Al-Azhar University Civil Engineering Research Magazine (CERM)
Vol. (40) No. (4) October, 2018

Evaluation of Surface Friction Characteristics for Egyptian Highways

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ملخص البحث

معدل الحوادث يزداد سريعا في مصر حيث يعتبر أعلى معدل حوادث فى العالم. وصل متوسط معدلات الوفيات على مدى السنوات الما ضية (6486 قتيلا) بناءا على تقارير الحوادث المسجلة فى إدارات شرطة المرور. حاليا تم تقدير الخسارة المادية كنتيجة للحوادث المرورية فقط بحوالى ستة (6) مليار جنيه مصري سنويا. هذا الرقم الكبير يوضح التأثير السلبى الشديد اجتماعيا واقتصاديا على المجتمع المصري. وعلى الرغم من تعقيد حوادث الطرق السريعة ، يمكن للعوامل المرتبطة بهذه الحوادث أن تتلخص في ثلاث فئات رئيسية: تتعلق بالسائق ، والمرتبطة بالسيارات ، وحالة الطرق السريعة. من بين هذه الفئات الثلاث يمكن للهيئات المعنية بالطرق السريعة التحكم فقط في ظروف الطرق السريعة مثل ؛ خصائص سطح الرصيف ، وحركة المرور ونظم الحركة المرورية ، وما إلى ذلك. واحدة من الأسباب الرئيسية وراء حوادث الطرق السريعة هو انخفاض الاحتكاك بين إطار المركبة وسطح الرصيف ، خاصة عندما يكون سطح الرصيف رطبًا و يعتبر هذا هو الهدف الرئيسي من البحث و هو تقييم معامل الاحتكاك السطحي للطرق المصرية.

ABSTRACT:

This paper presents the evaluation of international friction index for Egyptian highways and relation between that friction and other parameters. Skid Resistance (S.R.) is the force developed when a tire that is fully or partially prevented from rolling slides along a pavement surface under lubricated conditions. Pavement friction is defined as the resisting force developed between a vehicle tire and the pavement surface, which always acts in the opposite direction of the vehicle motion. Pavement surface friction provides safety while driving on pavements and plays a critical role in reducing wet-pavement friction Accidents due to skidding on pavement are a major concern of highway industries. These accidents are generally attributed to skid resistance deficiencies on the pavement surface, hence the tire pavement friction interaction mechanism is one of the most important issues of safe vehicle operations on pavements. Different friction measuring devices have been developed to evaluate the frictional values of a pavement surface.

Keywords: Friction Number, International Friction Index, Friction Testing, British Pendulum, Egyptian Roads.

INTRODUCTION

It has long been regarded that friction coefficients play a significant role in influencing both the frequency and severity of traffic accidents. This widespread acceptance arises due to the road surface’s ability to facilitate the development of the skid resistance required for various vehicle manoeuvres, most notably braking and cornering. As a result, many highway authorities have set minimum friction requirements for road surfaces within their jurisdictions. Due to the most recent changes in policy and the

incremental modernization of the vehicle fleet, this study sets out to re-investigate the relationship between friction coefficient and traffic accidents. Where prescribed minimum friction coefficients are set too low, savings associated with traffic accidents may be possible through increasing friction coefficient requirements. Conversely, where friction coefficient requirements are set too high, savings may be possible through reduced road maintenance expenditure.
Along many years ago, large number of researcher try to illustrate the concept of pavement friction as the resisting force developed between vehicle tire and pavement surface which always acts in the opposite direction of vehicle motion. In addition, SR can be defined also as a significant driving safety factor and plays a critical role in reducing wet pavement crashes (FHWA, 1980; Li et al., 2005). But according to Noyce it is the friction force developed at the contact area of tire and pavement. Furthermore SR is the pavement friction that resists sliding of vehicle tires on pavement surfaces. At the same time ASTM committee E17, define friction resistance as the retarding force generated by the interaction between a pavement and a tire under a locked non-rotating condition. In conclusion pavement friction can be defined as the ratio of vertical and horizontal force developed as a tire slides along a pavement surface that makes wagon under hegemony and be able to stop avoiding obstacles in the surrounding weather condition.

