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Laboratory Base Pavement Surface Analysis Based on Materials Characterization

Author

Prabhakar Kumar
B-Tech, M-Tech
National Institute of Technology Silchar Assam
Email: *prabhakarkumar51@gmail.com*

Abstract
Skid resistance is a condition parameter that characterizes the contribution that a road surface makes to the level of friction available at the contact patch between a road surface and vehicle tire during acceleration, breaking and cornering manoeuvres. The surface texture and the surface course properties affect the roughness (microtexture, macrotexture and megatexture) which is influenced by traffic, weather and the environment. Some statistics data indicate that the number of accidents increases by up to two folds during rainy conditions. The PSV value of the aggregates used is a significant but not the sole influencing factor. The Polished Stone Value is determined under standard laboratory conditions and indicates to which extent an aggregate is resistant to polishing under the action of traffic. Skid resistance changes over time. Typically it increases in the first two years following construction as the roadway is worn away by traffic and rough aggregate surfaces become exposed, and then decreases over the remaining pavement life as aggregates become more polished.
In the present study, skid resistance and aggregate polishing value were conducted under varying bitumen content and using fillers materials like cement, fly ash. Texture depth is also a direct measure of area of contacts between tire and HMA surface so it also has the direct effect on pavement surface skidding. Portable pendulum type skid resistance tester (ASTM E303 - 93) was used to obtain the skid resistance value and the polishing stone value. This testing is conducted under critical condition like dry and wet surface. The Guide for pavement friction NCHRP document-108, ASTM is referring for the friction mechanism, pavement-tire interaction, and machine recommendation. Main conclusion is the comparison of skid resistance value under several mixing condition.
Keywords: *Skid Resistance, Potable Pendulum Tester, Statistics Accident Data, Polishing Machine, Marshall Test.*

1. INTRODUCTION

Road accident is a significant problem and a major concern of most highway agencies. Statistics from the Ministry of Road Transport and Highway, New Delhi shows that the number of road accident increases almost every year. The total number of road accident in the year of 2013 is 486476 involving fatal condition (RAI-2013). Factors contributed to road accidents can be categorized into three main categories. These are the human, vehicle and road. However, engineers can only addressed the engineering aspects through proper design procedures and audits. There are many well-developed design procedures either for geometry or structural design of the roadways. It is unfair to say that the high accident rate is because of the poor design. Thus, apart from the design aspect, the possible answers may be due to the roadway features, drainage facilities.

In India where 90% transportation takes place over the road transportation network, such cases safety and comfort is the prime importance for any transportation system. There are several factors that contribute to the road accidents. One of the factors is skidding. Skid resistance is the most important characteristic of the road pavement. It is the measure of frictional characteristics of a pavement surface. Skidding will happen when the pavement surface does not provide adequate friction to the tire especially in wet condition. Therefore, it is important to regularly monitor and measure the skid resistance and texture of existing pavement surfaces. Skid resistance is monitored using different types of skid testing device. The most commonly used device is locked wheel trailer and British Pendulum Tester (BPT). Skid tests are subject to many influential factors, which can be classified into three categories: tire-related factors (rubber compound, tread design and condition, inflation pressure, and operating temperature); pavement-related factors (pavement type, pavement surface's microtexture and macrotexture (Corley-Lay, 1998) and surface temperature); and intervening-substance-related factors (quantity of water, presence of loose particulate matter, and oil contaminants). Now here we are discussing about the pavement surface factors and temperature effect over the skidding.

Adhesion – generated by the establishment of chemical bonds between the tire rubber and pavement aggregate.

Hysteresis – caused by deformation of the tire rubber by pavement surface projections.

1.1 Objective:-

1. To examine the effect of aggregate texture on the British pendulum test measurement and to provide a better understanding of the behavior of the test device on coarse-textured surfaces such as grooved and porous surface pavements.
2. To investigate the effect of polishing on skid resistance for several type of mixtures under critical condition and temperature effect on skid resistance value.
3. To gain the objective (2), several tests were conducted for aggregate, bitumen and Marshall test.
4. Finally main objective to investigate the effect of fillers and bitumen content on skid resistance and texture depth and Management approach of skid resistance.

