# DETERMINATION OF SURFACE ROUGHNESS INDEX OF VARIOUS BITUMINOUS PAVEMENTS

***Suleiman Arafat Yero, Mohd. Rosli Hainin & Haryati Yacoob**
Department of Transportation and Geotechnics
Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 skudai, Johor, Malaysia.
Email: arafatyero@yahoo.com

**ABSTRACT**

The roughness of the road surface constitutes the smoothness, and frictional properties of the pavement surface and in turn related to the safety, and the ease of the driving path. The roughness of a pavement is an important parameter in determining the comfort level of the riding path on a pavement, and this roughness of the pavement surface is related to the vehicle vibration, operating speed, wear and tear of the wheels. The surface roughness of a pavement is determined using the international roughness index (IRI), which is a measure of the texture of a pavement surface. This study investigated mainly three classes of bituminous pavement surfaces in Malaysia using the Australia road research board (ARRB) walking profilometer. The surfaces include asphalt concrete wearing (ACW), stone mastic asphalt (SMA), and surface dressed (SD) surfaces on jalan tebrau, jalan UTM-utama, jalan potian in Johor and jalan parit yaani in Batu Pahad. The study was conducted on the six selected roads and 60 test points where investigated. The results obtained from the study indicated that the surface dressed surfaces have the highest value of IRI, then the SMA surfaces and the least was the ACW surfaces indicating a smoother surface with more polished aggregates.

**Keywords:** *Profilometer, bituminous pavement, surface roughness index, texture and friction.*

## 1. INTRODUCTION

Among the various means of transportation which include sea, air, rail, the road transportation system becomes the leading means of transportation in Malaysia. There has been considerable publicity on the comfort and safety of these roads. Roughness of a road (or runway) is an important parameter which not only indicates the comfort level of ride over a pavement surface, but it is also related to vehicles vibration while in motion, the vehicle operating speed, wear and tear of the wheels with time, and the resulting operation cost of the vehicle. A pavement, which is structurally sound to sustain heavy load repetitions, may even be unserviceable functionally if its surface is rough and distressed.

Roughness index is typically considered to be the high frequency, short wavelength component of a measured surface [1]. Roughness plays an important role in determining how a real object will interact with its environment. Rough surfaces usually wear more quickly and have higher friction coefficients than smooth surfaces.The roughness index is a function of the smoothness of the pavement, comfort and its safety to the road user [2]. The surface roughness is quantified by the vertical deviations of a real surface from its ideal form. If these deviations are large, the surface is considered to be rough; if they are small the surface is smooth [3]. Roughness is often a good predictor of the performance of a mechanical component, since irregularities in the surface may form nucleation sites for cracks or corrosion that will eventually lead to the failure of the pavement [4]. It is also paramount to note that examining the performance of the wearing course of a pavement and the quantification of the roughness level of the pavement surface evolves as a prime concern to the highway engineer [1].

The road profile is a two-dimensional part of the road surface, taken along an imaginary line. A profile measurement is a series of numbers representing elevation relative to some reference level [5]. Generally, profile is measured along two lines per lane, one in each wheel track. Roughness is the summary of variation in surface profile that induces vibrations to the traversing vehicles and is defined over a length of the pavement surface.

The public works department of Malaysia (PWD) or Jabatan Kerja Raya (JKR) had adopted international roughness index (IRI) of 1.6m/km for four lane highways, 2.5m/km for two way highways and 8m/km for minor roads[6]. The measurements of the roughness index (IRI) for a completed pavement surface to be measured in terms of its lane IRI, can be achieved using the Australian Road Research Board (ARRB) walking profiler (WP) [7].The road surface often used by motorist has some frictional properties that is relatively associated with performance, of the road and its safety to the road user [8]. They include the aggregate interstices termed as the microtexture and the coarse component of the texture due to the aggregate particle on the road surface knwon as the macrotexture which are often mentioned as contributory factors to providing comfort to the road user or otherwise [9].

Generally the road pavement structure is classified into the sub-grade, sub- base, road base and the surfacing which consist of binding course and wearing course. The wearing course is the exposed topmost layer that provides the travel path, skid resistance, safety and comfort to the road user [10]. In view of this the study investigated specifically the pavement surface roughness of these categories of bitumen pavements, ACW, SMA and SD surfaces For this study, the roughness index of various bituminous test surfaces was determined in accordance to the international roughness index (IRI) standards [11]. The roughness index is a function of the smoothness of pavement, and its comfort, safety and convenience to the road user [3]. The roughness index depends on the road surface roughness, which in turn depends on the finishing of the road surface [1]. A good road is expected to give an improved riding quality, a reduce surface noise, provide minimum delays at road works, and provides enhance deformation resistance [9]. The roughness of different road surface can be determined by various design field testing equipments; these include the Australian roads research board walking profilometer and other Motorize sensors [11].

