



Evaluating the Friction Characteristics of Pavement Surface for Major Arterial Road

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Abstract

The performance of the pavement in terms of vehicle safety and tire wear is affected by the friction behavior of the pavement. To highlight the main characteristics that affect the production of better friction resistance of the pavement surface in this work. The micro-texture and macro-texture of the asphalt surface of Baghdad Airport highway were studied using two methods: (sand patch method and the British pendulum test). The sand patch was examined by drawing sand grains of a specific volume, while the micro-texture was analyzed using a BPT under dry and wet surface conditions. All data obtained from the two examinations were analyzed and modelled statistically using SPSS 25 software. Results show that skid resistance of pavement surface increase with the increase of MTD, this increase may be due to the increase of coarse aggregate which lead to increase the roughness of the pavement surface, this increase ranged between (96 - 91%). MTD decreases with the increase of traffic flow due to the friction between the road surface and the vehicle tires leading to increase of smoothness of the road surface. This is mean that MTD is highly affected by the traffic flow and this effectiveness ranged between (84-97%). Skid resistance also is highly affected by the traffic flow with an effectiveness ranged between (81-94%) for both pavement conditions. According to the regression analysis for friction and other parameters, it can be concluded that surface friction values are highly affected by cumulative traffic (asphalt mix deterioration) over time.

Keywords: Pavement Surface Texture; Macrotexture; Microtexture; Skid Resistance; BPN; Sand Patch; MTD; SPSS.

1. Introduction

For safe road travel, tires must have adequate friction with the road. Also known as skid resistance, the road surface texture (or roughness) is a source of friction between the tire and the ground. Without friction, there would be no acceleration, deceleration, or adjusting the vehicle's path safely. People are more likely to be in an accident if the car has low skid resistance, especially on wet roads [1]. One of the key factors in driving safety is the surface friction of the pavement, which plays a vital role in reducing accidents on wet pavements [2]. Pavement surface texture, also known as surface asperity, is a surface feature that measures the divergence between the natural plane and the actual surface. [3]. In terms of wavelength and amplitude, the pavement surface has been classified into three layers; based on the measurements of the surface asperities, these layers are mega-texture, macro-texture, and micro-texture [4]. Generally, there are three different texture types: macro and microtextures, which affect skid resistance, and textures of all three types have macro and micro textures as their primary features [5]. Of particular importance, the micro-texture takes

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effect at lower vehicle speeds when they help induce tire adhesion to the road surface; at higher vehicle speeds. However, the macro-texture is mainly responsible for promoting slip resistance through increasing the friction gradient and channeling drainage of water [6-8]. The pavement friction is described as "a force that resists relative motion between the tire of vehicle and surface of pavement" [9]. A non-dimension coefficient, defined as friction coefficient, is typically used to describe the friction of the tires. The Coefficient of friction between the surface of pavement and tire can be defined as the quotient of the tangential force at the tire's contact surface and the longitudinal force at the wheel. A variety of causes Tire-pavement friction. That include:

- 1) The characteristics of the surface of the ground;
- 2) The properties of the tire;
- 3) The working conditions of the vehicle;
- 4) Environmental conditions.

Skid resistance must maintain on pavements for safe vehicle manoeuvring [10]. Several studies have proven that a focused approach to improving skid resistance in high-risk areas with frequent braking provides significant safety advantages compared to increasing skid resistance in all areas. Road engineers must consider skid resistance when designing the pavement [11]. Moreover, skid resistance is now a component of the common control of pavement conditions that allows road authorities to be vigilant in the safe and successful maintenance of the road network.

2. Research Methodology

The tire's slipping resistance on the pavement is referred to as skid resistance [6]. Skid Resistance (SR) is a critical parameter for the assessment of the pavement. That is a crucial element in road safety, and it is the force that maintains the traction that the tire requires to hold the car under control and stop in emergencies [12]. Also referred to as resistance to skidding, skid resistance has been used interchangeably to describe the force resisting relative motion between the pavement surface and the vehicle's tire. It is opposite to the movement between the rubber and the surface that the friction force acts [6]. Skid resistance is essential to road safety because it prevents a vehicle from sliding and falling across the surface of the roadway, even when the driver makes different types of driving movements (increases speed, shifts directions, or both) [13]. The skid resistance of the standard pavement lane might deteriorate over time due to repetitive traffic movements in a set direction [6, 14]. Improper skid resistance may lead to more injuries caused by skidding [12]. Skid resistance can affect other important aspects of pavement durability when it comes to vehicle safety, including vehicle stability [13]. In the skid resistance of the pavement, there are four significant influences: the characteristics of the road surface (texture, temperature, and materials), the properties of the tires (pad shape, rubber structure, sliding velocity, and temperature), and climatic and environmental factors [15, 16].

2.1. Pavement Tire – Interaction

One of the most fundamental aspects in infrastructure and transportation safety design is tire–pavement friction. Friction is a major factor in many of the equations used in road design. The friction rate, for example, is essential in airport design for horizontal curves, Stopping Sight Distance, and emergency lines. Furthermore, the amount of friction between the tire and the pavement influences the quantity and severity of car accidents. Driving accidents have been a major cause of death in recent years, although developing countries account for only 54 per cent of vehicle traffic. However, developing countries account for more than 90% of the death toll from traffic accidents that have occurred in these countries [17]. In developed countries, road crashes are also one of the leading causes of death. The negative consequences of vehicle crashes are certainly not confined to human mortality, and the economic and social expenses of a car accident have always been and will continue to be an enormous burden for human society [18]. Human mistakes, ambient conditions, car or tunnel faults, or combinations of these elements can cause a traffic accident [19]. Friction between the tire and the pavement is one of the essential pavement features, and it directly impacts traffic safety [20]. Tire – Pavement friction influenced (on) tire wear, the quantity of internal and external noise created by the vehicle's movement on the pavement [21], driving comfort, and a few more criteria in addition to traffic safety [22]. The presence of pavement friction is express by a friction coefficient (μ). This ratio is known as the Coefficient of friction, and it can be calculated as the inverse of the force of friction (opposite direction of motion) multiplied by the normal force (the force that applied normal to the surface) (from the axle of the wheel)), as shown in Equation 1;

$$\mu = \frac{F_R}{F_N} \quad (1)$$

where: μ =Coefficient of friction; F_R = Friction force; F_N = Normal force.

Two commonly accepted components contribute to the friction of the pavement; these processes know as hysteresis and adhesion. Both of them are closely associated with the thickness of the pavement at various wavelengths [14]. Hysteresis occurs because the rubber tire deforms and the internal friction of the rubber creates friction with the surface of the road, which results in a loss of energy [23]. The other factor to consider is adhesion forces. When rubber molecules

contact the pavement surface, they tend to stick, strongly dependent on the exact contact area between the surface and rubber. The friction hysteresis effect is caused by a significant deformation of the rubber content when it comes into contact with the pavement asperities. In this case, the deformation of the rubber causes energy losses when it slips across the pavement. Failures that occur in the rubber content when loaded and unloaded lead to a reduction in energy efficiency [6]. Friction is prominent in rubber hysteresis, which can be seen as strongly associated with rubber's properties (e.g., dynamic modulus). This softer rubber is more susceptible to interface deformations due to the lower modulus of the material, and as a result, it experiences more conflict [24]. Hysteresis has also been associated with the pavement base's macrotexture [6]. Generally, higher wavelength macrotextures exhibit higher friction than those with lower macrotextures. Rubber deformation caused by surface asperities contributes to more rubber deformation at the interface, which, in turn, causes more energy losses [14].

The adhesion friction force, created by the interaction of the rubber pavement at the micro-level, is highly dependent on the actual contact field. It can be inferred that the adhesion side of the friction force is related to the micro-texture of the pavement's surface, which relies primarily on the pavement surface texture properties of the individual coarse aggregate particles. [25]. Furthermore, the adhesion component forms due to the shear frictional stresses that occur at the contact area between the resurfaced road surface and the tire. The manufacturing process for this component arises due to chemical and dispersive interactions, such as the energy dissipation that occurs when bonds and tensions are formed [23]. A higher macrotexture with similar microtextures has a greater influence on friction than surfaces with similar microtextures and lower macrotextures [26]. Aggregates lose some of their texture over the service life of the concrete surface as a result of polishing as a result of frequent traffic loading [27]. Aggregates with higher resistance to polishing and abrasion can maintain higher friction throughout the pavement's service life [28, 29].