1.2 SCOPE:-

This study is limited to laboratory test measurement and the statistical accident data were taken from the Road Accident in India-2013 Ministry of Road Transport & Highway, New Delhi. To accomplish the predefined objective, skid test data collected over the laboratory based sample. Total five set of HMA sample are prepared based on bitumen content, fillers. Temperature for each test measurement is collected and determines the standard skid resistance value at 20^{o}c. Marshall test has done to know the optimum bitumen content and mould are use to prepared the HMA sample for testing. Also accelerated polishing machine is used to undergo the polishing effect on prepared various aggregate type samples and measuring the polishing value and skid number. For each sample texture analysis should be done to identify the texture properties.

1.3 Literature Review

Studied are conducted by Kamran Muzaffar Khan, Faizan Ali, they investigated the phenomenon of aggregate texture on pavement surface frictional properties. Wheel polishing were simulate by polishing machine, surface texture profile and statics friction coefficient were taken in consideration. This analysis showed that skid resistance value comparison before and after polishing process. It can also be conclude that microtexture can changes the result of effective role of friction over the surfaces, I got one more thing he was found that as the bitumen content increases skid resistance also increases for the same aggregate. (1)

M.R. Ahadi and K. Nasirahmadi, measured the skid resistance using asphalt sample prepared from the gyratory compactor machine. He had consider the dense and open grade sample for the analysis of microtexture properties. I also conclude that effect

of change of percent in bitumen content on BS pendulum number. I found that microtexture analysis as per ASTM E965-96 standard. (2)

Harish H.S, Avinash N.P and M.K. Harikeerthan, has conducted the research to have better understanding the pavement surface phenomenon on the field due to dry-wet seasonal change and polishing of aggregate. He compared the friction value from the wet surface and obtained from the speed data. I can conclude here that the effect of oil, water and dry surface on skidding characteristics of pavement. (3)

Mohammad Ali Khasawneh, Robert Y. Liang, they suggested the better understanding of polishing effect of aggregate by varying the polishing time of aggregate and showed the effect of British Pendulum Number. We also conclude that the effect of temperature on British Pendulum Number. (4)

Yong lee, Tien FWA, Yoo Sang Choo, developed a loading mechanism of British Pendulum Tester using the finite element mess at rubber-pavement interface to understand the phenomenon of pendulum testing. They have used the energy conservation where energy lost by pendulum during the swing is equal to the work done in overcoming the friction between the slider and the surface (Giles et al., 1964). (5), i.e.

For better understanding of skid resistance and accelerated polishing test, Eyad Masad, Arash Rezaei, Arif Chowdhury, and Pat Harris, he developed the predictive model of skid resistance and I conclude that the descriptive analysis of skid resistance and polishing effect. (6)

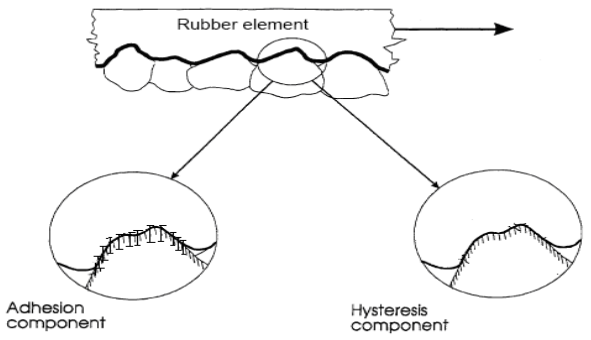

Fig.1 Schematic Plot of Hysteresis and Adhesion (Choubane et al., 2004)