### 1.1 Objective

The objective of the study is to assess the roughness levels of the various bituminous pavements surfaces in johor, Malaysia. The study deals with measurement of a number of parameters characterizing the level of roughness of a given stretch of a road surface using the Malaysian road classification code [12].

## 2. EXPERIMENT

The study involved a field survey and testing using the ARRB walking profilometer on the various bituminous pavement surfaces. The walking profiler is an instrument used to produce series of numbers to represent a profile. The profiler works by combining three parameters mainly, a reference elevation; a height relative to the reference; and a longitudinal distance. The international roughness index (IRI) is calculated from a measured single longitudinal road profile. First, the profile is smoothened with a moving average of base-length 250 mm [11]. Then, response of a quarter car model, in the form of vertical vibration, is accumulated, which on dividing by the profile length yields IRI. If profile information of two wheel track is available, point-by-point average is considered, and the index is called Half car Roughness Index (HRI) [2].

The study investigated 10 test points per road surface for each of the 6 selected test road surfaces. The test was conducted at an interval of 1km along each test road spanning 10km each, and the total of 60 test points where investigated. These tests were conducted in accordance with the ARRB walking profilometer code [7]. The Table 1 shows the location and categorization of the test roads;

*Table 1 Number of sites categorized by surface type and age*

| Road | Surface Type | Age (months) |
|---|---|---|
| Jalan Utama-UTM | ACW14 | 4 |
| Jalan Pontian | ACW20 | 36 |
| Jalan Tebrau 01 | SMA14 | 24 |
| Jalan Tebrau 02 | SMA20 | 24 |
| Jalan Parit yani | SD | 60 |
| Jalan Pt. Bulat | SD | 56 |

## 3. RESULTS AND DISCUSSIONS

All the data collected from the study were analyzed in accordance with the Jabatan Karja Raya (JKR) of Malaysia and the IRI specification. It should be noted that the following roughness indices obtained from the study could also be used to quantify other pavement surface roughness indices using the Mean Panel Rating (MPR); Profile Index (PI); Ride Number (RN); and Root Mean Square Vertical Acceleration (RMSVA).

The roughness index obtained from the study for the various bituminous pavement surfaces investigated indicates that the ACW14 showed the lowest IRI of 1.2m/km indicating a smooth surface, and the surface dressed road surface showed the highest IRI of 8.05m/km indicating a rough surface and the SMA 4.1m/km.

The results obtained shows that only the surface dressed roads conforms with the JKR specification [6], with the IRI value of 1.6m/km for 4 lane Highway, 2.5m/km for 2lane Highway and 8m/km for minor roads is specified [12].

Based on the Arahan Teknik (jalan) 8/86 classification of roads in Malaysia [12 ], the surface dressed are considered as R2 minor roads with average daily traffic (ADT) volume less than 1000. While the ACW and SMA surfaces in this study are urban arterials U4 with ADT volume less than 3000.

The low value for the ACW makes the surface to be smooth and could be attributed to the age of the pavement and the polishing of the aggregate[13], while in the case of the SMA the surface is rough and generating a high IRI value that exceeds the JKR specification [6]. The SD surface as a minor road [12], generated an IRI that is slidely above the JKR recommendation [12], for such surfaces in Malaysia.

For this study, the international roughness index indices test profiles for some of the test roads are illustrated in Figure 1-3.

