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Field Evaluation of Longitudinal Skid Resistance on Pavement Surface in Bangalore City - A Case Study

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ABSTRACT

Skid resistance is the force developed when a tyre is prevented from rotating along the pavement surface. Skid resistance is thought of as a pavement property, it is the antonym of slipperiness. Among other road surface conditions, slippery pavement during precipitation is of great concern to road safety authorities. Some statistics indicate that the number of accidents increases by up to two folds during rainy conditions. Loss of skid resistance affects driver's ability to control vehicle. In addition to increasing the stopping distance while braking, lower skid resistance reduces steering controllability since both braking and steering depend on tire-pavement friction. In the present study, longitudinal skid resistance studies were conducted on four different road stretches. The test stretches selected are within the Bangalore city, catering to high volume of traffic. Portable pendulum type skid resistance tester was used to obtain the skid resistance value along the longitudinal direction. Longitudinal skid resistance studies were conducted for critical conditions like dry sand and oil on pavement to obtain the skid resistance values. Tests were conducted during summer and rainy season (March and June respectively) under different pavement surface condition. International Friction Index was used to establish friction value at 60 Km/hr from friction value obtained in wet condition using portable pendulum skid resistance tester.

Keywords:- *International Friction Index, Longitudinal Skid Resistance, Pavement, Portable Pendulum Tester.*

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I. INTRODUCTION

1.1 GENERAL

The properties of the road surface affect the economy, comfort and safety of the motor travel. Tyre wear can be increased by some types of surface and comfort is adversely affected by surfaces that are very much rough or has undulations and tyre makes a loud noise when moving on such surfaces. The nature of the road surface also affects the light reflecting properties of roads and determines their slipperiness in wet weather. If the skid resistance of road surface falls below a desirable minimum, it can bring about an increase in number of accidents that occur when pavement surface is wet.

The friction between the vehicle and pavement surface is one of the important factors determining the safe operating speed and the distance required for stopping the vehicle can negotiate a given horizontal curve and also the maximum rate of acceleration, particularly at the time of starting of the vehicle from rest. The coefficient of friction between the surface of tyre and the pavement is generally called the skid resistance. When the pavement surface has low skid resistance, the wheels easily skid over the pavement surface on brake application and such a condition is called pavement slipperiness[14].

When a vehicle negotiates a horizontal curve, if the centrifugal force is greater than the countering forces (i.e. lateral friction force and component of gravity due to super elevation), lateral skidding takes place. The lateral skid is considered dangerous as the vehicle goes out of control leading to an accident. In spite of many improvements made to road surfaces and their characteristics, the number of accidents in which skidding occurs remains high and for accidents in which skidding on wet roads to increase. Undoubtedly one important reason for this is the improved performance and greater speeds of the modern vehicle[13]. Water, clay, dust, dry sand, oil and grease on the pavement surface are the few factors which cause skidding. These materials on the pavement surface causes reduction in grip between tyre and pavement surface[10].

The effect of macrotexture is more significant in wet condition than in dry condition. The macrotexture provides drainage channels in wet condition and thus allows the water entrapped between tyre and pavement surface to escape thus increasing the available skid resistance values.

The PIARC (Permanent International Association of Road Congresses) international experiment to compare and harmonize texture and skid resistance measurement, conducted in Belgium and Spain in the fall of 1992, developed the International Friction Index (IFI). This index allows for the harmonizing of friction measurements taken with different equipment and/or at different slip speeds to a common calibrated index. ASTM E1960-03 provides for harmonization of friction reporting for devices that use a smooth-tread test tire. The 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. The IFI is based on the assumption that the friction is a function of speed and macro texture and that for a specific pavement surface macrotexture, the value of friction is reduced as the speed increases [8, 16].

1.2 FACTORS DETERMINING SKID RESISTANCE

The following factors determine the skid resistance developed at the pavement interface:

Pavement: Different types of pavements have different skid resistance properties. For instance, surfaces like open texture premix carpet have a better skid resistance property than mastic asphalt.