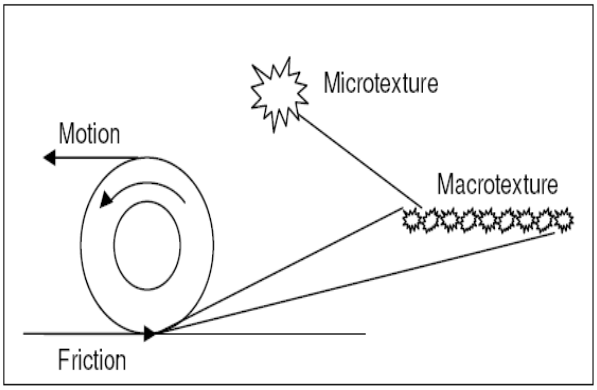

Fig.2 Schematic Plot of Microtexture/Macrotexture (Noyce et al., 2005)

2. BACKGROUND

During 1998, the New Zealand RIMS1 Group initiated a national project called 'Implementation of Predictive Modelling for Road Management' commonly known as the 'NZdTIMS project'. The NZdTIMS project arose from the need to implement a credible system that could be used to predict future long-term maintenance and rehabilitation needs for road networks (Pradhan, Henning and Wilson, 2001). (7)

There are categories of pavement structure exist in modern pavement surface design. Skid resistance is the force developed when a tire that is prevented from rotating slides along the pavement surface (Highway Research Board, 1972). Skid resistance is an important pavement evaluation parameter because:

a) Inadequate skid resistance will lead to higher incidences of skid related accidents.

b) Most agencies have an obligation to provide users with a roadway that is "reasonably" safe.

c) Skid resistance measurements can be used to evaluate various types of materials and construction practices.

Causes of low skid resistance in road surfacing

- Aggregate polishing;
- Bitumen bleeding;
- Aggregate stripping;
- Aggregate embedment causing flushing;
- Water accumulation on the road surface which may be from poor drainage or pavement rutting;
- Surface contamination;
- Pavement markings with low friction; and
- Crack sealants with low friction.

3. MATERIALS

The following section requires to specified the materials selection use to diminish the skidding over the road surface. The materials use for research is in three way likes aggregates use under polishing process, bitumen use in preparation of asphalt samples, use of fillers to check the skidding effect over fillers

3.1 Aggregate

Aggregate is a collective term for the mineral materials such as sand, gravel, and crushed stone that are used with a binding medium (such as water, bitumen, Portland cement, lime, etc.) to form compound materials (such as bituminous concrete and Portland cement concrete). By volume, aggregate generally accounts for 92 to 96 percent of Bituminous concrete and about 70 to 80 percent of Portland cement concrete.

Fig. 3 Aggregate sample

3.2 Bitumen

Bitumen is use as binder material to bind up the aggregate together and provide smooth surface and at the top tack coat is given to increase the skid resistance of the surface. Bitumen has wide effect over the skid resistance value; excess of bitumen will decrease the skid value.

3.3 Emery grit

Commonly use to polish the aggregate sample, these are two types like corn emery grit and flour emery grit.

Fig. 4 emery grit

5. METHODOLOGY

The test was conducted in three parts:

a) Samples of stone are subjected to a polishing action in an accelerating polishing machine.
b) The state of polish reached by each sample is measured by means of a friction test and expressed as laboratory determined PSV.
c) Marshall Samples are prepared at various bitumen content and different gradations and they are tested for skid resistance.
d) Use of fillers materials and check the effect on skid value.