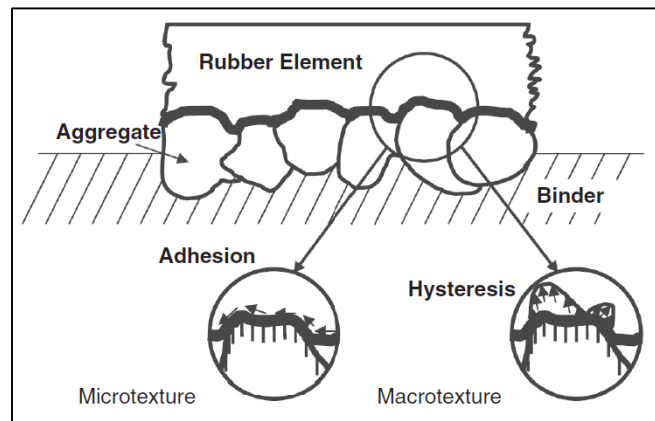


Figure 1. Components of surface texture contributing to friction

2.2. Pavement Friction Measurements

Achieving accurate ground friction measurements is a difficult job due to the susceptibility of the ground friction to a variety of different variables. These considerations include surface conditions of pavement, such as form and thickness of pollutants, fluids on the surface and their contact with friction forces; the operating conditions of the system, such as the speed of sliding, the characteristics of the material and the rubber geometry, and the operating temperature [15]. Friction, which measures the force between the tire and the road, also incorporates three bodies: the measuring tire, the road surface, and any contaminant (wet friction, dust, or wear particles) that affects both the tire and the road surface. Therefore, the calculated friction values depend on all three bodies, their material characteristics, relative velocity, local contact pressures, and other factors. Table 1 lists the essential factors impacting road surface friction [30]:

Table 1. Factors that impacted road surface friction

Road	Contaminant (fluid)	Tyre
Macrotexture	Chemical structure	Tread pattern design
Microtexture	Viscosity	Rubber composition
Unevenness/Mega texture	Density	Inflation pressure
Chemistry of Materials	Temperature	Rubber hardness
Temperature	Thermal conductivity	Load
Thermal conductivity	Specific heat	Sliding velocity
Specific heat	Film thickness	Temperature
		Thermal conductivity
		Specific heat

2.3. Skid Resistance

Secure road travel requires adequate friction between the paved road surface and the tires of the car. One of the key reasons causing the friction between the tire and the ground surface is the roughness of the road surface texture called skid resistance. Friction forces are required to accelerate, decelerate or adjust the driving path of the vehicle safely. Low skid resistance directly links to the increased risk of accidents, especially on wet roads [1]. Road friction can be calculated using one out of five principles: locked wheel, constant slip, variable slip, constant slip angle, and retardation measurement of a standard ABS braked car [31]. The slip resistance of the pavement is influenced by characteristics of the paved road surface (texture, temperature, and materials), the properties of the tires (paw shape, rubber structure, sliding velocity, temperature), and the climatic and environmental factors [15, 16].

Sarsam (2009) studied the macrotexture and micro-texture of the asphalt concrete pavement surface in the field using four different methods (the sand patch process, the Outflow Time (OFT) method, the sand cone method, and the British Pendulum Test (BPT)). Two different grain sizes of sand were used for both sand patch and sand cone techniques, while the micro-texture was investigated using the micro-texture method. The test outcomes of the four strategies were modelled and compared. Also, the skid number was calculated. He argued that the contribution of sand size to the determination of micro-texture is almost insignificant enough to disregard. For the two sand sizes measured, the outflow time method is more beneficial for rough texture estimation, and the 1000 cc water volume is very appropriate for this technique. Testing techniques applied for both micro and macro textures are more accurate models after added skid number phenomena. The mathematical models producing from this field investigation should be successfully implementing [32].

Ahmed et al. (2019), has investigated the evaluation of pavement friction values for major types of Egyptian roads; desert, agriculture, and urban roads. According to the American Society for Testing and Materials, the tested roads have been evaluated by a portable skid resistance mechanism using a British Pendulum (BP) tester. The field tests were performed within the same region during an equivalent summer temperature. The surface skid resistance is anticipated at its low value because of high asphalt viscosity according to a high temperature to control test conditions that led to minimizing variability in test results. Relations between friction values and Cumulative Traffic (CT), surface layer ages and accident rates have been developed for evaluating roads. From regression analysis for friction and other parameters, they concluded that surface friction value is highly affected by road ages and CT, leading to (asphalt mix deterioration) over time [33, 34].

2.4. Pavement Surface Texture

The main function of highway pavement is to standard traffic and allow mobility in a safe, comfortable, and economical way by distributing the surface loads to the existing natural subgrade [35]. As pavement is the main structural element of the road infrastructure, it must provide a durable, solid structure capable of withstanding the traffic loads carried during its service life without suffering damages that can eventually reduce its safety. Along with the structure, the pavement's surface functional performance is a key factor due to its direct relation to safety, riding quality, noise, and appropriate visibility at night and in adverse weather conditions [36]. The texture of the pavement's surface is described as a deviation of the pavement's surface from the actual plane of the pavement's surface [6]. Pavement roughness can be divided into four textures according to the wavelengths of the deviations [37, 38]. Therefore, the texture of the pavement is categorizing into:

2.4.1. Macrotexture

Macrotexture of wavelengths of 0.5 mm and 50 mm. The style and scale of aggregate particles on the pavement's surface and the presence of grooves on any surface are commonly used to create the macrotexture. Also, it is influenced by the area spacing and placement of large aggregate particles. It regulates slip-resistance on wet pavement surfaces, with slip resistance decreasing as the speed of the vehicle increases. Pavement Surfaces with a higher degree of macrotexture tend to have greater friction at high rates than at low rates, but this is not always the case [39, 40]. When driving at speeds greater than 90 km/h on wet pavements, macro-texture is responsible for a significant section of surface friction, regardless of slippage speed [6]. It influences water runoff from the tire surface area and is considered responsible for friction because of high-speed hysteresis [25]. The macro-texture is controlled by the greatest aggregate size, the fine and coarse aggregate forms, the mixing of binder material and viscosity, the mixing of gradation, and the mixing of air content [6].

2.4.2. Microtexture

The microtexture wavelengths range from 0-0.5 mm; the micro-texture of the floor refers to the surface roughness of the floor at the microscopic level of resolution [27]. When applied to the surface of big aggregate particles in asphalt, it is defined as a fine texture that reacts with rubber tires on the molecular level, producing adhesion. Therefore, it is essential to all wet and dry pavements and must be present at any rate [25, 40]. Furthermore, the micro-texture of

aggregates helps break through the water layer between the aggregate particle and tire rubber, thereby playing an essential role in the wet slip resistance [41, 42]. The micro-texture is primarily influencing by the coarse aggregate type [6].

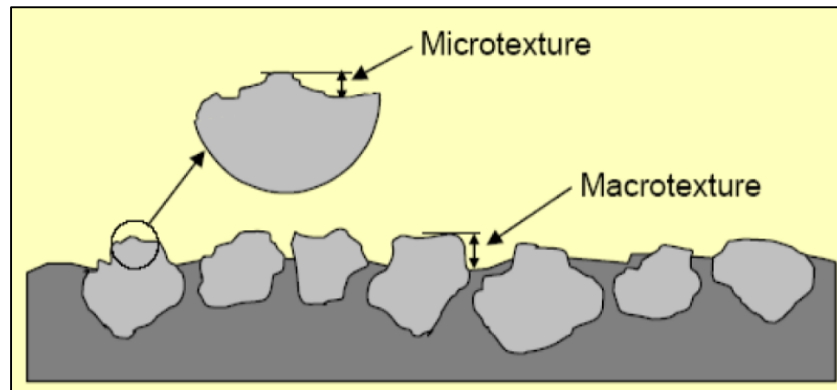


Figure 2. Micro and Macro textures

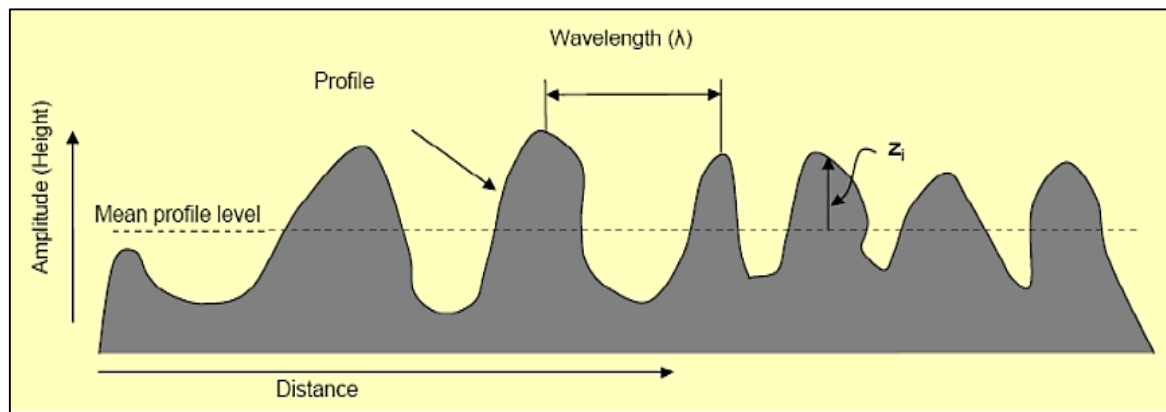


Figure 3. Schematic of Mean Profile Depth Computation

2.4.3. Mega Texture

The mega texture of wavelengths ranging from 50 mm to 500 mm. Openings, critical joints, and cracks. It is responsible for the vibrations of the tire walls and is thus associated with both noise and rolling resistance. [25]. Mega texture and is not ideal for optimal pavement performance [43].