The texture of the surface is provided by:

1. Macro texture which the determines the large scale roughness provided by the size and shape of the coarse aggregates.
2. The micro texture which refers to the fine scaled roughness caused by the asperities on the individual aggregates.

The macro texture helps in providing a good drainage of surface and also in the deforming the rubber of the tyres, which brings into play the hysteresis component of the friction. The macro texture aids in puncturing the thin film of water on the surface and in mobilising the adhesion component of friction.

1.3 OBJECTIVE OF THE PRESENT STUDY

Among several factors influencing the skid resistance, texture depth and micro texture are important. Texture depth plays a major role in generating sufficient skid resistance for different pavement conditions such as dry, wet, oily and sandy conditions. In the present study an attempt has been made to study the skid resistance under different weather conditions i.e. during summer and winter seasons.

The main objectives of the present study are listed below:

1. To study the effect of texture depth on skid resistance in dry condition.
2. To study the skid resistance on dry and wet condition.
3. To study the effect of dry sand on skid resistance characteristics of the pavement surface.
4. To study the effect of oil/grease on skid resistance characteristics of the pavement surface.

1.4 SCOPE OF THE PRESENT STUDY

After a reconnaissance survey, a total of 4 road sections in Bangalore city were selected based on the parameters such as, before humps/high rise crosswalks, at the junctions, near bus stop, upward and downward gradient. All the test sections selected were straight sections. Tests were conducted using portable pendulum skid resistance tester. Texture depth was measured by the sand-patch method. All the relevant data pertaining to the skid resistance studies were collected using portable pendulum skid resistance tester under dry and wet condition. Studies were conducted for special conditions such as dry sand and oil/grease on pavement by using portable pendulum skid resistance tester. Data collected from portable pendulum skid resistance tester were used to find International Friction Index (IFI).

II. METHODOLOGY

2.1 MEASUREMENT TECHNIQUES

The proposed plan to accomplish the overall objectives of the study is given as under:

1. Selection of the test section, reconnaissance survey is carried out on the selected stretches on the Bangalore city. Based on the parameter such as before the humps, at the intersections, downward and upward gradient and at accident spots.
2. After selecting the test spots by the reconnaissance survey, the test has conducted on macrotexture and microtexture of the pavement. By sand patch method macrotexture of the pavement was calculated and by portable pendulum skid resistance tester microtexture of the pavement was calculated.

3. Road sections, each test spots 20 m in length, will be identified on different categories of roads under heavy traffic conditions.
4. The equipments proposed to be employed under the study include:

- Portable skid resistance tester
- Sand patch method for measurements of mean texture depth

5. Tests were conducted during summer and rainy season (March and June respectively) under different pavement surface condition.
6. Comparative analysis has been conducted on the collected skid resistance value and macrotexture value.
7. IFI was estimated by using wet skid resistance value from portable pendulum skid resistance tester and texture depth from sand patch method.

2.2 SELECTION OF THE TEST SECTION

Review of the literature indicates that the research on skid resistance is mostly directed towards the studies on longitudinal skid resistance. Hence in the present study, it was decided to consider the various parameters affecting the longitudinal skid resistance. Several roads were selected within the Bangalore city are catering to heavy traffic.

TABLE 1: TEXTURE DEPTH VALUES

Sl.No.	**Texture depth**	**Depth in mm**
I	Smooth	Less than 0.3
II	Medium	0.31 To 0.60
III	Rough	more than 0.61

Prior to the selection of test section, a reconnaissance survey was carried out on all the selected road stretches. By considering the parameters such as before humps/ high rise crosswalks, at the junction, downward and upward gradient and near bus stop a test sections were selected. For longitudinal skid resistance studies only straight approach for a length of 0 to 20 meter were selected. It was decided to select the different test sections on the selected roads, considering the following criteria.