5.1Performing Test

4.1.1 Aggregate polishing machine

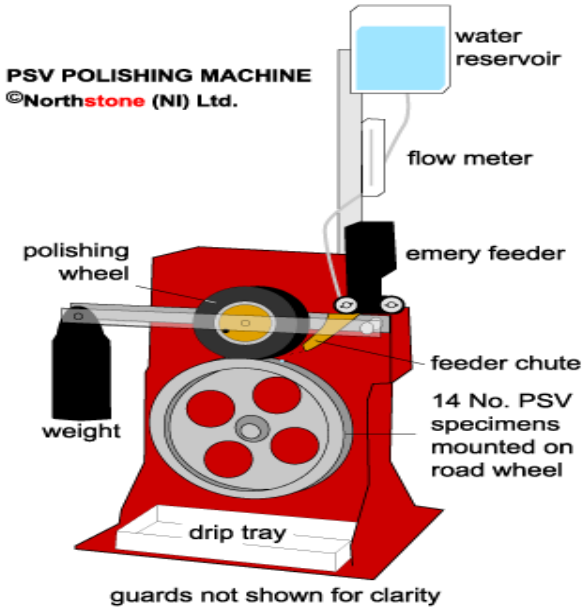

Fig.5 Accelerated polishing Machine

This gives a measure of the resistance of aggregate to the polishing action of vehicles tires under condition similar to those occurring on a road surface. 14 samples are mounted with road wheel and subjected to tire polishing; the polishing time can be at 0 hours, 3 hours and 6 hours. The PSV test is carried out in two stages - accelerated polishing of test specimens followed by measurement *of* their state *of* polish by a friction test.

4.1.2 Skid resistance measurement

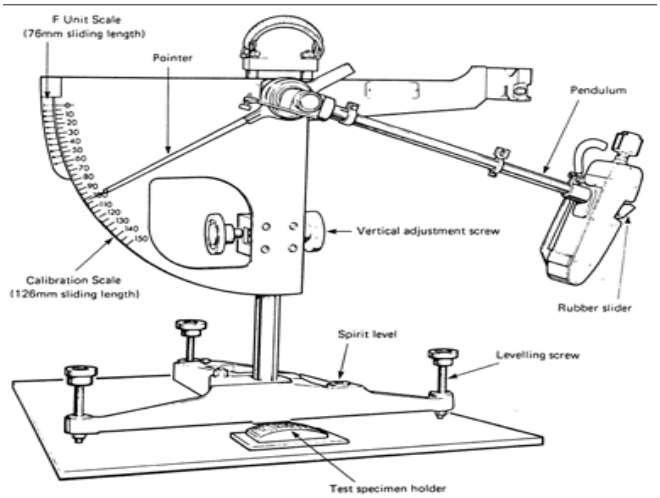

Fig.6 Pendulum Skid Resistance Tester (ASTM-E 303)

The machine is based on the static approach. It has a pendulum consisting of a tubular arm rotating about a spindle attached to a vertical pillar. At the end of the tubular arm is a head of constant mass with a spring loaded rubber slider. The pendulum is released from a horizontal position so that it strikes the sample of aggregate with a constant velocity. The distance the head travels after striking the sample is determined by the friction of the surface of the sample and aggregate polishing value, which has undergone preparation by the Accelerated Polishing Machine.

4.1.3 Texture depth measurement

Macro texture play dominant role in availability of friction on wet surfaces at high speed. In this method a well-known volume of sand (passing 300 micron sieve & retained on a 150 micron sieve) is spread over the test surface.

This procedure was developed by TRRL and was one of the first methods used to calculate surface texture (Hosking and Woodford, 1976). This involves spreading of a known volume of fine, dry sand over a circular area until flush with aggregates tips of the pavement surface (Figure 2.11). The area of this patch is determined from an average of several diameter measured and the texture depth can be calculated by dividing the known sand volume to the patch area.

Average texture depth (mm)	Texture classification
<0.25	Fine
0.25-0.50	Medium
>0.50	Open

Fig.7 Sand-patch method of measuring texture depth
Texture depth = (Volume of sand / Area of sand)

4.1.4 Marshall Test

This test here is require for determining optimum bitumen content to use in preparing asphalt sample and in variation of bitumen along with this sample is also required for skid resistance determination.

