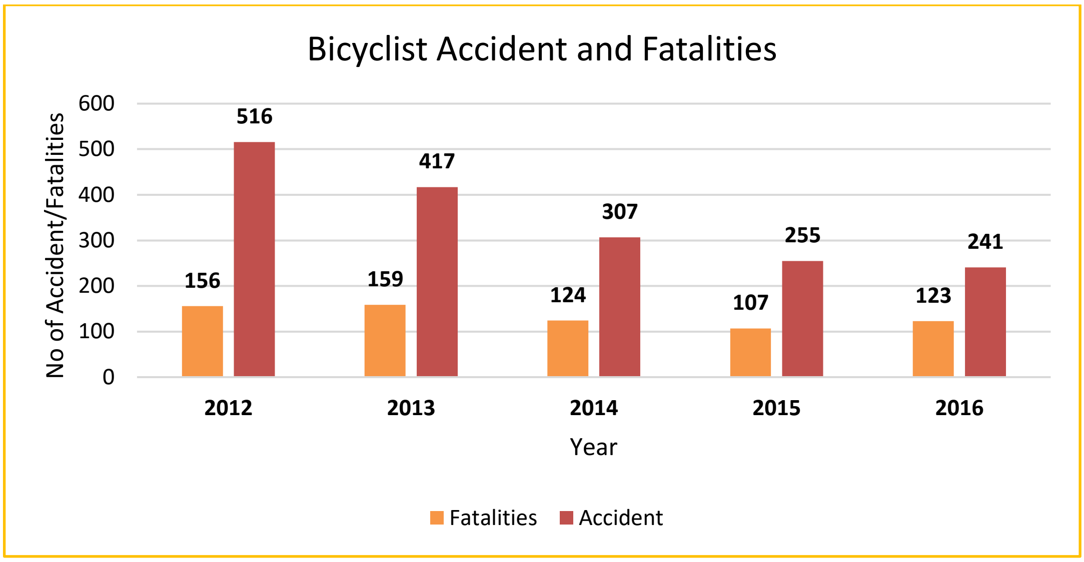

Figure 1: Bicyclist accident and fatalities (Source: Royal Malaysia Police)

The local authorities play an important role to ensure the continuity of the agenda whereby a lot of work has been done to improve the bicycle lane. Enhancement was done in every aspect including maintaining capacity and traffic flow, ensuring continuity of the facility provided, assuring the sustainability of the materials used, and increasing safety for road users from the safety aspects of traffic flow, continuity, and materials. In Malaysia, there are two (2) types of bicycle lane development facilities provided for bicyclists, i.e., the exclusive lanes for bicycles and shared lanes with other modes of transportation as stated in AASHTO (2012). The exclusive lane is provided for the use of bicycle traffic only and usually, it was built with a different type of surface material that is more suitable for the bicycle. The lane is typically separated from the motorized vehicle lane. On the other hand, a shared lane is usually defined as the sharing path between bicycle users with other motorized vehicles and normally sharing the lane surface is made of the same material as road pavement. surface with the other vehicle which is road pavement while the exclusive lane usually with a different type of surface and can be used by bicycle users only.

However, in Malaysia from the observation conducted, some of the shared bicycle lane pavement surfaces were marked with paint to differentiate the lane from the motorized vehicle lane. As a consequence, the lane may have a different value of friction and texture compared to the motorized vehicle lane existing road. It was anticipated that the lane with paint may give a small skid resistance value to vehicle tires and this may increase the risk to road users. As travel safety and efficiency of the bicycle lane surface increase in importance to highway agencies and local authorities, texture measurements have become an important tool in the management of pavement surfaces. Generally, pavement surfaces can be classified into four (4) categories as follows: (1) rough and harsh surface; (2) rough and polished surface: (3) smooth and harsh surface; and (4) smooth and polished surface (Panagouli & Kokkalis, 1998). The friction-related properties of a pavement depend on its surface texture characteristics. Li et al. (2016) stated that there are four (4) types of texture characteristics that influenced the ride quality which are microtexture, macrotexture, megatexture, and roughness. To find out all texture characteristics, there is a lot of tests can be done for that certain characteristic but need high technology equipment (Ueckermann et al., 2015). The purpose of this paper is not to recommend the best bicycle lane surfaces based on texture determination but to add value to the knowledge related to measuring the macrotexture.