LITERATURE REVIEW

Pavement surface friction is a current critical issue to highway safety, General Authority of Roads, Bridges, and Land Transport (GARBLT) historical data indicate that traffic accidents cause nearly 2.5 million injuries and over 41,000 fatalities annually in Egypt, on the other hand, according to Kuemmel approximately 13.5 percent of fatal crashes and 25 percent of all crashes occur under wet pavement conditions ; factors associated with those crashes may be summarized into three main categories: driver related, vehicle related, and highway condition related , out of the three categories only the highway condition factors may be controlled by highway agencies, this has led to the strong interests at both the federal and state level in advancing crash reduction programs with specific attention focusing on better understanding the relationship between measurable surface characteristics (e.g., friction and texture) and the occurrence of wet pavement crashes , in a study performed in Texas, it was found that higher percentage of crashes occur on roads with low friction while fewer crashes happen on roads with high friction . Many researchers have developed models to predict the associations between car crashes and friction, most studies confirm the association between high rates of car crashes and low levels of pavement friction.

The notion that friction coefficients are a significant contributory factor in traffic crashes has been firmly entrenched in the literature, as a result, many highway authorities have set minimum friction requirements for road surfaces, below which the probability of a crash is considered unacceptably high; the safety benefit ascribed to friction coefficients arise from its ability to facilitate various vehicle manoeuvres, most notably breaking and cornering . Pavement friction depends on both the microtexture of aggregates and the macrotexture of the overall pavement surface. Microtexture, usually defined as small-scale texture up to 0.5 mm wavelengths, is largely a function of the surface texture of aggregate particles, while Macrotexture is a larger texture between about 0.5 mm and 50 mm wavelengths of the two texture types, microtexture affects the adhesion area between aggregate and tire rubber and controls the pavement friction level at low speeds, while macrotexture has a greater effect on hysteresis friction; unlike microtexture, macrotexture also helps to provide a drainage channel for water to escape., macrotexture assumes a greater role at high speeds and is the controlling factor in the speed dependency of friction. The International Friction Index (IFI) includes measurements of both macrotexture and friction on wet pavements; a speed constant derived from the macrotexture measurement that indicates the speed-dependence of the friction and a friction number corresponding to a slip speed of 60 km/h (38 mph), the IFI is based on the assumption that the friction is a function of speed and macrotexture and that for a specific pavement surface macrotexture, the value of friction is reduced as the speed increases; this relationship is shown below in Figure (1) that shows the relationship between speed and friction and it's clear that as the speed increases the coefficient of friction decreases.

