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Evaluating Pavement Skid Resistance: Ensuring Safety and Performance

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Abstract:- Skid resistance is a fundamental characteristic of road pavements, directly influencing vehicle control and traffic safety, especially under wet and slippery conditions. Skid resistance is not just about enhancing road surface quality but also about ensuring public safety, economic efficiency, regulatory compliance, and overall user satisfaction within transportation systems. The primary objective of this study is to compare the required and measured skid resistance values of flexible pavement on curved sections of feeder roads originating from Suryabinayak in Bhaktapur district, Nepal. This road is newly developed road with sharp curves which is prone to accidents. This comprehensive study aims with ensuring the safety of drivers and pedestrians by providing necessary recommendations regarding Skid Resistance, Super elevation, Speed of vehicles and Radius of curve. The research encompasses an extensive review of current methodologies for assessing skid resistance, including the British Pendulum Tester. The test results showed that the current pavement design practice of considering skid resistance is unsatisfactory in the case of wet muddy surface.

Keywords:- *"Skid Resistance", "Traffic Safety", "Flexible Pavement", "Super Elevation", "Pedestrians".*

I. INTRODUCTION

Skid resistance of roads is an essential figure in guaranteeing secure and productive transportation. It alludes to the capacity of a street surface to give adequate grinding between vehicle tires and the asphalt, especially vital amid braking and cornering maneuvers. This frictional interaction is fundamental for avoiding sliding, particularly in unfavorable climate conditions like rain, snow, or ice, where misfortune of footing can lead to accidents. Measurement of skid resistance is regularly conducted utilizing specialized gadgets such as the British Pendulum Tester (BPT) or Dynamic Friction Tester (DFT). These instruments evaluate the frictional resistance between a standardized test tire and the street surface beneath controlled conditions, yielding numerical values that demonstrate the pavement's skid resistance characteristics.

Several components impact skid resistance, with surface playing a noteworthy part. Micro-texture, including small-scale inconsistencies on the asphalt surface, improves hold, especially in damp conditions, by expanding the surface zone in contact with the tire. Macro-texture, which comprises of bigger abnormalities, makes a difference in depleting water from the street surface, decreasing the chance of hydroplaning. Material properties moreover influence slip resistance. The sort and measure of total utilized in black-top blends or the surface characteristics of concrete asphalts can affect contact levels. Moreover, natural variables such as temperature varieties, dampness substance, and the nearness of contaminants like oil or clean can impact slide resistance over time. Maintaining satisfactory slide resistance is pivotal for street security and life span. Normal upkeep hones, counting cleaning, surface medicines, and intermittent re-emerging, offer assistance protect and upgrade slip resistance levels. Adherence to national and worldwide benchmarks for slip resistance guarantees that streets meet security necessities and give dependable transportation infrastructure. In conclusion, optimizing slip resistance through legitimate plan, development, and support hones is basic for minimizing mishaps, moving forward vehicle control, and improving generally activity security on roadways. Skid resistance is of paramount importance for several reasons:

- *Safety*: Skid resistance is crucial for preventing accidents. Adequate friction between the tires and the road surface ensures that vehicles can brake effectively and maintain control, especially during emergency maneuvers.
- *Accident Prevention*: Roads with poor skid resistance increase the risk of skidding, especially during cornering or sudden braking. This can lead to collisions, rollovers, and other serious accidents. High skid resistance helps to minimize these risks by providing better traction.
- *Economic Impact*: Accidents resulting from inadequate skid resistance lead to significant economic costs, including vehicle damage, medical expenses, insurance claims, and loss of productivity. Ensuring roads have proper skid resistance can reduce these costs by lowering accident rates.
- *User Confidence*: Roads with good skid resistance provide a safer driving experience, boosting driver confidence. This is particularly important for high-speed roads and curves, where maintaining control is critical.
- *Maintenance Efficiency*: Regular monitoring and maintenance of skid resistance can prevent severe degradation of road surfaces. Timely interventions can prolong the life of the pavement, reducing the need for costly repairs and extensive roadwork.
- *Environmental Considerations*: Maintaining skid resistance can also have environmental benefits. By reducing the likelihood of accidents, it decreases the need for emergency responses and associated environmental

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impacts such as fuel spills and emissions from traffic congestion.

The feeder road originating from Suryabinayak is increasingly preferred as an alternative route by locals. With heavy traffic congestion and ongoing construction on the main highway leading to significant delays and pollution, this feeder road offers a more efficient and cleaner option. As more people recognize and use this route, ensuring that the road remains smooth and safe is of utmost importance. A particular concern is a sudden narrow curve along this road, which has become a major hazard, causing frequent accidents. Addressing this issue by ensuring that the curve meets safety standards is crucial for the well-being of those who travel this route.