Fig.8 Marshall Testing Machine

4.2 Preparation of sample

Fourteen sample are prepare to be clamp on aggregate polishing machine to go under polishing test

Fig.9 Aggregates placement and preparation in Mould

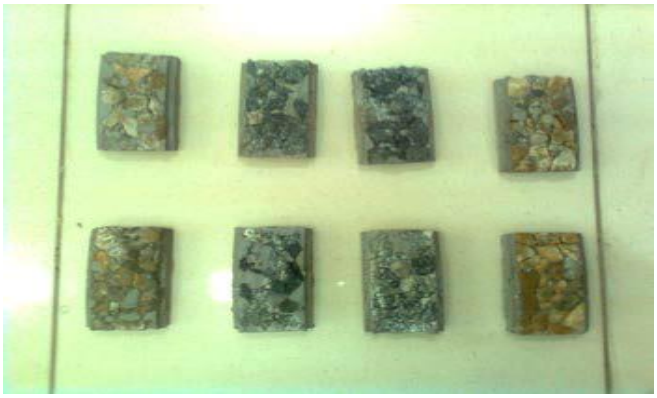

Fig.10 Prepare samples

A. Construction of Marshall Sample

In this research, Marshall Samples were constructed according to the ASTM D1559 standard [12], and were compacted with 75 strokes of the Marshall Hammer on two sides of the samples as specified for heavy traffic conditions. The Marshall Stability parameters, the density of the asphalt mixture and percentage of air voids in the asphalt mixture for compacted samples were distinguished for determination of the optimized percentage of bitumen, flow parameters and percentage of Voids in Mineral Aggregate (VMA) according to the standard of the Iran Road Pavement Code.

Fig. 11 Marshall test samples

B. Determination of Percentage of Optimized Bitumen:-

The main purpose of determining the most suitable percentage of bitumen is that it will allow preparation of asphalt with the best characteristics for improving road safety.

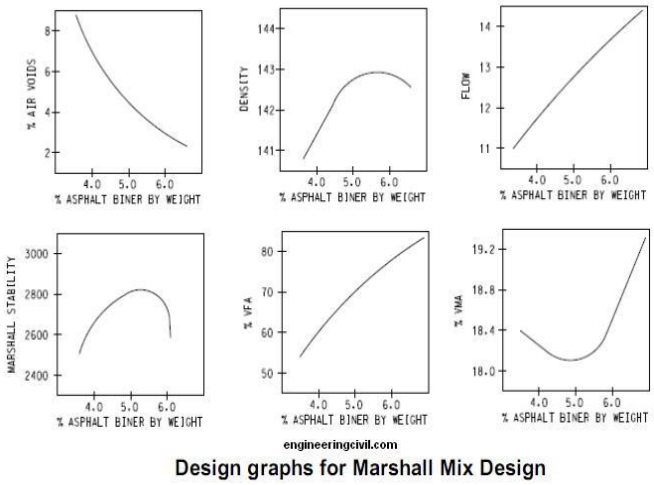

Fig.12 OBC Determination

c) Addition of fillers

As modern commerce depends on reliable and cost-effective methods for delivering products from suppliers to users, the availability of durable and reliable highways, roads and other support surfaces for vehicles is vital for sustaining a modern economy. To provide better support surfaces, highways, roads, and sidewalks are commonly paved with a layer or mat of asphaltic concrete that is laid over the surface of the sub-base. Asphalt is preferred over cement to pour roads because it is less expensive and very durable. Asphalts are essentially mixtures of bitumen, as binder, with aggregate, in particular filler, sand and stones.

Fillers are the finest materials that are generally used to fill voids and decrease the texture depth. Here we selected the two fillers like cement and fly ash. These are two fillers to use as fillers and also act as binders to increase the strength of HMA surface. Also because of low cost materials for fly ash this is also reduced the cost of construction and this is added during the Marshall Sample preparation.