2.4.4. Unevenness

The unevenness has wavelengths ranging from 500 mm to 50 m. It is typically caused by building fault or deformation because of the vehicle's load on the pavement. It impacts vehicle dynamics, ride consistency, and pavement runoff, and it can reduce tire-to-pavement contact [25]. Therefore, it is unacceptable for optimum pavement performance [43].

2.4.5. Standard Specification of Texture

The Committee on Surface Characteristics of the World Road Association [44] recommended selecting texture wavelengths for each category, as seen in the Table 2.

Table 2. Texture classifications according to wavelength

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

2.5. Factors Contributing to Skidding in Accidents

2.5.1. The Characteristics of Vehicles

Goods truck traffic and passenger car traffic have various criteria for road surface skidding resistance. Both types of vehicles vary in terms of tire properties and weights and terms of acceleration and spatial parameters. The division of goods vehicles covers all kinds of trucks with or without a trailer, including coaches, mini-busses, combination cars, and small cars, all with or without a trailer in passenger cars. Certain vehicles (e.g., motorcycles) have a limited share of traffic volume [45]. The motorcycle's small size makes it possible for the rider to navigate and pass the other car while driving. Speeding is vulnerable to motorcycling and pillaging when faster speed causes a high degree of damage or impact on a traffic crash. The motorcyclist will have little power over their motorcycle at a specific speed rate due to the human capability factor, raising the likelihood of a road crash [46]. Speeding is an insufficient activity that increases the risk of getting involved in a traffic crash rather than frustration leading to aggressive driving. More than 50 per cent of motorcyclists travel over the speed limit set by all road types, and at some stage, the speed is greater than the other car [47].

2.5.2. Condition of the Road Surface

Properties like skid resistance and roughness can help determine how safe a pavement surface is. All pavement surfaces should be built and maintained to meet the roadway's friction requirements. According to decades of research, skid resistance is particularly important on wet pavements; as a result, most highway safety management decisions are made solely based on wet pavement crashes. Recent research has discovered. However, that skid resistance may have an impact on crash risk on dry surfaces. Because dry pavements are more common than wet pavements, management choices based only on wet collisions are made using smaller data sets. If skid resistance affects crash risk on dry pavements, including dry crashes in highway safety management can enhance the number of crash observations, improve safety analysis, and result in better maintenance decisions [48]. McCarthy et al. (2021), investigated the association between skid resistance and crash occurrence in dry and wet situations using visual and regression analyses. Figures were created to depict the crash-friction link visually, and crash models were generated using statistical regression. The estimated regression coefficients were used to determine whether there was a statistical relationship. They discovered that skid resistance affects collisions in dry and wet situations, with wet weather having a bigger impact [48].

3. Materials and Methods

This fieldwork was done on Baghdad International Airport Highway. Baghdad Airport Expressway is a 12-kilometre-long (7.5-mile-long) stretch of highway in Baghdad that connects different parts of the city to the airport and neighbouring areas. It was taken to analyze a flexible pavement section on the freeway leading to Baghdad international airport with a width of 3.5 meters. The pavement of the highway layers consists of a natural subgrade with deep of 40 cm, a subbase layer with deep of 30-40 cm, a stabilizer layer (base) with deep of 10 cm and a binder and surface layer with deep of 5 cm for each. One hundred twenty locations have been selected; the distance between each location and another was 5 meters; Figure 4 shows the location map for each section. Figure 5, shows the steps of work developed in this research.

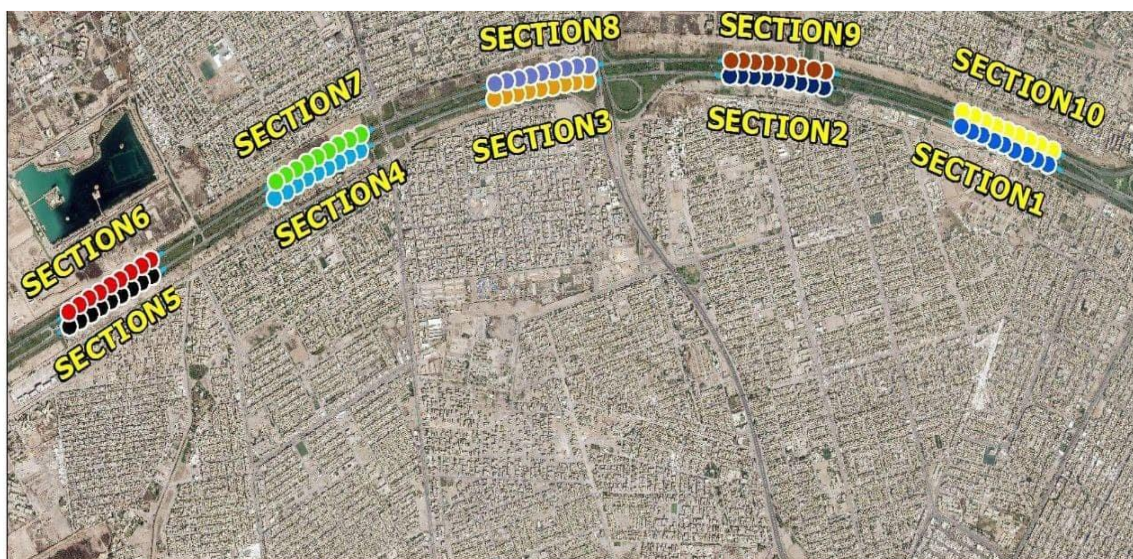


Figure 4. Location map of the freeway sections



Figure 5. Location map for each section

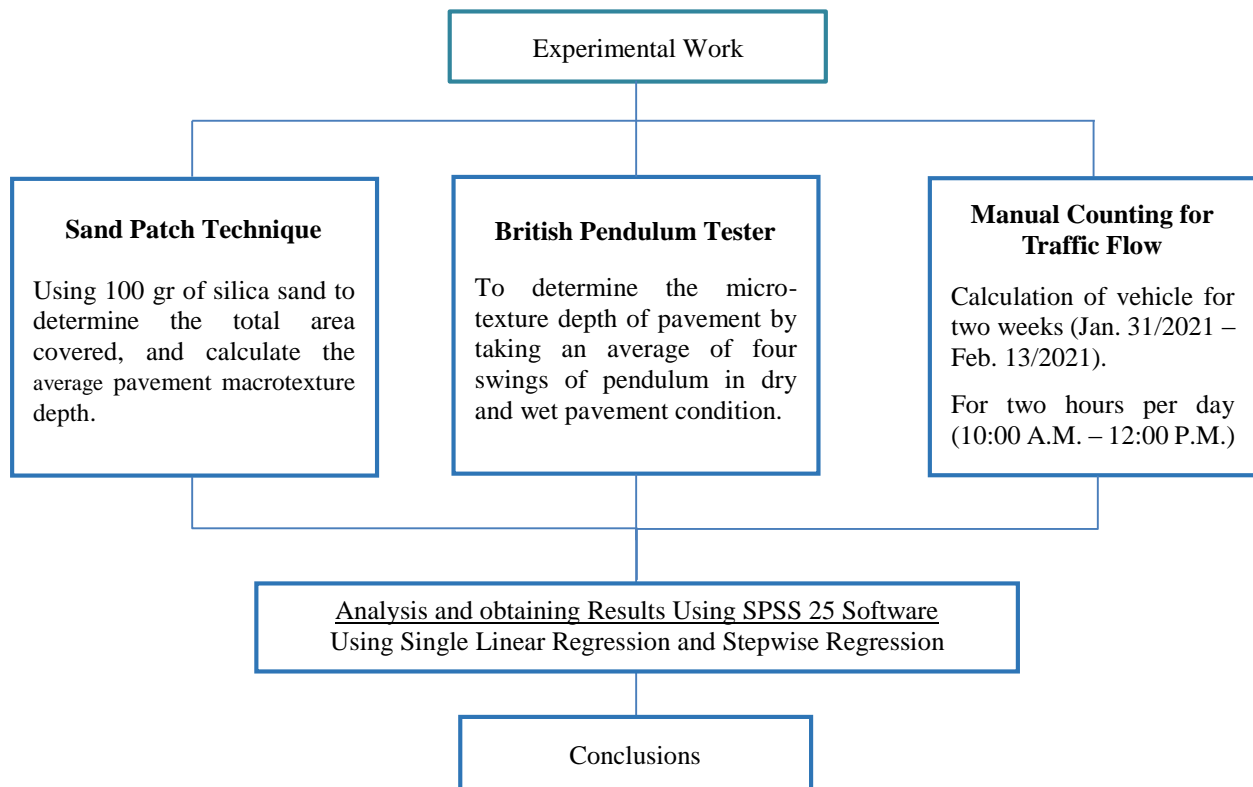


Figure 6. Flow chart of the experimental work

3.1. Volumetric Method (Sand Patch Technique)

According to the American Society for Testing Materials (E-965-15), the sand patch technique has been used. This research method explains the process for calculating the rate macro-texture depth of pavements surface by the dynamic process of a measured quantity of material on the pavement's surface and calculates the total area covered. The purpose of this test is to have a rate depth value of the pavement's surface macro-texture only. The sand patch evaluation equipment requires:

- A brush to scrub the surface of the pavement from dust and particles.
- Sample container cylindrical metal or plastic container with a fixed internal volume of at least 1.5 cubics in. (25 000 mm³) shall be used to calculate the quantity of sand distribution.
- Type of material (silica sand with a density of 1.44 (g/cm³) with known volume (usually 100 g. Passing sieve no. 60).
- Spreader tool—a flat, hard disk to spread the substance (sand) on the test pavement.
- Using a laboratory balance, which is sensitive to 0.1 g, is advised for this test procedure to provide additional control and ensure that the quantity of material used by each surface macrotexture depth calculation is equal in both mass and thickness.

The average pavement macrotexture depth was calculates using Equation 2 [49]:

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

where: MTD = mean texture depth of pavement macrotexture, in. (cm); V = sample volume, in³ (cm³), and; D = average diameter of the area covered by the material, in. (cm).



Figure 7. Sand Patch Test

3.2. British Pendulum Tester

According to the American Society for Testing Materials (E303-93) standard specification protocols, the British Pendulum Number was calculated using the British Pendulum Tester device. It's a dynamic pendulum impact device that calculates energy loss while the edge of the rubber slider is paid across the tested pavement's surface. The tester is suitable for laboratory and field experiments with smooth surfaces and polishing measurements on curved laboratory specimens with rapid polishing-wheel tests. The frictional characteristics of the tested pavement's surface are determined using a pendulum-style tester with a standard rubber slider, which is part of the procedure. Before testing, the test surface should be thoroughly swept and wetted with water. The pendulum slider is angled to make only minimal contact with the tested pavement's surface before testing. Therefore, it is necessary to raise the pendulum to a locked position before lowering it to allow the slider to contact the tested pavement's surface. To ensure that surface voids of concrete were saturated, 500ml of water was applied to the surface of the concrete. An average of four pendulum swings has been performed at each test point [33].



Figure 8. British Pendulum Tester

4. Results and Discussion

4.1. Effect Of Mean Texture Depth (MTD) On Skid Number at Dry Pavement Condition (SN_{dry}) and Wet Pavement Condition (SN_{wet})

According to the findings of the model summary tables, there was a statistically significant relationship between MTD and SN, and the impact of MTD on skid number (SN) was significant. The coefficients of multiple determination for dry and wet pavement conditions were (0.964-0.914), respectively, the highest value obtained in dry conditions. This increase may be due to the increase in the ratio of coarse aggregate. But for design, wet pavement conditions must be considered because it is the case used in all highway design standards. Tables 3 and 4 respectively illustrate model summary for skid resistance in both dry and wet pavement conditions with the mean texture depth. Figures 9 and 10 illustrate the relation between SN at both dry and wet pavement conditions, which shows an increase in the coefficients of multiple determination (R^2),

Table 3. MTD and SN_{dry} Model Summary ^b

Model	R	R ²	Adjusted R Square	Std. Error of Estimate
1	0.982 ^a	0.964	0.964	0.126

a. Predictors: (Constant), Mean Texture Depth (mm.)

b. Dependent Variable: Skid Number (At Dry Pavement Condition)

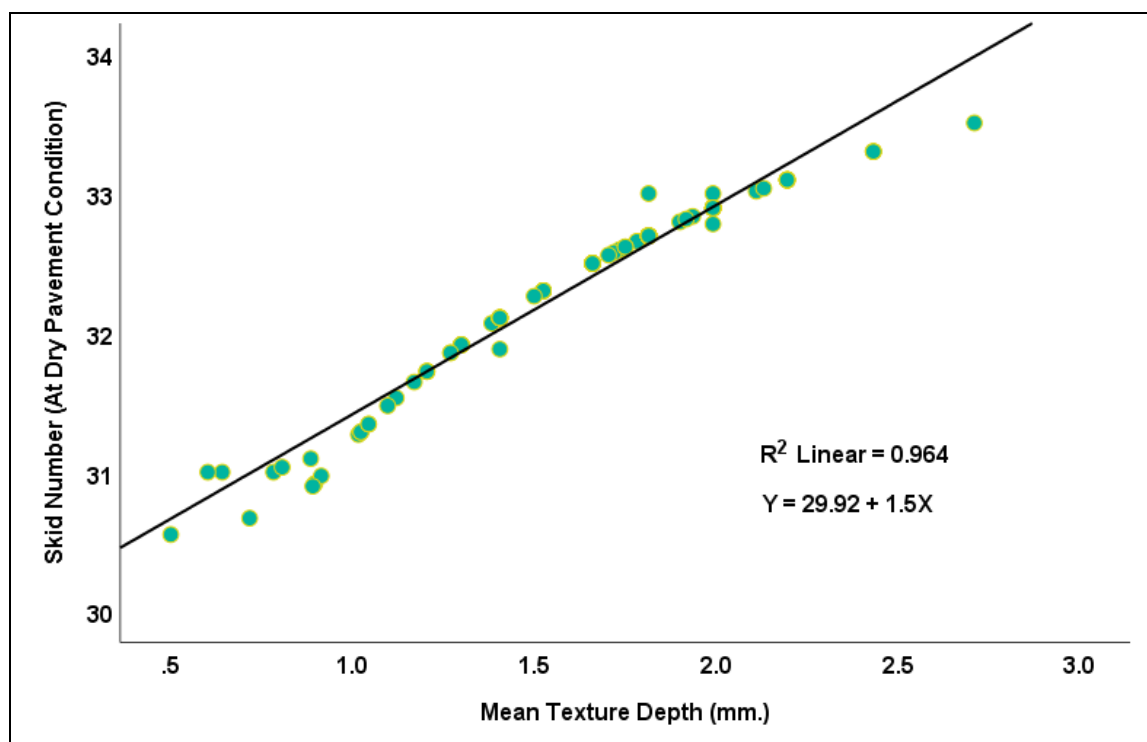


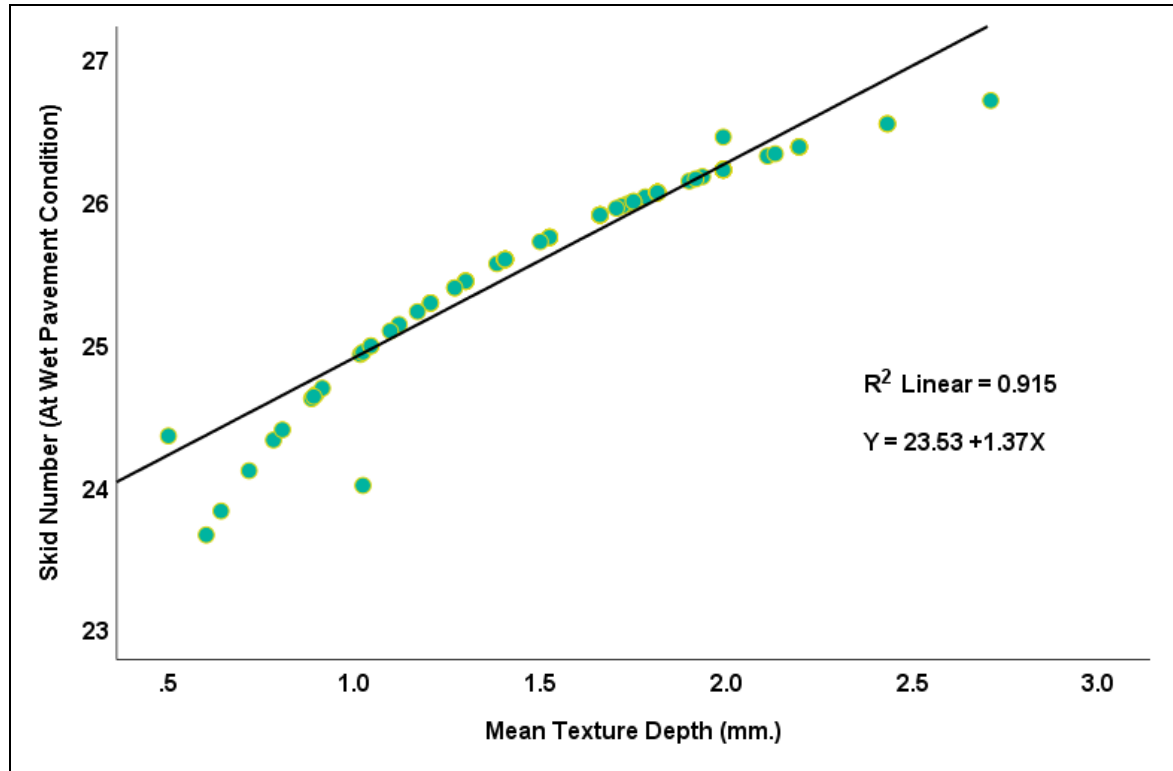
Figure 9. Effect of MTD and Pavement Condition (Dry Condition) On SN