2.0 LITERATURE REVIEW

Determining macrotexture on pavement correctly and quickly is important for the safety and economy aspect of bicycle lane pavement. In determining the riding quality for a bicycle on a bicycle lane, the texture of the lane needs to be determined as stated by (Li et al., 2016). This study is focusing on the macrotexture of the bicycle lane pavement where (Aktas et al., 2011) defined the macrotexture as the deviation of the pavement's surface with the characteristic dimension of wavelength and amplitude greater than 0.5mm. Bicycle lane pavement should provide adequate friction and drainage ability to minimize the number of accidents that occur because of friction deficiencies. It is widely recognized that pavement surface texture influences many different pavement-tire interactions as obtained through the grooves or channels placed intentionally in the road to allow for water to escape from the under vehicle tire and prevent hydroplaning (Sarsam & Ali, 2015). Usually, a shared bicycle lane is placed at the edge of the main road which is nearly the road drainage. The surface runoff from rain or other sources will flow into the bicycle lane surface before going into the road drainage. Therefore, the ability of the bicycle lane pavement to prevent hydroplaning from occurring is highly recommended. The example of water stagnant in the bicycle lane that will contribute to the hydroplaning occur is shown in Figure 2. All these surface defects would definitely affect the safety of bicyclists and other road users.

Figure 2: Water stagnant in a bicycle lane

Some studies conducted preferred to develop modeling method in order to determine the pavement texture because of the time, energy consumption, mathematical knowledge improvement, and also improvement in dimension determination such as in 3D (Aktas et al., 2013; Hu et al., 2016; Puzzo et al., 2017). The modeling still needs data from the site to develop a model and there is some issue with the accuracy of the model when compared to the real data taken from the actual site. Basically, methods for measuring pavement macrotexture can be divided into three (3) groups which are volumetric methods, profile meters, and visualizing techniques (Uz & Gokalp, 2017). In measuring the pavement macrotexture, several studies have been done but not for bicycle lane pavement yet. The studies include the pavement, chip seal, and the material of the pavement in making sure the pavement development provides a good texture for the road users (Kokkalis & Panagouli, 1998; Panagouli & Kokkalis, 1998; Praticò & Vaiana, 2015; Praticò & Astolfi, 2017). The most common method used is using the volumetric such as the sand patch test (ASTM E965, 2009), and outflow meter test (ASTM E2380, 2009). Flintsch et al. (2003) and Sengoz et al. (2012) compared sand patch test, laser profiler, and ASTM 2157-01 (2009) Circular Track Meter (CTM), where the result shows that there is a good correlation between the test for the road pavement at Virginia. Fisco & Sezen (2013) and Sezen & Fisco (2013) evaluated and compared the surface macrotexture and microtexture using the volumetric method and laser scanning method respectively for asphalt specimens on different types of asphalt and finishing.

3.0 METHODOLOGY

3.1 The Sand Patch Test

The sand patch test is used to measure the texture of the bicycle lane pavement. Surface texture is a measurement that influences the depth of the texture and thus determines the surface skid resistance ability. The test procedure used for the study follows the procedures contained in (ASTM E965, 2009) which show the standard method using a volumetric method. By careful application of a known volume of material on the surface and sharp measurement of the total area covered. It uses a volumetric approach to measuring pavement macrotexture. The hypothesis of the test principle is greater the texture, the more sand diameter will be taken up by it, and the smaller the circle that can be achieved from the standard quality of sand. The sand should be dry and fined grained with the dry condition and swept free on the test area. In this study, a known volume of sand (20 ml) was spread evenly over the pavement surface to form a circle shape. The volume of material that fills the surface voids determines the surface texture. The diameter of the circle as shown in Figure 4 was measured in four (4) parts and the value was averaged. This value was used to calculate the MTD in mm value. The MTD (mm) for 20ml of sand as shown in Figure 3 where the sand was poured and spread evenly as specified in ASTM E965-96 is determined as follows:

$$MTD = \frac{4v}{\pi d^2}$$

Where,
v = the exact volume of glass sphere in, ml
d = the average diameter of the sand patch in, mm