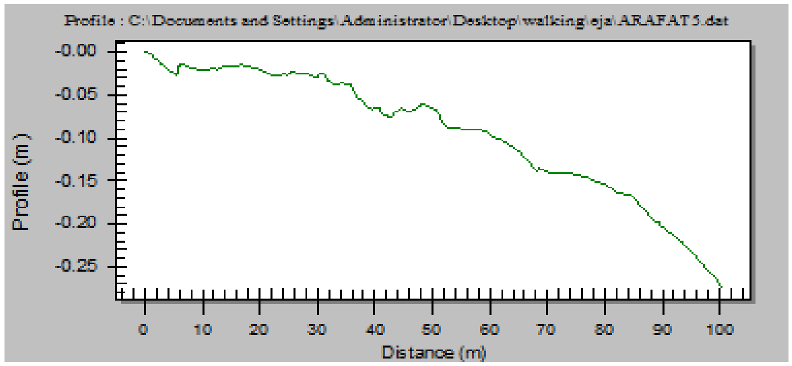


*Figure 1: ACW profile Jalan UTM-UTAMA*

The road profile for the Jalan Tebrau SMA surface could be seen in Figure 2;

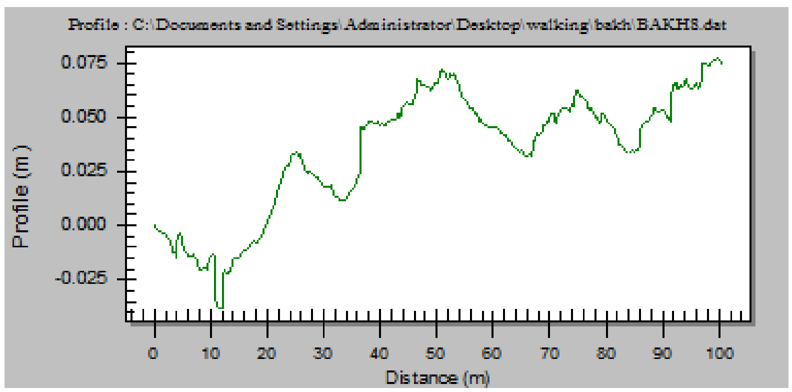


*Figure 2: SMA profile Jalan Tebrau*

The road profile of Jalan Parit yaani in Muar is shown in Figure 3 as recorded by ARRB walking profiler used in this study.

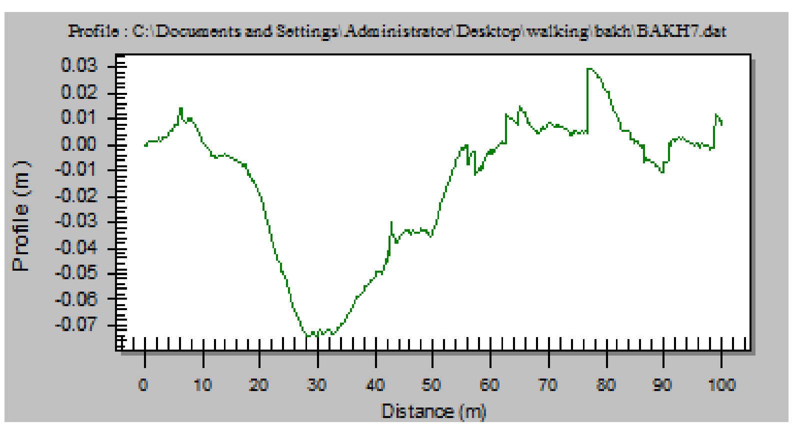


*Figure 3: SD surface profile Jalan parit yaani*

**T**he data obtained from the walking profiler were analyzed in accordance with ARRB specification [13] using the formula below and the average and combine IRI for all the surfaces presented in the Tables 2-3.

Formula used to determine the Roughness Index (IRI)

$$\mathbf{IRI = \{IRI1 + IRI_2\}/2}$$

Where IRI is the International roughness index
$IRI_1$ is the first single lane roughness index
$IRI_2$ is the second single lane roughness index

*Table 2: The Average IRI for the test roads*

| Km | SD IRI(m/km) | SMA IRI(m/km) | ACW IRI(m/km) |
|---|---|---|---|
| 1 | 3.52 | 2.3 | 1.28 |
| 2 | 5.18 | 3.4 | 2.23 |
| 3 | 6.79 | 3.3 | 1.75 |
| 4 | 4.15 | 3.6 | 1.96 |
| 5 | 8.04 | 3.7 | 2.05 |
| 6 | 5.31 | 4.1 | 2.06 |
| 7 | 8.05 | 2.02 | 2.76 |
| 8 | 7.29 | 2.50 | 1.20 |
| 9 | 4.12 | 3.22 | 2.02 |
| 10 | 4.43 | 3.4 | 3.03 |

The IRI results obtained from the study are presented in Table 3 below;