Table 4. MTD and SN_{wet} Model Summary^b

Model	R	R ²	Adjusted R Square	Std. Error of Estimate
1	0.956 ^a	0.914	0.914	0.182

a. Predictors: (Constant), Mean Texture Depth (mm.)

b. Dependent Variable: Skid Number (At Wet Pavement Condition)

**Figure 10. Effect of MTD and Pavement Condition (Wet Condition) On SN**

4.2. Effect of Traffic Flow on MTD

According to the findings of the model summary tables, there was a statistically significant relationship between MTD and Traffic flow, and the impact of MTD on traffic flow was significant. The relationship between traffic flow and mean texture depth indicates that there is an indirect relationship and the coefficient of multiple determination were (0.849-0.940-0.974) for passenger cars, buses and trucks, respectively. Tables 5 to 7 illustrate the model summary results between Traffic flow (number of passenger cars, traffic volume, and number of buses) and MTD. Figures 11 to 13 illustrates the effect of traffic flow (number of cars, number of buses, and number of trucks) to the mean texture depth, it shows that as the traffic volume increase, the mean texture depth decrease. This decrease in MTD may be due to the decrease in SN, which is highly affected by traffic flow [34], and the increase in the ratio of uncrushed aggregate, the increase in traffic volume and the proportion of vehicles lead to the smoothness of paving surface.

Table 5. Number of passenger cars and MTD Model Summary^b

Model	R	R ²	Adjusted R Square	Std. Error of Estimate
1	0.922 ^a	0.849	0.848	0.1690

a. Predictors: (Constant), Number of Passenger cars / hr.

b. Dependent Variable: Mean Texture Depth (mm.)

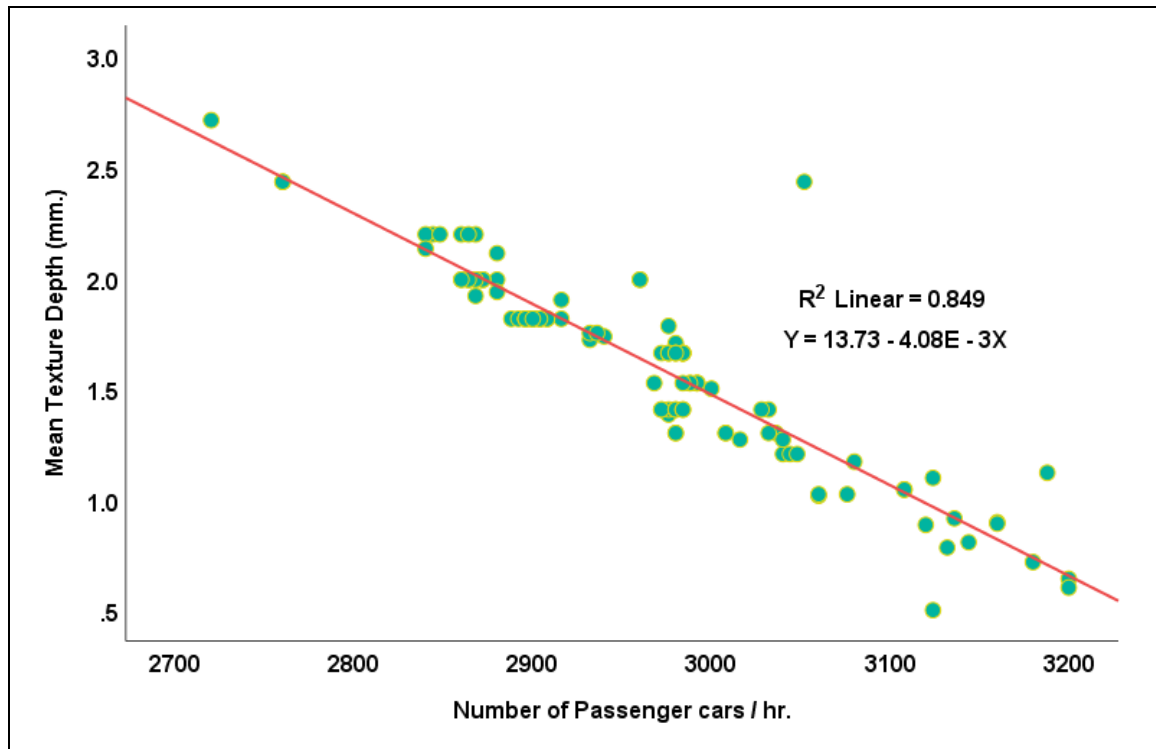


Figure 11. Effect of Number of Cars on Mean Texture Depth.

Table 6. Number of Buses and MTD Model Summary^b

Model	R	R ²	Adjusted R Square	Std. Error of Estimate
1	0.970 ^a	0.940	0.939	1.856

a. Predictors: (Constant), Number of Buses /hr.

b. Dependent Variable: Mean Texture Depth (mm.)