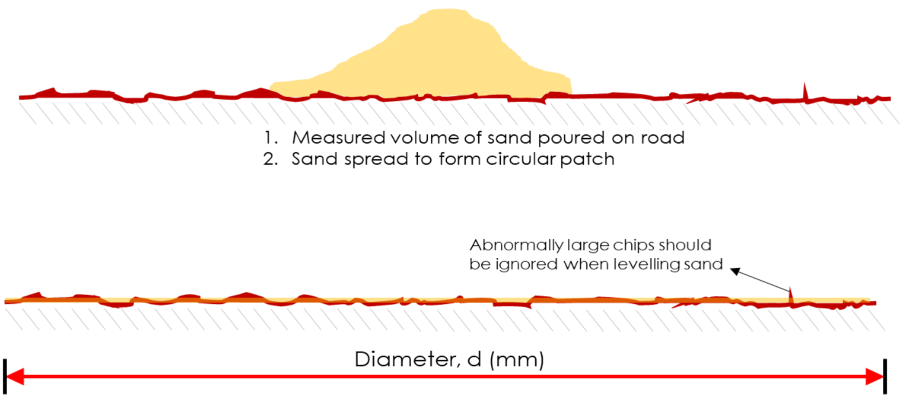

Figure 3: Characteristics of bicycle lane

Figure 4: Sand patch test on the bicycle lane surface

3.2 The Outflow Meter Test

The test procedure used for the outflow meter test follows the procedures contained in (ASTM 2157-01, 2009). This method does not measure the texture depth directly as it measures the ability of the depth and the space of the voids in the surface to let the water pass through the bicycle lane pavement. It is based on a known volume of water under a standard of pressure which is the allowed water to pass through the voids and the road surface. The equipment is shown in Figure 5 where the time it takes to pass the known water (the outflow time) is measured. This outflow meter test quantifies the connectivity of the texture as it relates to the drainage capability of the pavement through it is surface and sub-surface voids. The technique is intended to measure the ability of the surface to relieve pressure on the face of vehicular tires and thus is an indication of hydroplaning potential under wet conditions. The hypothesis of the test principle is when the faster water flows out of the cylinder, the higher value of surface macrotexture while the slower it flows out, the smaller the surface texture. This is because the water easily passes out of the surface when there are more voids on the surface.

$$MTD = \frac{3.114}{OFT} + 0.636$$

Figure 5: Outflow meter test on bicycle lane surface

3.3 Test Track

This study was conducted on the bicycle lane pavement in Malaysia around Kuala Lumpur, Putrajaya, and Penang. The areas were chosen based on the different types of materials and surfaces used for bicycle lane pavement in that area. There were 20 bicycle lane pavements (on-road and off-road) selected for this study. Four different types of pavements were used for these study samples that are: concrete, concrete interlock, asphalt, and bricks interlock. The types of surfacing/finishing used in this test include painted, painted with beads, existing pavement, and normal concrete. Table 1 shows the characteristics of the 20 study locations. Each experiment section is exposed to the same environment but different surfaces condition. Figures 6 to 8 present the bicycle lane in three (3) states which are in Putrajaya, Penang, and Kuala Lumpur, respectively. Nevertheless, this paper focuses on the differences between the outflow meter test and the sand patch test for measuring MTD on a variety of surfaces for asphalt and concrete surfaces only. Tests were taken in the right wheel path and between the wheel paths for each section. Thus, differences in the texture measured by sand patch and outflow meter test were compared. An unintended output of this research is the ability to check correlations between the two (2) macrotexture measurement methods on a variety of surfaces and perhaps make recommendations about which testing method is suitable and appropriate for a bicycle lane.