*Table 3 Average combine IRI for all the test roads*

| Dist (km) | | | IRI(m/km) | | | |
|---|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | T5 | Ave. |
| 1 | 1.62 | 5 | 8.32 | 3.07 | 3.52 | 4.31 |
| 2 | 2.55 | 2.76 | 5.1 | 5.87 | 5.18 | 4.29 |
| 3 | 7.93 | 6.29 | 4.51 | 4.07 | 6.79 | 5.92 |
| 4 | 2.71 | 5.76 | 5.86 | 7.38 | 4.15 | 5.12 |
| 5 | 6.77 | 6.75 | 8.59 | 8.61 | 8.94 | 7.93 |
| 6 | 4.95 | 3.11 | 3.65 | 5.87 | 5.31 | 4.58 |
| 7 | 5.01 | 4.03 | 3.06 | 4.12 | 8.95 | 5.03 |
| 8 | 4.38 | 3.81 | 3.53 | 4.00 | 7.29 | 4.60 |
| 9 | 3.26 | 4.10 | 4.69 | 3.02 | 4.12 | 4.43 |
| 10 | 4.41 | 2.70 | 5.90 | 5.36 | 2.83 | 4.24 |

From the study the SD surfaces indicated the highest frequency IRI as illustrated in Figure 4;

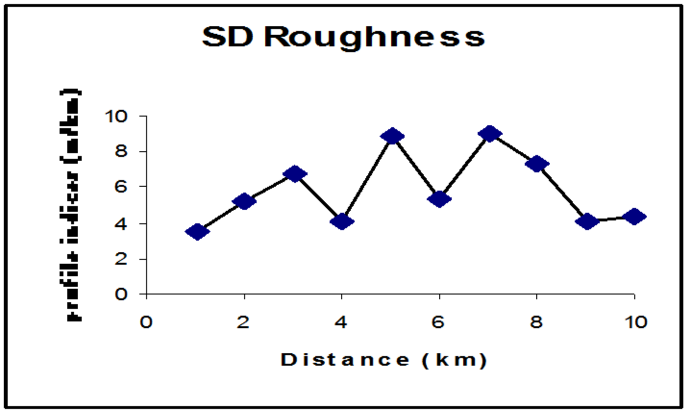


*Figure 4: IRI for SD*

The SMA surfaces generated an IRI value that exceeds the JKR specfication [6], as presented in Figure 5;

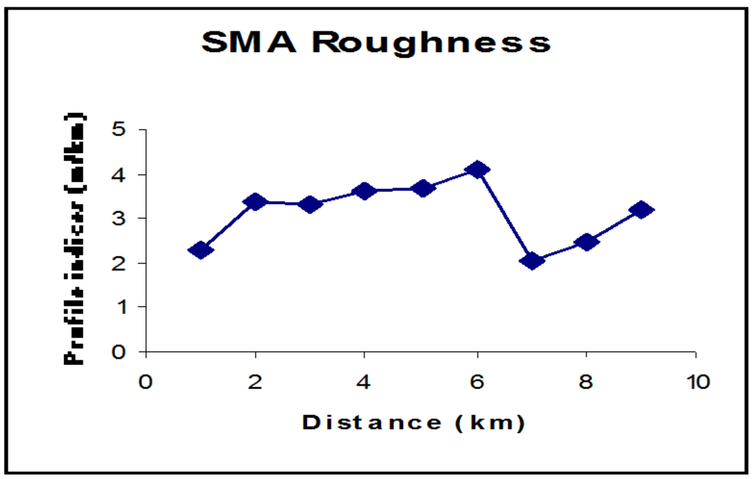


*Figure 5: IRI for SMA*

The ACW generated the least IRI values and illustrated in Figure 6.

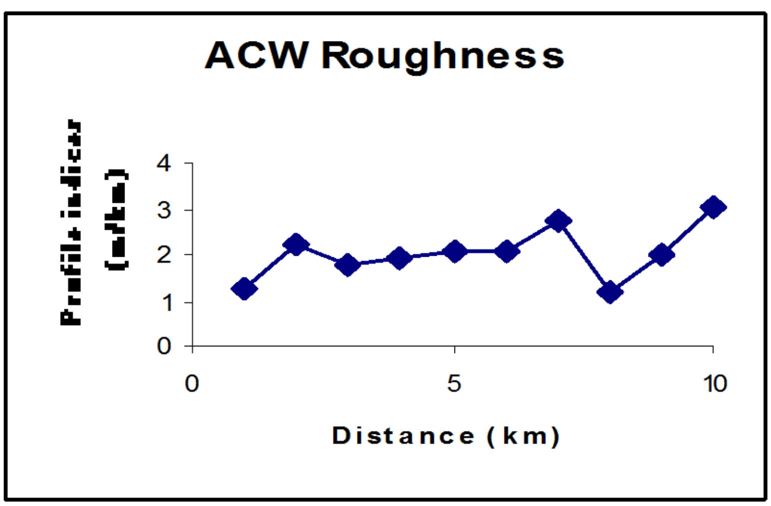


*Figure 6: IRI for ACW*

The combine IRI for all the test roads in this study are illustrated in Figure 7.