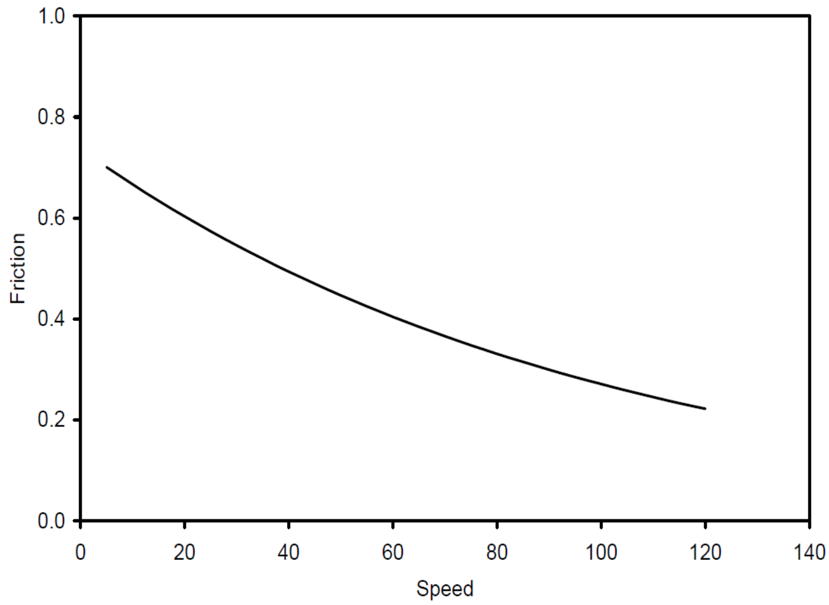

Fig. 1 Relationship between Speed and Friction

METHODOLOGY

Field tests were carried out to converge most Egyptian road types as rural desert and agriculture according to road location also urban and freeways according to road function, Moreover; that selection was depending on the availability of selected road data in General Authority for Roads, this study doesn't deal with the climatic variation; however, to overcome the possible effect of climatic variation most of the field tests were performed during the same temperature at which surface skid resistance is expected at its low.

A framework has been adopted for field tests for selected roads by sequence of steps outlined below:

1- A preliminary study of roads was conducted to know general information about selected roads such as number of traffic lanes and the type of transport available to choose the most suitable time to take readings.
2- The selected roads were divided into sectors according to the division of the General Authority for Roads, where the tested sections matches data that provided by the Authority.

3- The data necessary (ADT, construction date, number of accidents) to reach the objective of the study were collected.
4- Field tests were carried out on four days to collect pavement surface friction and texture data from a selected pavement sections and record pavement surface friction numbers in friction record table shown in Table 1.

Table 1 Friction Record Examination Model

Road Data					
Date		From		To	
Road Name		Section No.		Section	
Road Width		No. of Lanes		Road Type	
Road Description				Traffic Type	
Temp.		Radius of		Spot Speed	
Begin of Section		End of Section		B.P Record 1	
B.P Record 2		B.P Record 3		B.P Record 4	
B.P Record 5		B.P Average Record			

BRITISH PENDULUM

The British Pendulum Tester is a dynamic pendulum impact-type tester used to measure the energy loss when a rubber slider edge is propelled over a test surface. The tester is suited for laboratory as well as field tests on flat surfaces, and for polish value measurements on curved laboratory specimens from accelerated polishing-wheel tests. The values measured, BPN = British Pendulum (Tester) Number for flat surfaces and polish values for accelerated polishing-wheel specimens, represent the frictional properties obtained with the apparatus and the procedures stated herein and do not necessarily agree or correlate with other slipperiness measuring equipment. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

Apparatus

British Pendulum Tester as shown in Figure 2 consist of the pendulum with slider mount shall weigh 1500 ±30 g. The distance of the center of gravity of the pendulum from the center of oscillation shall be 411 ± 5 mm (16.2 ± 0.2 in.). The tester shall be capable of vertical adjustment to provide a slider contact path of 125± 1.6 mm (79/16 + 1/16 in.) for tests on flat surfaces, and 76 to 78 mm (3 ± 1/16 in.) for tests on polishing-wheel specimens. The spring and lever arrangement shall give an average normal slider load between the 76-mm (3-in.) wide slider and test surface of 2500 ±100 g as measured by the method prescribed in the annex.