- Test sections should be within the city limits catering the needs of heavy traffic.
- Test sections should be selected based on the parameters such as before humps/ high rise crosswalks, at the junction, downward and upward gradient and near bus stop.
- Test sections with different pavement types in the selected roads were selected.
- All test sections are on straight stretches.

2.3 SKID RESISTANCE MEASURING METHODS

1. Texture Depth
2. Skid Resistance Test

2.3.1 Texture Depth

Select the spot on the road to be tested, normally in the nearside wheel track. Ensure that the area to be tested is dry and free from loose materials. A known volume of sand is spread on the road surface; the average macro-texture depth is calculated from the area of the circular patch produced.(The sand particles are those passing a 300 micron sieve and retained on a 150 micron. sieve). Report the sand circle diameter in millimeter to the nearest 5 mm. Textures Producing diameters in excess of 350 mm (which cannot be measured accurately by this procedure) are to be reported as ‘greater than 350 mm’. (Kadiyali L.R). Report the average texture depth to the nearest 0.1 mm. A suggested classification of the surface texture is:

2.3.2 Skid Resistance Test

Procedure

- Select the spot in which the texture depth has been measured.
- Set the apparatus (Figure 3) on the road so that the slider will swing in the direction of traffic flow and level the base screws.

- Raise the swinging arm clear of the road and clamp in the horizontal position. Release the arm and check that the pointer reads zero.
- With the pendulum arm free and hanging vertically, place the spacer, attached to a chain on the base of the column, under the lifting handle setting screw to raise the slider. Lower the head of the tester so that the slider just touches the road surface and clamp in position. Remove the spacer.
- Check the sliding length of the rubber slider over the road surface by gently lowering the pendulum arm until the slider just touches the surface first on one side of the vertical and then on the other. When passing the arm through the vertical, use the lifting handle so that the slider does not touch the road. The sliding length should be between 125 and 127 mm. If not, adjust by raising or lowering the head.
- Place the pendulum arm in the horizontal and clamp in position
- Wet the road surface and slider with water. Bring the pointer to its stop then release the pendulum by pressing the button. Take care to catch the arm on its return swing before it hits the ground.
- Return the arm and pointer to the release position keeping the slider off the road surface by means of the lifting handle. Repeat the test, wetting the surface between swings. Record the mean of five successive readings, provided they do not differ by more than three units. If the range is greater than this, repeat swings until three successive readings are constant; record this value. The skid resistance value (SRV) is the mean of three readings as stated above. Suggested values of skid resistance from Dr.G. Venkata Rao et al. are shown in Table 2.

III. TEST RESULTS

3.1 Effect of Pavement Surface Condition

3.1.1Water on Pavement

Majority of the skid resistance studies were carried out were under wet pavement surface condition since it represents the most common critical condition of the pavement surface leading to slipperiness. The results of these studies on wet pavement surface and the comparison between dry and wet surface conditions were represented in the figure 3.1, 3.2, 3.3 and 3.4.

3.1.2 Dry Sand on Pavement

Skid resistance studies were carried out on selected test stretches by spreading dry uniformly graded sand along a strip of sufficient width along the sliding length of pendulum. Tests were carried out using portable pendulum skid resistance tester using bald specimen. The graphs from 3.1, 3.2, 3.3 and 3.4. indicate the unpredictable nature of skid resistance that is mobilized when a pendulum slides over a pavement with dry sand on the surface. The sand particles could partially roll between the pavement surfaces during sliding.

TABLE 2: SKID RESISTANCE VALUES

Category	Type of site	S.R. values
A	Difficult sites such as 1. Roundabouts 2.Bents with radius less than150m on unrestricted roads 3.Gradients 1 in 20 or steeper of lengths greater than 100m 4.Approaches to traffic lights on unrestricted roads	65
B	Motorways, trunk and class 1 roads and heavily trafficked roads in urban areas (carrying more than 2000 vehicles per day	55
C	All other sites	45

3.1.3 Oil on Pavement

Skid resistance studies were carried out by spreading oil on surface. It was observed that represent most critical condition of the pavement surface leading to slipperiness. These results on oil pavement surface and the comparison between other parameters were represented in the figure 3.1, 3.2, 3.3 and 3.4.