Fig 1 Plan View of Site

II. LITERATURE REVIEW

Road crash investigations and historical statistical data by researchers worldwide have shown that the number of wet-weather crashes increases as pavement skid resistance decreases (Cairney, 1997; Ivan et al., 2010; Lindenmann, 2006; Merritt et al., 2015; Rizenbergs et al., 1977). Determining and predicting pavement skid resistance is recognized as a crucial requirement in friction management of highway networks to reduce wet-weather crash risks (Crisman and Roberti, 2012; Merritt et al., 2015).

Significant insights into the mechanisms of vehicle skidding and hydroplaning have been gained through experimental measurements involving different tires, water film thicknesses, and pavement types. Research has highlighted the effects of tire properties, pavement surface characteristics, and water-film thickness. By the early 1970s, key characteristics of pavement skid resistance behavior under the impacts of tire, pavement, and surface runoff were noted (Giles and Sabey, 1959; Horne and Joyner, 1965; Horne and Tanner, 1969; Meyer and Kummer, 1969; Moore and Geyer, 1972, 1974; Sabey, 1966).

Generally, skid resistance is higher on dry roads due to maximum adhesion and hysteresis. On wet roads, adhesion drops significantly, reducing overall skid resistance (Siriphun et al., 2016; Vaitkus et al., 2017a). Ensuring adequate skid resistance is essential for safe road operation, which depends on the ability of asphalt wearing course aggregates to resist frictional forces. Continuous wheel impact over a smooth road surface decreases skid resistance and the angularity of the aggregates, making the road surface slippery. This slippery condition is especially dangerous in wet or icy conditions when side-friction between the wheel and the road surface is minimized (Noyce et al., 2005; Räisänen et al., 2003; Santucci & Engineer, 2013; Vaiana et al., 2012; Wasilewska et al., 2019).

III. METHODOLOGY

Skid resistance is influenced by many various factors therefore many skid measurement devices was developed and currently are being used in practice. Some measurement devices are similar due to measurement principle, but the measurement method is different. Skid resistance measurement principles are divided in 3 groups (Descornet et al., 2006; kokkalis et al., 1998):

- Longitudinal friction measurement principle
- Transverse friction measurement principle
- Stationary of slow-moving friction measurement principle

Traverse friction measurement principle is applied when the vehicle is travelling in a horizontal curve and the vehicle wheels are turned. Angle between vehicle and turned wheel direction is called slip angle (δ). Slip angle induce friction between tyre and road, which in turn generates a centripetal force opposing the centrifugal force exerted on the vehicle in the bend, allowing the vehicle to follow round the curve. When braking force increases the wheel starts to slip over the road surface.

➢ *Evaluation of Curve Geometry*

First of all, radius of curve, curve length, entry/exit tangents and superelevation were evaluated with the help of Odometer and tape.

➢ *Analysing Traffic Condition*

Traffic volume and their spot speed along with vehicle type were analysed using manual method. Traffic volume count was performed for an hour in the mid-morning during peak hour and peak count for 15 minutes was determined. With the help of it, the volume count for whole day was determined using expansion factor (NYS CTAP Centre - Cornell Local Roads Program) given as:

Daily Traffic = C*F

C = 15-minute count

F = multiplier based upon area

- 36 in urban area
- 33 in suburban area
- 27 in rural area

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The area of this paper is treated as Suburban. The count was performed for 7 days. And the average speed of vehicles was determined.

- *Calculation of Coefficient of Friction of Pavement*

The theoretical coefficient of friction is determined using the formula,

$f + e = v^2/127R$

Where,

f = coefficient of Friction

e = Super elevation

v = speed of vehicle in km/hr

R = Radius of curve in m

- *Calculation of Skid Resistance*

The actual coefficient of friction of the road section was measured with the help of Pendulum Skid Tester. The representative section of the road surface to be tested was chosen and the area was ensured to be flat and free from debris, oil, water, or any contaminants that could had affected the test results. The calibration device was placed on the road surface, and it was checked to meet the required standards.

The pendulum skid tester was set up, levelled, calibrated near the starting point of the road section to be tested. The pendulum arm was adjusted to its initial position and made secure. A rubber slider was attached to the bottom of the pendulum arm. With the rubber slider in contact with the road surface, the pendulum arm was released from its initial position. The pendulum slid freely along the road surface, simulating the motion of a vehicle tire. The pendulum was released and the slider made contact with the surface and created a skid mark. The adjustment of tester was made in such a way that the skid distance marked by the rubber slider was equal to 5 inch. Then the pendulum was adjusted to the initial position and was released from its position. The Deflection reading indicated by the drag pointer was noted down. The test was repeated at five times for dry condition of road and the same portion of road was wetted and same no of reading was observe.