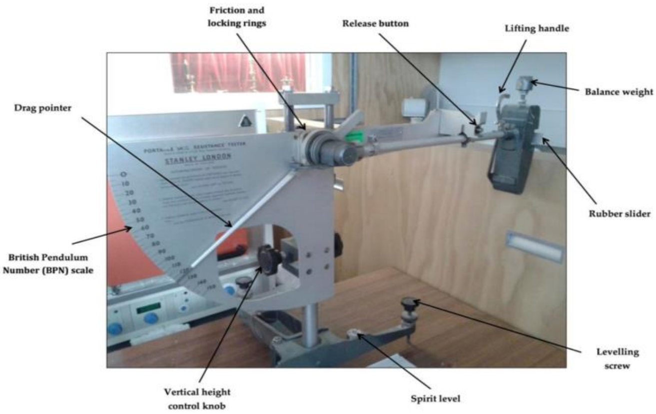

Fig. 2 Slider Assembly Illustrating the Maximum Wear on Striking Edge

• Summary of Test Method

This test method consists of using a pendulum-type tester with a standard rubber slider to determine the frictional properties of a test surface. The test surface is cleaned and thoroughly wetted prior to testing. The pendulum slider is positioned to barely come in contact with the test surface prior to conducting the test. The pendulum is raised to a locked position, then released, thus allowing the slider to make contact with the test surface. A drag pointer indicates the British Pendulum (Tester) Number. The greater the friction between the slider and the test surface, the more the swing is retarded, and the larger the BPN reading. Four swings of the pendulum are made for each test surface.
Field test surfaces shall be free of loose particles and flushed with clean water. The test surface does not have to be horizontal provided the instrument can be leveled in working position using only the leveling screws and the pendulum head will clear the surface.

- **Test procedure**

1- Level the instrument accurately by turning leveling screws until the bubble is centered in the spirit level.
2- Raise pendulum mechanism by loosening locking knob (directly behind pendulum pivot) and turn either of pair of head movement knobs at center of tester to allow slider to swing free of test surface. Tighten locking knob firmly.
3- Place pendulum in release position and rotate the drag pointer counter clockwise until it comes to rest against adjustment screw on pendulum arm.
4- Release pendulum and note pointer reading. If reading is not zero, loosen locking ring and rotate friction ring on bearing spindle slightly and lock again. Repeat test and adjust friction ring until the pendulum swing carries pointer to zero.
5- With pendulum hanging free, place spacer under adjusting screw of lifting handle. Lower pendulum so edge of slider just touches surface. Lock pendulum head firmly, raise lifting handle, and remove spacer.
6- Raise slider by lifting handle, move pendulum to right lower slider, and allow pendulum to move slowly to left until edge of slider touches surface. Place gage beside slider and parallel to direction of swing to verify length of contact path. Raise slider, using lifting handle, and move pendulum to left, then slowly lower until slider edge again comes to rest on surface. If the length of the contact path

is not between 124 and 127 mm (47⁄8 and 5.0 in.) on flat test specimens or between 75 and 78 mm (215⁄16 and 31⁄16 in.) on curved polishing-wheel specimens, measured from trailing edge to trailing edge of the rubber slide, adjust by raising or lowering instrument with the front leveling screws. Readjust level of instrument if necessary. Place pendulum in release position and rotate the drag pointer counter-clockwise until it comes to rest against adjustment screw on pendulum arm.

7- Apply sufficient water to cover the test area thoroughly. Execute one swing, but do not record reading.
8- Always catch the pendulum during the early portion of its return swing. While returning the pendulum to its starting position, raise the slider with its lifting handle to prevent contact between the slider and the test surface. Prior to each swing, the pointer should be returned until it rests against the adjustment screw.
9- Without delay, make four more swings, rewetting the test area each time and record the results.

Note: Care should be taken that the slider remains parallel to the test surface during the swings, and does not rotate so that one end rather than the entire striking edge makes the initial contact. Available data indicate that tilting of the slider may cause erroneous BPN readings. Installation of a small flat spring will relieve the problem. The spring can be inserted into a slot in the spring clip and the assembly secured by the cotter pin as shown in Fig. 4.The free ends of the spring can rest on the slider backing plate to restrain the slider from tilting.
Slider: The slider assembly shall consist of an aluminum backing plate to which is bonded a 6 by 25 by 76-mm (1⁄4 by 1 by 3-in.) rubber strip for testing flat surfaces or a 6 by 25 by 32 mm (1⁄4 by 1 by 5⁄4-in.) rubber strip for testing curved polishing-wheel specimens. The rubber compound shall be natural rubber meeting the requirements of the Road Research Laboratory (R.R.L.) or synthetic rubber as specified in Specification E 501. New sliders shall be conditioned prior to use by making ten swings on No. 60 grade silicon carbide cloth4 or equivalent under dry conditions. The swings shall be made with a tester adjusted. Wear on the striking edge of the slider shall not exceed 3.2 mm (1⁄8 in.) in the plane of the slider or 1.6 mm (1⁄16 in.) vertical to it, as illustrated in Figure (3.5) Contact path gage shall consist of a thin ruler suitably marked for measuring contact path length between 124 and 127 mm (47⁄8 and 5.0 in.) or between 75 and 78 mm (215⁄16 and 31⁄16 in.) as required for the particular test.