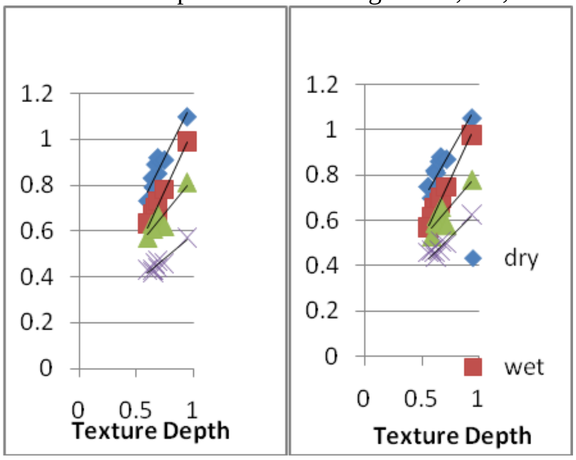

Figure 3.1 Correlation chart of skid resistance versus texture depth at Nayandahalli Jn to Silk Board

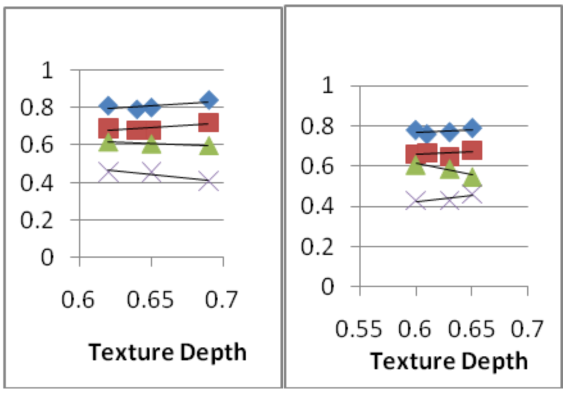

Figure 3.2 Comparison chart of skid resistance versus texture depth at Kengeri Satellite to Dr.AIT College

3.2 ASTM Designation E 1960: Standard Practice for Calculating the International Friction Index (IFI)

This practice covers the calculation of the IFI from a measurement of pavement macro-texture and wet pavement friction. The IFI was developed in the PIARC international experiment to compare and harmonize texture and skid resistance measurements.

This index allows for the harmonizing of friction measurements with different equipment to a common calibrated index.

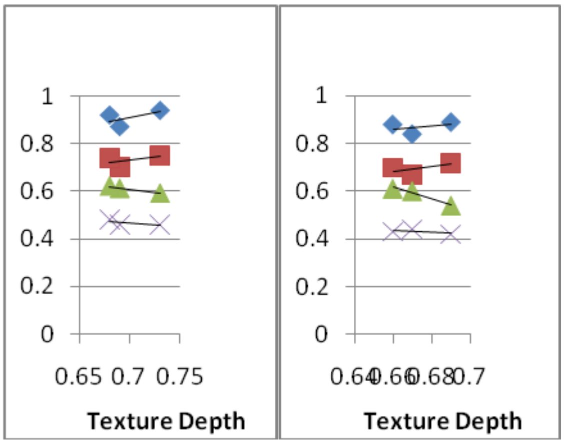

Figure 3.3 Comparison chart of skid resistance versus texture depth at Dr.AIT College to Sumanahally Flyover

The above ASTM practice provides for harmonization of friction reported for devices that use a smooth tread test tire.