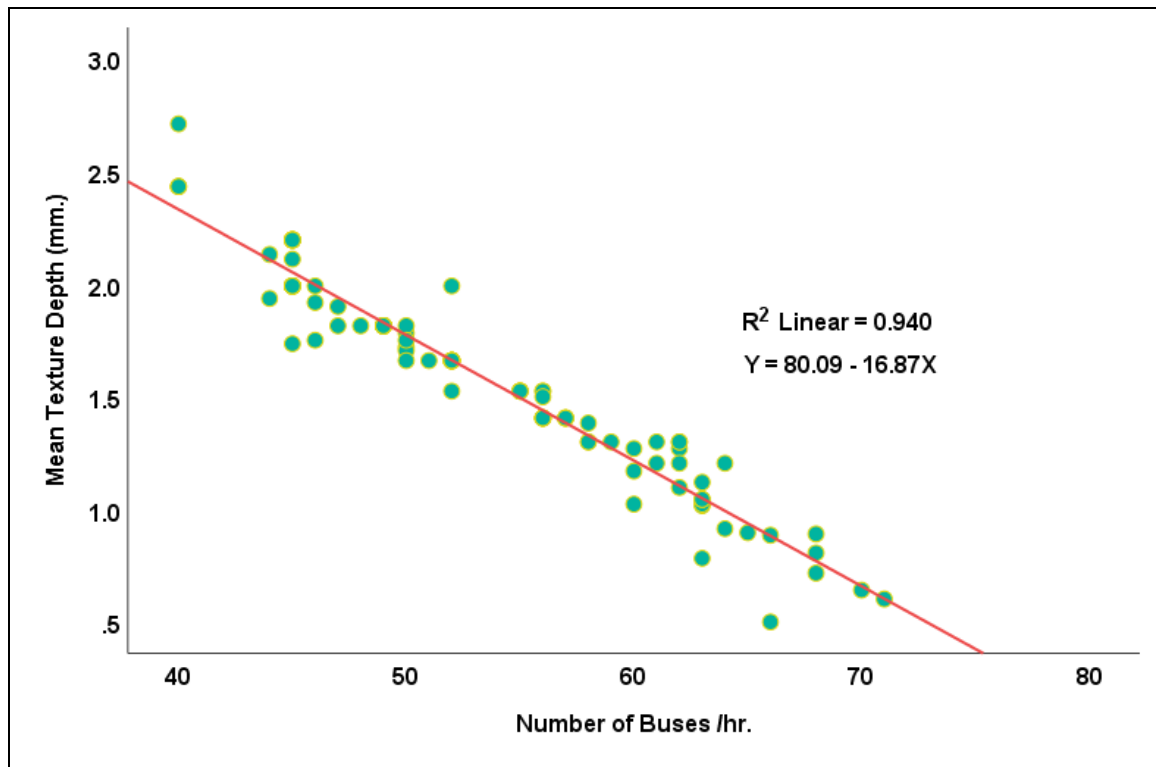


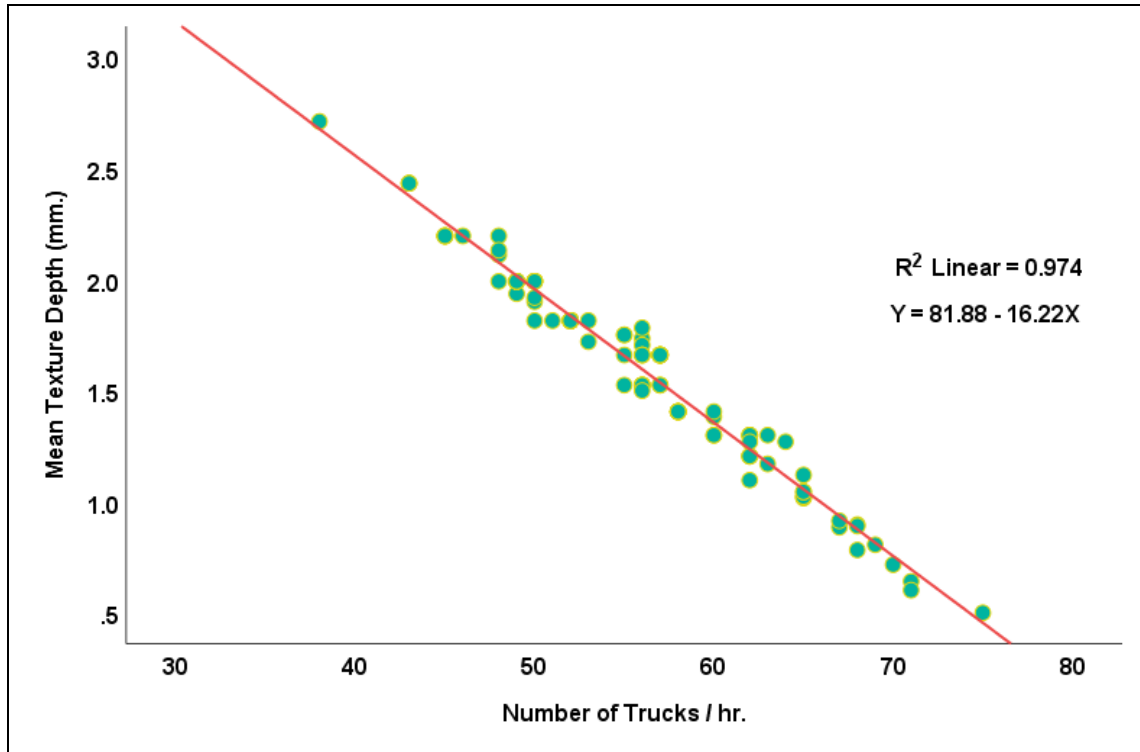
Figure 12. Effect of Number of Buses on Mean Texture Depth

Table 7. Number of Trucks and MTD Model Summary^b

Model	R	R ²	Adjusted R Square	Std. Error of Estimate
1	0.987 ^a	0.974	0.973	1.160

a. Predictors: (Constant), Number of Trucks / hr.

b. Dependent Variable: Mean Texture Depth (mm.)

**Figure 13. Effect of Number of Trucks on Mean Texture Depth**

4.3. Effect of Traffic Flow on Skid Number at Dry Pavement Condition (SN_{dry})

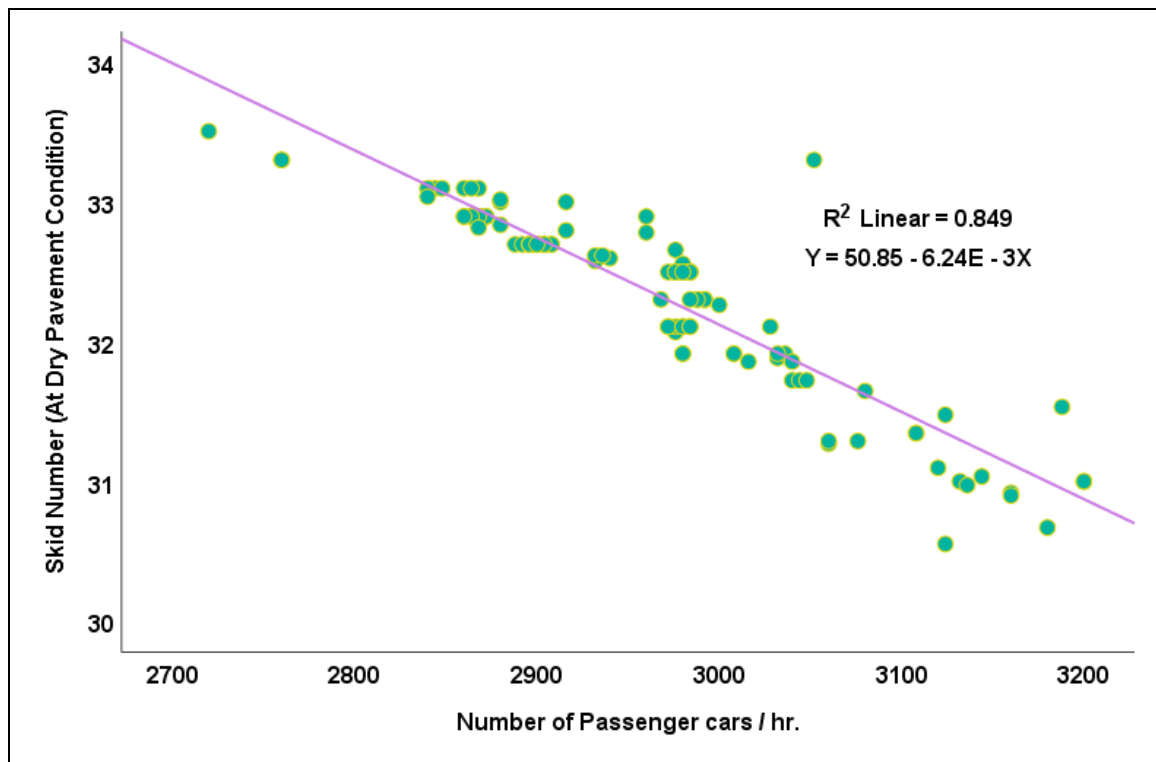
According to the findings of the model summary tables, there was a statistically significant relationship between SN_{dry} and Traffic flow. The relationship between traffic flow and skid resistance indicates that there is an indirect relationship and the coefficient of multiple determination were (0.849-0.927-0.940) for passenger cars, buses and trucks, respectively. Tables 8 to 10 respectively show the regression analysis of traffic flow and SN_{dry} . Figures 14 to 16 illustrates the effect of traffic flow (number of cars, number of buses, and number of trucks) to skid Number at dry pavement condition, it shows that as the traffic volume increase, the skid resistance decrease. Such results correlate with [34].

Table 8. Number of Passenger Cars and SN_{dry} Model Summary^b

Model	R	R ²	Adjusted R Square	Std. Error of Estimate
1	0.921 ^a	0.849	0.848	0.259

a. Predictors: (Constant), Number of Passenger cars / hr.

b. Dependent Variable: Skid Number (At Dry Pavement Condition)

Figure 14. Effect of Number of Passenger Cars on SN_{dry} Table 9. Number of Buses and SN_{dry} Model Summary^b

Model	R	R ²	Adjusted R Square	Std. Error of Estimate
1	0.963 ^a	0.927	0.926	2.051

a. Predictors: (Constant), Number of Buses /hr.

b. Dependent Variable: Skid Number (At Dry Pavement Condition)