Figure 6: Bicycle lane surfaces in Putrajaya

Figure 7: Bicycle lane surfaces in Penang

Figure 8: Bicycle lane surfaces in Kuala Lumpur

Table 1: Test section area

Test Section Number	Test Section Surface	Type of Lane
PE1	Concrete and painted with beads	Exclusive
PE2	Normal concrete	Exclusive
PE3	Concrete and painted with beads	Exclusive
PE4	Brick Interlock and Painted	Exclusive
PE5	Normal concrete	Exclusive
PE6	Concrete Interlock	Exclusive
PE7	Normal concrete	Exclusive
KL1	Pavement and painted with beads	Shared
KL2	Concrete and painted with beads	Exclusive
KL3	Concrete and painted with beads	Exclusive
KL4	Concrete and painted with beads	Shared
KL5	Concrete and painted	Exclusive
KL6	Pavement and painted	Shared
PU1	Pavement and painted with beads	Shared
PU2	Painted with beads	Exclusive
PU3	Painted with beads	Exclusive
PU4	Normal concrete	Exclusive
PU5	Concrete interlock	Exclusive
PU6	Normal concrete	Exclusive
PU7	Brick interlock	Exclusive

4.0 RESULTS AND DISCUSSION

In this study, macrotexture data were analyzed in 20 test sections. Sand patch and outflow meter tests were completed on each test section where MTD on the road surfaces was calculated. Macrotexture depths and relative differences between the methods are shown in Figure 9. The difference in macrotexture measured by each method is expressed as a percentage. As shown in the figure, the largest difference recorded at the PU5 with 120% is the concrete interlock surface. Concrete interlock usually has a design texture that has a curve like a mosaic. This type of surface is not ideal for the outflow meter test because the rubber is not properly attached to the surface. PE2, PE5, PE7, KL1, PU1, and PU4 showed differences of lower than 20%. The section is from normal concrete and pavement surfaces. The macrotexture is in the range of 0.7mm – 0.90mm. The other areas such as PE3, PE6, KL2, KL4, KL5, KL6, PU2, and PU6 have percentage differences between 20% to 60%. The range of the macrotexture recorded for this area is >0.90mm. the texture of the bicycle lane for pavement and concrete that is painted with beads shows a higher value in texture compared to painted only. It shows that the beads increase the texture of the surfaces. This leads to the conclusion that each method has inherent functional limitations to be used for a bicycle lane. The outflow meter test is not ideal for high macrotexture surfaces because it cannot measure outflow times less than 1s (Aktas et al., 2011). For the macrotexture less than 1.00mm, the outflow meter test is suitable to be used because for smooth surfaces, the surface nearly does not have the texture and the other reason is the sand cannot fill in the voids.

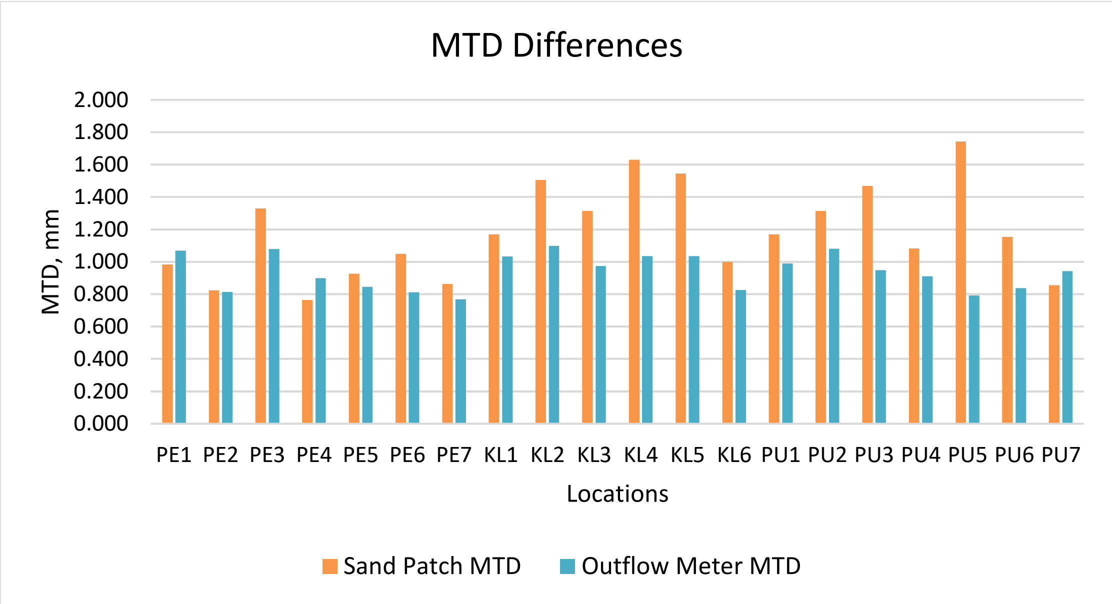

Figure 9: Test sections macrotexture results and differences between two (2) test methods