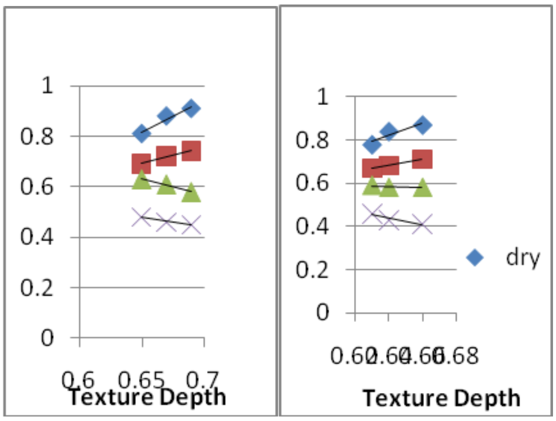

Figure 3.4 Comparison chart of skid resistance versus texture depth at Sumanahally Flyover to Kanteerava studio

The IFI consists of two parameters; the calibrated wet friction at 60 km/hr (F60) and the speed constant of wet pavement friction (Sp). The mean texture depth (MTD) has been shown to be useful in predicting the speed constant (gradient) of wet pavement friction. A linear transformation of the estimated friction at 60 km/hr provides the calibrated F60 value. The estimated friction at 60 km/hr is determined from a measurement made at any speed by using the speed constant and has been graphically tabulated in the below figures.

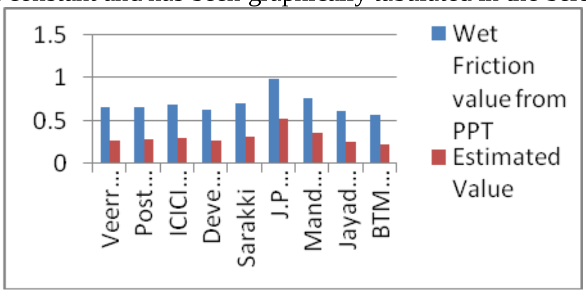

Figure 3.5 comparision chart for wet friction and Etimated Friction value at 60 km/h at Nayandahalli Jn to Silk Board

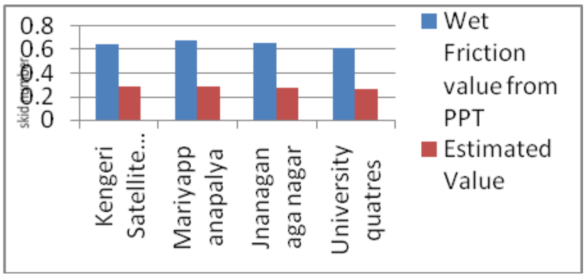

Figure 3.6 comparision chart for wet friction and Etimated Friction value at 60 km/h at Kengeri Satellite to Dr.AIT College

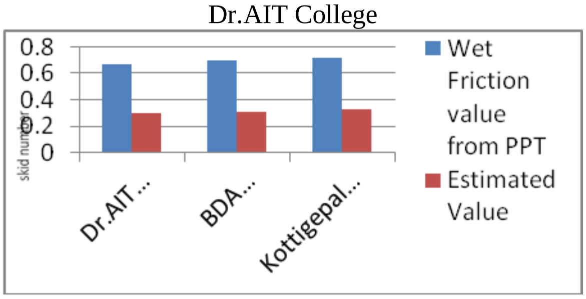

Figure 3.7 comparision chart for wet friction and Etimated Friction value at 60 km/h at Dr.AIT College to Sumanahally Flyover

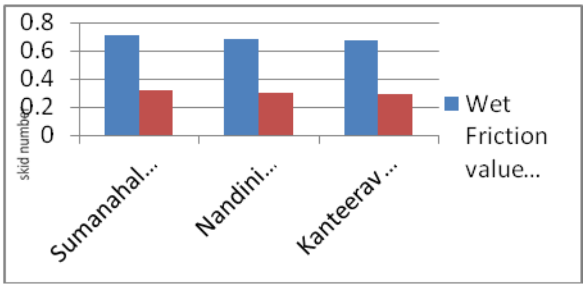

Figure 3.8 comparision chart for wet friction and Etimated Friction value at 60 km/h at Sumanahally Flyover to Kanteerava studio

The significance of the IFI model is that the measurement of friction with a device does not have to be at one particular speed used in the experiment. FRS can be measured at one slip speed S and is always adjusted to 60 km/hr (FR60). The above tables shows that estimated wet friction value at 60 km/hr. Since the test were carried out with a portable pendulum skid resistance tester, the swinging velocity of the pendulum is 10 km/hr. Hence an attempt has been made to estimate the wet friction value at 60 km/hr from wet friction from the portable pendulum skid resistance tester. It is observed from figures 4.8 to 4.12, there is a decrease in skid resistance value with the increase in speed coefficient. Estimated friction value at 60 km/hr is lower than the skid value from pendulum tester. Hence from this, it is known that value of skid resistance in wet condition will decrease with increase in speed coefficient.