A) As per Yoder and Witczak-1975

Table 1: Suggested minimum values of Skid Resistance for PST (Yoder and Witczak, 1975)

category	Types of sites	Min skid resistance (wet surface)
A	Difficult sites such as: • Roundabouts • Bends with radius less than 150m on unrestricted roads • Gradients 1 in 20 or steeper of lengths greater than 100m • 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 veh per day)	55
C	All other sites	45

B) As per (IRC: SP: 83 – 2008)

1) Values between 45 to 55 indicates satisfactory surface in only favorable weather and vehicle condition.

2) Value of 55 or greater indicates generally acceptable skid resistance in all conditions.

3) Value of 65 and above indicates good to excellent skid resistance in all conditions.

6. Performance Analysis

A) Skid resistance value Vs Temperature

Most studies agree that temperature of four elements interacting on tire pavement interface (air, water, tire, and pavement) affect skid resistance. Ibrahim reported that skid resistance also affected by temperature; it decreases with increase in temperature. Several investigations have studied these relationships likes Runkle and mahone (1980) found that water temperature and pavement temperature were highly correlated. Hill and Henry (1982) studied the relationship between air temperature, pavement temperature and tire temperature.

$$T_t = 8.54 + 0.810\ T_a\ (R^2 = 0.83)$$
$$T_t = 6.78 + 0.558\ T_p\ (R^2 = 0.76)$$
$$T_a = 0.87 + 0.573\ T_p\ (R^2 = 0.80)$$

These are the relationships obtained by these researchers.

Where T_t = Tire Temperature

T_p= Pavement Temperature

T_a= Air Temperature

B) Skid resistance value affected by Temperature

For each testing temperature should be noted and a formula used for temperature correction applied to the skid value.

$$SRV_{20} = SRV/\{1-[0.00525(t-20)]\}$$

Where:

SRV_{20} = mean skid resistance value corrected to 20° C

SRV = mean skid resistance value

t = temperature of wetted pavement surface in °C.

C) Skid resistance management (State of Queensland 2006)

Equipment

QDMR mostly uses a Norsemeter ROAR (Road Analyser and Recorder) device for measuring skid resistance. QDMR also uses the Portable Pendulum Tester (also known as the British Pendulum Tester) for project level work, such as: testing small areas, monitoring locations with very high friction demand, for acceptance of new surfacing, and in preparing responses to enquiries, requests for action, and complaints.

Measurement Regimes

QDMR has adopted two regimes each for measurement of skid resistance and surface texture (macrotexture) – one for network level monitoring, and one for project level assessments, The QDMR network level regime for skid resistance is broadly consistent with the proactive approach described in Austroads 2005, and the QDMR project level

regime is broadly consistent with a reactive approach. This management needs a balance between:-

• The cost of skid resistance testing;

• The need to be aware of and to monitor locations with low skid resistance; and

• The need for quality data on skid resistance to establish relationships between skid resistance and the incidence and severity of crashes and to establish trends in skid resistance over time.

Analysis

There are four levels at which QDMR will perform analysis of skid resistance data on the SCR network. These analyses are inter-related, and are:

1. Strategic research (strategic level)
2. State-wide planning (network level)
3. Development of the RIP (program level)
4. Detailed site analysis (project level)

CONCLUSIONS

Further laboratory testing should be continue for various types of aggregate and bitumen types including penetration test, ductility test, specific gravity test, impact test and so on. This test gives the specification choosing the materials. Further polishing test, texture classification and skid testing should be continue to classified the materials use for better pavement surface serviceability under various climate region and traffic speed data.

The high texture depth corresponds to the skid value between tire and pavement surface. The texture of pavement surface and its ability to resist the polishing effect of traffic is of prime importance in providing skid resistance. Also as asphalt content increases above the optimum asphalt content value, decreases the skid resistance As the aggregate polishing value increases, skid resistance value also increases. In other words high PSV, gives good resistance to skidding. Finally we also would see the effect of use of fillers over the skid resistance value and texture depth variations. Also I would conclude that skid resistance value increases for two years and decreases over the remaining life after the road construction.

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