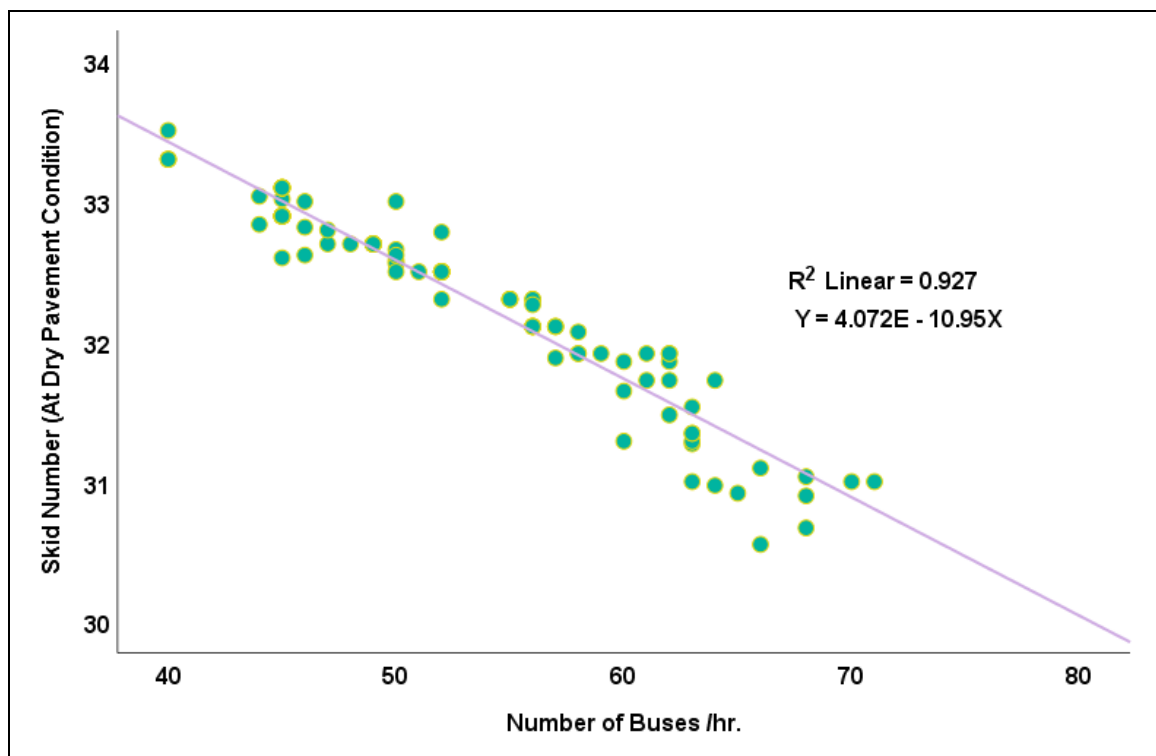
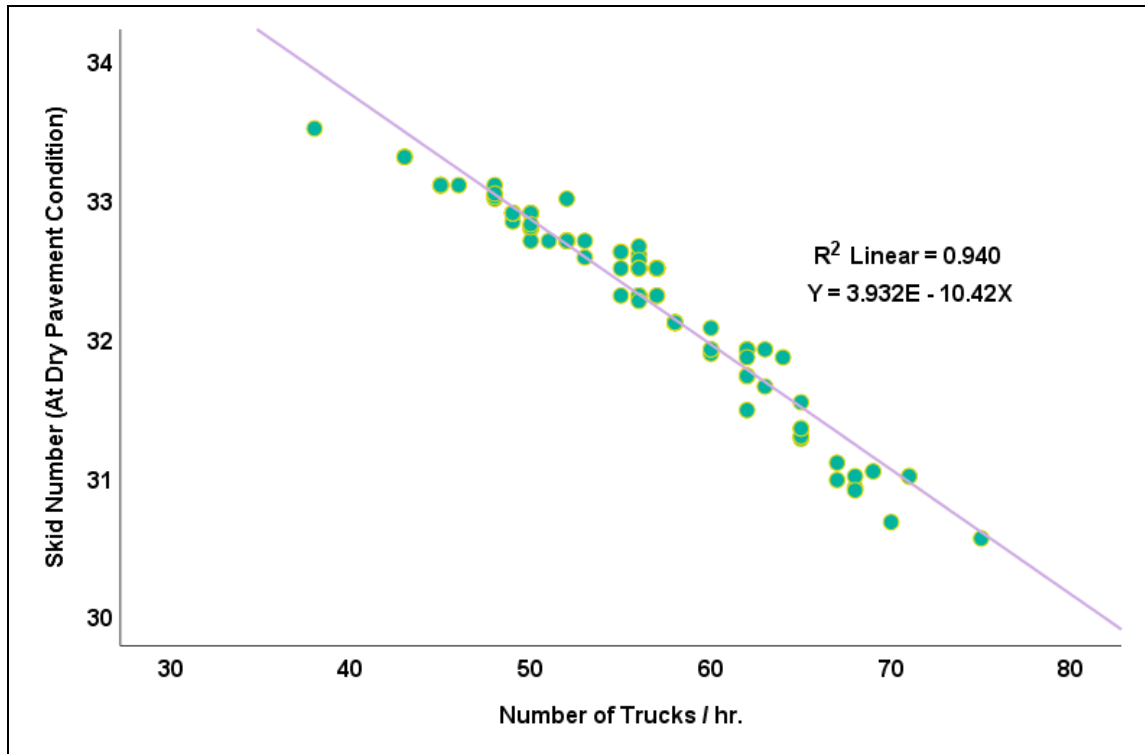
Figure 15. Effect of Number of Buses on SN_{dry}

Table 10. Number of Trucks and SN_{dry} Model Summary^b

Model	R	R ²	Adjusted R Square	Std. Error of Estimate
1	0.969 ^a	0.940	0.939	1.755

a. Predictors: (Constant), Number of Trucks / hr.

b. Dependent Variable: Skid Number (At Dry Pavement Condition)

**Figure 16. Effect of Number of Trucks on SN_{dry}**

4.4. Effect of Traffic Flow on Skid Number at Wet Pavement Condition (SN_{wet})

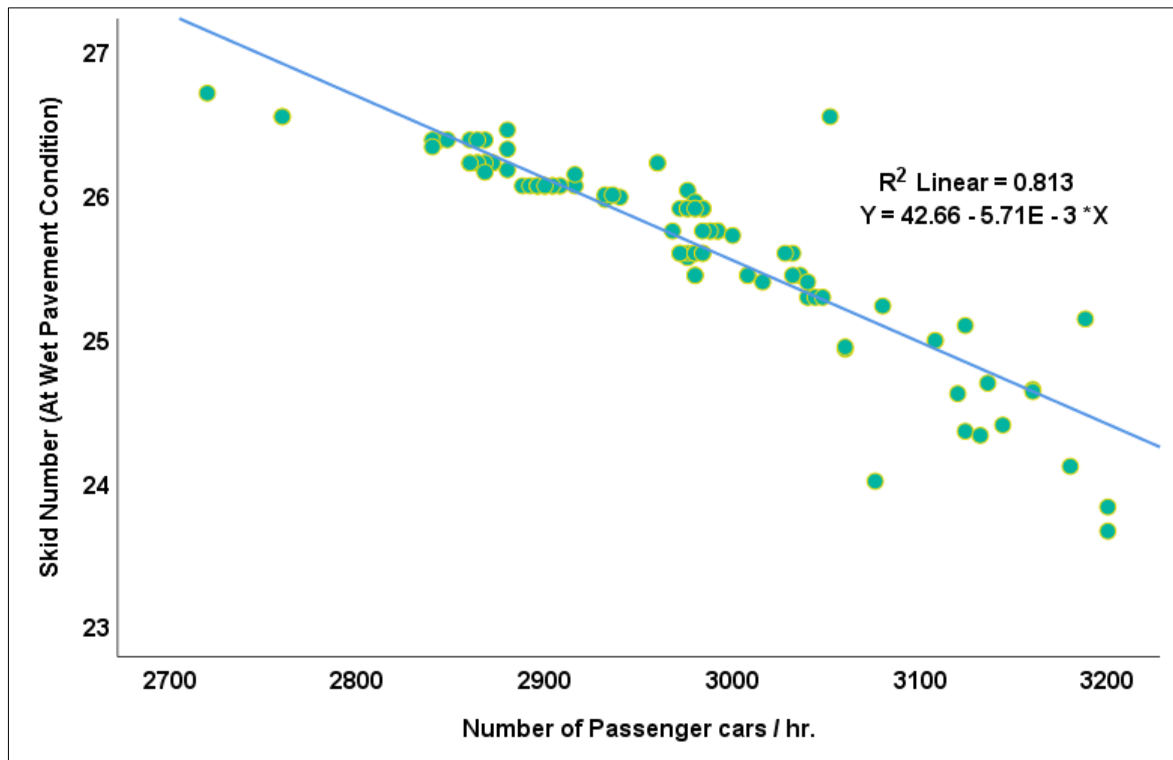
According to the findings of the model summary tables, there was a statistically significant relationship between SN_{wet} and Traffic flow. The relationship between traffic flow and skid resistance indicates that there is an indirect relationship and the coefficient of multiple determination were (0.813-0.879-0.882) for passenger cars, buses and trucks, respectively. Tables 13 to 16 shows the regression analysis of traffic flow and SN_{dry} . Figures 17 to 19 illustrates the effect of traffic flow (number of cars, number of buses, and number of trucks) to skid Number at wet pavement condition, it shows that as the traffic volume increase, the skid resistance decrease. Such results correlate with [34].