IV. RESULTS AND ANALYSIS

4.1 Discussion

1. From the table 3.1-3.4, it was observed that variation of skid resistance under both dry and wet condition. The skid value decreases an average of 0.75 to an average of 0.58 for the wet condition considered in the study.
2. For special condition such as dry sand on pavement skid resistance value decreases when compared with dry conditon from the range an average value of 0.75 to 0.60. Since the sand will act somewhat similar to ball bearing causes rolling action of dry sand on pavement surface. For special condition such as oil on pavement causes most worst condition leading to more slipperiness compared with other parameters. The skid value decreses an average of 0.45-0.50 compared with dry condition. This will cause pavement very smooth resulting slipperiness.
3. On the other hand a pavement surface with smooth or low macrotexture depth the skid resistance values will also be low as the layer of dry sand and oil act as a lubricating material, there by covering the asperities which prevents the generation of sufficient skid resistance.
4. However it is difficult to assess the skid behaviour of vehicles when there is a layer of dry sand and oil on pavement surface. The skid resistance and its variation is likely to depend more on the properties of dry sand and properties of pavement surface and the type and condition of the tyre rather than the macrotexture of the surface alone.
5. It is observed from figures 3.5 to 3.8, there is a decrease in skid resistance value with the increase in speed coefficient. As per the guidelines of IRC, the value of wet friction at stopping sight distance should be 0.35 at a speed of 60 km/hr. The values from the PPT has been used to estimate the friction value at 60 km/hr. It has been observed that all the esimated values are almost nearer to the recommended friction value of 0.35.

V. CONCLUSION

1. For the range of macrotexture considered the skid resistance values shows an increasing trend with increase in texture depth. The skid resistance values at wet condition decreases as compared with decreases in texture depth. The value at dry condition is increases when the texture depth value increases.
2. From the studies observed that, there is an considerable decrease in the value of macrotexture and skid resistance has been found. The skid values and macrotexture decreases in between March and June due to weather condition and heavy traffic.

3. For dry sand on pavement surface there is only a very slight decrease in the skid resistance value from 0.65 to 0.60 has been observed from these study. The rolling action of sand particles between pavement surface and tyre during breaking may cause a reduction in skid resistance which cannot be easily predicted.
4. For oil on pavement surface may lead to worst pavement condition may lead to decrease in the skid resistance value compared with wet and dry sand condition. The occurance of oil on pavement lead to worst slipperiness on the pavement surface.
5. From the study it can be observed that value of skid resistance in all the pavement condition will decreses over a period of time. From the graphs 4.4 to 4.8, it can be observed that variation in skid resistance value among different pavement conditions such as dry, wet, dry sand and oil.
6. Presence of dry sand on dry pavement causes considerable reduction in skid resistance values of pavement surface at all speeds. The reduced skid resistance values due to presence of dry sand on pavement could be equal to "or even lower than mud on wet pavement surface. Rougher pavement surface with good macrotexture does not help much in improving the skid resistance of dry sand on pavement condition. Therefore it is desirable to take suitable steps to keep the pavement surface clean without sand on all roads.
7. A comprehensive analytical study was performed to investigate the applicability of the ASTM IFI computational procedure for standardization of friction measurements from pendulum value. The skid value from portable pendulum tester has been used to estimate the friction value at 60 km/hr. It is observed from the figure 4.9 to 4.12 decrease in value of skid resistance as the speed coefficient increases.

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