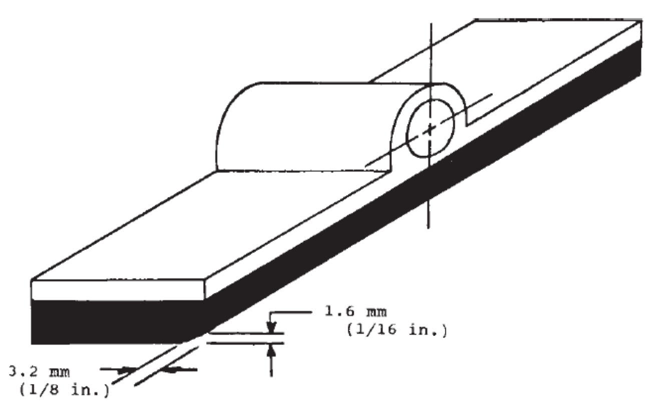

Fig. 3 Slider Assembly Illustrating the Maximum Wear on Striking Edge

SURVEY DATA

Data was collected in preparation to start the analysis stage in order to achieve the objectives of this study; the following steps were conducted:

1- Preparation of accidents data, ADT, selected roads construction date or the last massive maintenance from GARBLT.

2- Recording British Pendulum readings in an excel sheet be able to analyze.

3- Roads has been coded in a serial code

4- To achieve the purpose of this study **P**redictive **A**nalytics **S**oft**W**are (PASW) was used to get a correlation factor between friction number and the independent variables.

REGRESSION ANALYSIS

Simple linear regression for friction number was used to check the correlation coefficient between this dependent variable and independent variables. Stepwise regression analysis was used to select the most statistically significant variables. In some cases, the data did not support running regression analysis due to limited available number of sections the Analysis of Variance (ANOVA) was used to compare the means of the special geometric design sections with their reference sections.

1- Desert Roads Friction Regression Analysis

The application of single regression method between friction value, ADT and accidents number using ENTER method of regression showed that there was no statistically significant relationship at the level of 93.4% for ADT and 70.8% for accidents number. On The Other Hand, when applying the same regression analysis method there was statistically significant relationship at the level of 0.0%, between friction values and desert road ages. For more correlation analysis by multiple regression between friction number and affected parameters using stepwise method assuming that friction number will be dependent variable and the other corresponding ADT and road age as dependent variables. Results showed that there was statistically significant relationship at the level of 0.0%.

2- Agriculture Roads Friction Regression Analysis

Difference between desert and agriculture roads as when applying single regression method between friction values, road ADT, road ages and accidents numbers using ENTER method of regression, there was statistically significant relationship between friction values and ADT at the level of 0.0%

For multiple regression analysis between friction number and affected parameters using stepwise method assuming that friction number will be dependent variable and the other corresponding ADT and road age as independent variables. Results showed that there was statistically significant relationship at the level of 0.00% but the results of multiple regression analysis showed strong effect for road age where at the same time the weak effect of ADT for Agriculture Roads type so ADT has been an exclusion variable.

3- For Urban Roads

As same to Agriculture roads when applying single regression method for urban roads between friction values, road ADT, road ages and accidents numbers using ENTER method of regression, there was statistically significant relationship between friction values and ADT at the level of 0.0%.

For multiple regression analysis between friction number and other affected parameters using stepwise method assuming that friction number will be dependent variable and the other corresponding ADT and road age as independent variables for urban roads. Results showed that there was statistically significant relationship at the level of 0.00% but the results of multiple regression analysis showed strong effect for ADT where at the same time the weak effect of road ages and that is against results for Agriculture Roads type so road ages has been an exclusion variable.

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