Table 11. Number of Passenger Cars and SN_{wet} Model Summary^b

Model	R	R ²	Adjusted R Square	Std. Error of Estimate
1	0.902 ^a	0.813	0.811	0.269

a. Predictors: (Constant), Number of Passenger cars / hr.

b. Dependent Variable: Skid Number (At Wet Pavement Condition)

Figure 17. Effect of Number of Passenger Cars on SN_{wet} Table 12. Number of Buses and SN_{wet} Model Summary^b

Model	R	R ²	Adjusted R Square	Std. Error of Estimate
1	0.938 ^a	0.879	0.878	2.632

a. Predictors: (Constant), Number of Buses /hr.

b. Dependent Variable: Skid Number (At Wet Pavement Condition)

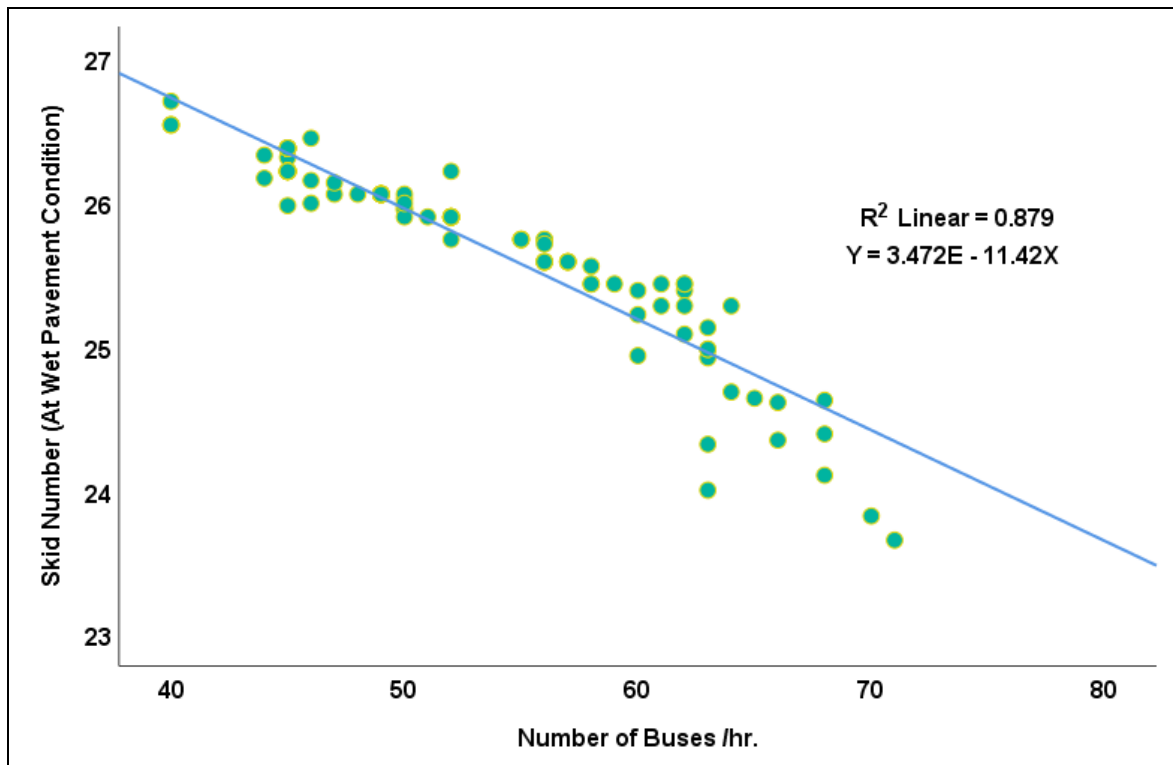
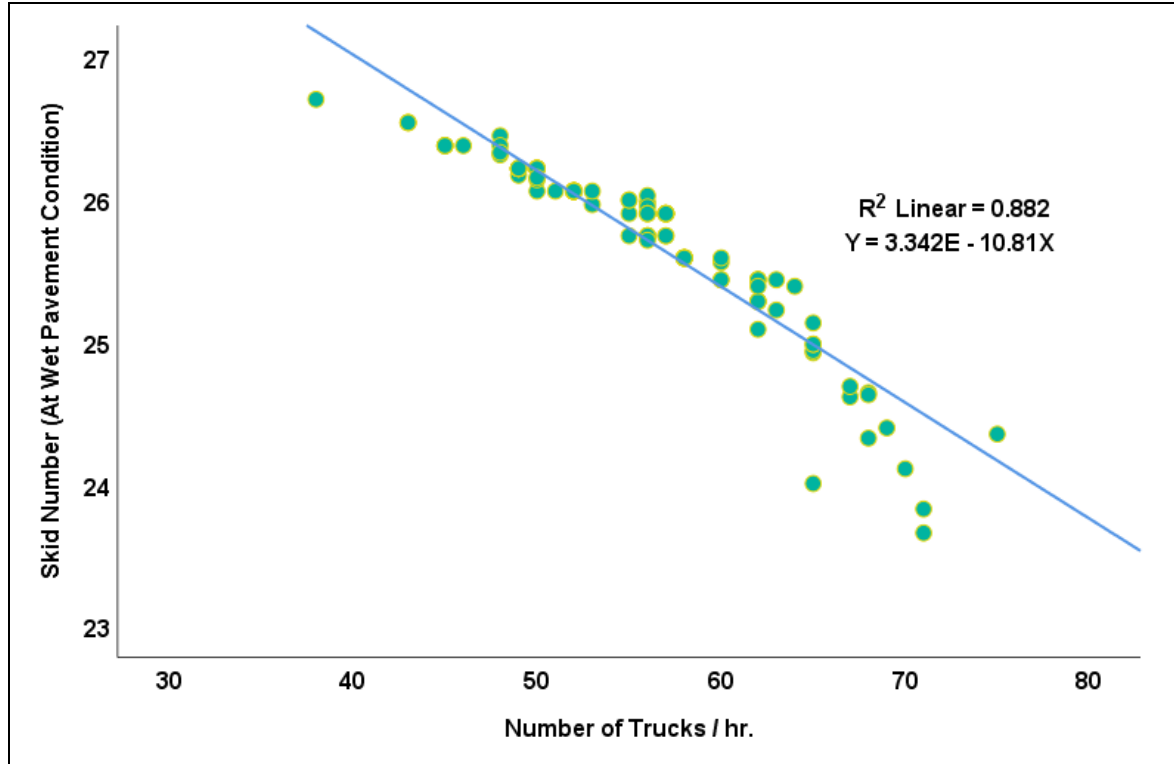
Figure 18. Effect of Number of Buses on SN_{wet}

Table 13. Number of Trucks and SN_{wet} Model Summary^b

Model	R	R ²	Adjusted R Square	Std. Error of Estimate
1	0.939 ^a	0.882	0.881	2.461

a. Predictors: (Constant), Number of Trucks / hr.

b. Dependent Variable: Skid Number (At Wet Pavement Condition)

**Figure 19. Effect of Number of Trucks on SN_{wet}**

5. Conclusions

Based on the work program and field tests employed in this research, the following conclusions were drawn:

- Tire – Pavement friction is not a fixed number and should always be considered in existing studies conditions.
- The testing technique adopted (sand patch) for macrotexture determination and British Pendulum Test for microtexture determination are considered good enough for evaluation of pavement surface texture for the site condition tested.
- Skid resistance of pavement surface increase with the increase of mean texture depth, this increase may be due to the increase of coarse aggregate which lead to increase the roughness of the pavement surface, this increase ranged between (91-96%).
- Mean texture depth decreases with the increase of traffic flow due to the friction between the road surface and the vehicle tires leading to increase of smoothness of the road surface. This is mean that mean texture depth is highly affected by the traffic flow and this effectiveness ranged between (84% - 97%).
- Skid resistance also is highly affected by the traffic flow with an effectiveness ranged between (81% - 94%) for both pavement conditions.
- The speed coefficient can be ignored on major arterial roads, this is because the vehicle's speed on these roads exceeds 60 km/hr., resulting in less impact on the surface.
- According to the regression analysis for friction and other parameters, it can be concluded that surface friction values are highly affected by cumulative traffic (asphalt mix deterioration) over a time.

6. Declarations

6.1. Author Contributions

Conceptualization, M.Q.I.; methodology, M.Q.I.; software, D.J.M.; writing—original draft preparation, D.J.M.; writing—review and editing, M.Q.I.; supervision, M.Q.I.; All authors have read and agreed to the published version of the manuscript.

6.2. Data Availability Statement

The data presented in this study are available in article.

6.3. Funding

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6.4. Conflicts of Interest

The authors declare no conflict of interest.

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