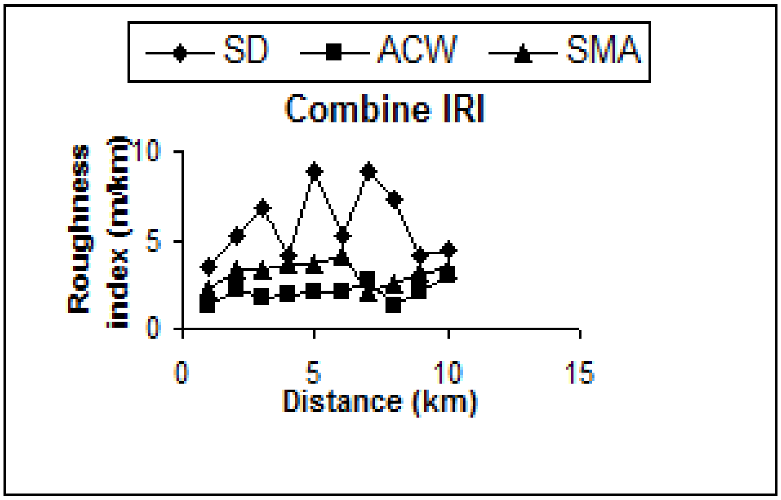


*Figure 7: Combine IRI for all the surfaces*

## 4. CONCLUSION AND RECOMMENDATION

The study was undertaken with the primary objective to assess the roughness indices of various bituminous surfaces in Johor, Malaysia. The study indicates;

The results obtained from the study shows that the surface dressing surfaces gave the highest average IRI value but within the JKR acceptable limits, indicating high roughness and the tendency for high vibration and noise. While the SMA and ACW surfaces show a relatively lower IRI compared to SD surfaces, but greater than the JKR acceptable limits. They also produced low vibration and noise, due to polishing of the aggregates.

The study recommends further investigation on more test surfaces with a propare view of understanding the mean IRI values of these pavement surfaces.

## 5. ACKNOWLEDGMENT

The work described in this paper was carried out by the department of transportation and highway engineering, faculty of civil engineering Universiti Teknologi Malaysia (UTM) in collaboration with Bina Mahsyur Sdn Bhd. and the author will like to thank the supervisors and all those involved in making the study a huge success.

## 6. REFERENCES

[1]. Awasthi G. and Das A. (2001), Pavement Roughness indices.Transport Research Laboratory TRB vol.84, may 2003.
[2]. Sayers M.W (1995), *profiles of Roughness.* Transport research board (TRB), Washington D.C no.1260.
[3]. Kwang H.J, Morosiuk G. and Emby J. 1992 *Assessment of skid resistance and macrotexture of bituminous road surface in Malaysia.* Seventh REAA conference, Singapore.443-449.
[4]. Hasnur R. B (1990). *The deterioration of bituminous binders in road surfacings.*Sixth, REAA4-10March 1990.
[5]. Beaven P.J and Tubey L.W (1978*). The polishing of road stone in peninsular Malaysia.* TRRL supplementary report 421.TRRL Crowthorne.
[6]. Design of flexible Pavements, 2008. JKR specification.
[7]. ARRB, Walking profiler AG:PT/T450, technology note, 2006. 1-37.
[8]. Wilson D.J and Dunn R.C.M (2005). *Polishing aggregates to equilibrium skid resistance.* 55-71.
[9]. Hunter R.N (2000). *Asphalt in Road construction.* 125-196.
[10]. Ford W.G, Suffian Z and Smith HR (1996). *The benefits of using Chipseals in Malaysia.*
[11]. Book of profiling university of Michigan (USA), Source (www.umtri.umich.edu/erd/roughness)
[12]. Arahan Teknik (jalan) 8/86 classification of roads in Malaysia.
[13]. Walking Profiler G2, ARRB technology user note, 2006.