Comparing the overall texture of the bicycle lane in that three (3) states by referring to Table 2, the mean value recorded for texture shows a difference of 0.246 mm where the sand patch test showed higher texture because of the suitability to the variation of bicycle lane pavement that has different types of surface based on the local authority preference. It shows the 26% difference between the sand patch and the outflow meter test. Usually, local authorities tend to share the existing pedestrian and bicycle lane which is by using the brick interlock and just by painting. Therefore, the texture of the lane becomes smaller and too smooth.

Referring to Table 3, the comparison between sand patch test MTD and outflow meter test MTD reveals there is a significant difference between sand patch test MTD and outflow meter test MTD (p-value less than 0.05). It shows that the MTD measurement method between both tests has a significant difference that leads to the conclusion that both tests have different suitability for measuring MTD. No correlation relationship was found between both tests. The value recorded is 0.415 as shown in Table 4.

Table 2: Descriptive analysis for MTD Sand Patch and MTD Outflow Meter Test

Case	Types	MTD SP	MTD OFT
Number of Sample, N	Statistic	20	20
Mean	Statistic	1.185	0.939
	Std. Error	0.064	0.025
Median	Statistic	1.163	0.945
Mode	Statistic	1.170	1.040
Std. Deviation	Statistic	0.288	0.110
Variance	Statistic	0.083	0.012
Skewness	Statistic	0.363	-0.056
	Std. Error	0.512	0.512
Kurtosis	Statistic	-0.893	-1.495
	Std. Error	0.992	0.992
Range	Statistic	0.980	0.330
Minimum	Statistic	0.764	0.770
Maximum	Statistic	1.744	1.100
Sum	Statistic	23.700	18.790

Table 3: T-test for Sand Patch and Outflow Meter Test MTD

	Paired Differences			t	P-value
	Mean	95% Confidence Interval			
		Lower	Upper		
MTD Sand Patch MTD Outflow	0.246	0.123	0.368	4.195	0.000

Table 4: Pearson Correlation between Sand Patch and Outflow Meter Test MTD

		MTD Sand Patch	MTD Outflow Meter
MTD Sand Patch	Pearson Correlation	1	0.415
	P-value		0.069
	N	20	20
MTD Outflow Meter	Pearson Correlation	0.415	1
	P-value	0.069	
	N	20	20

5.0 CONCLUSION

Determining macrotexture on bicycle lane pavement correctly and quickly is important for safety and economy in bicycle lane pavement evaluation. This study investigated and compared two (2) methods commonly used to determine macrotexture on pavement surfaces which are the sand patch test and the outflow meter test. The research and analysis results show that there are functional limitations in each method‘s ability to accurately measure bicycle lane pavement macrotexture. The outflow meter provides users with results measured in seconds and converted into MTD. It is portable, practical on wet surfaces, inexpensive and fast, but the measured outflow time can be inaccurate for high macrotexture. While the sand patch test method should be avoided on surfaces with low macrotexture because it cannot be filled in the void. This results in the following recommendations for the appropriate use of each test method:

- For macrotexture of < 0.9mm use the outflow meter test only
- For macrotexture of > 0.9mm use the sand patch or outflow meter

Previous studies were done to establish relationships of various test methods to measure pavement macrotexture. However, those studies are typically on the road pavement which does not include the bicycle lane, especially on the shared lane. Some bicycle lanes collided with the road pavement which can cause a hazard to other vehicles. The results discussed in this paper are the first to give guidance to researchers regarding bicycle lane pavement where the two (2) test methods become more appropriate for differing bicycle lane pavement. It is recommended that the macrotexture limitations for each test method be contained in specifications for each test to ensure that those agencies that use these tests are aware of the test limitations.

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