IV. RESULT AND DISCUSSION

Table 1 Volume Count and their Average Speed in 7 Days

Days	**Volume Count (Nos.)**		**Average Speed (km/hr)**	
	Motorbikes	**Cars/Vans**	**Motorbikes**	**Cars/Vans**
Sunday	5709	1848	24	18
Monday	5181	1584	25	20
Tuesday	4257	1617	20	17
Wednesday	5115	1782	20	18
Thursday	5841	1419	24	21
Friday	4884	1287	27	22
Saturday	6039	2112	29	26
			24.14	20.29

- *General Observations*

Width of road = 3 m

Length of Curve = 10 m

Length of Chord = 9.1 m

Radius of Curve (R) = 13.34 m

Superelevation (e) = 0.07

Table 2 Coefficient of Friction according to their Speed

Vehicle Type	**Speed (km/hr)**		**Coefficient of Friction**	
	Average	**Maximum**	**Average**	**Maximum**
Motorbikes	24.14	29	0.274	0.426
Cars/Vans	20.29	26	0.173	0.329

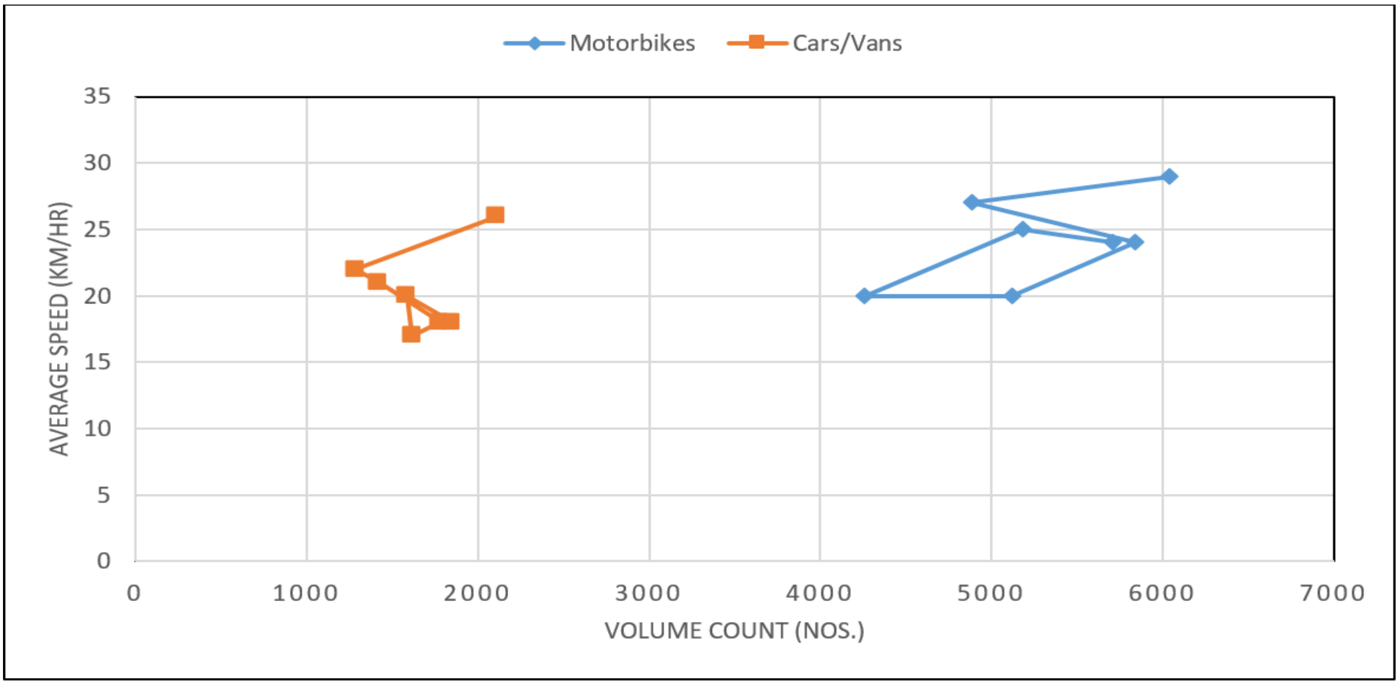

Fig 2 Volume Count vs Average Speed

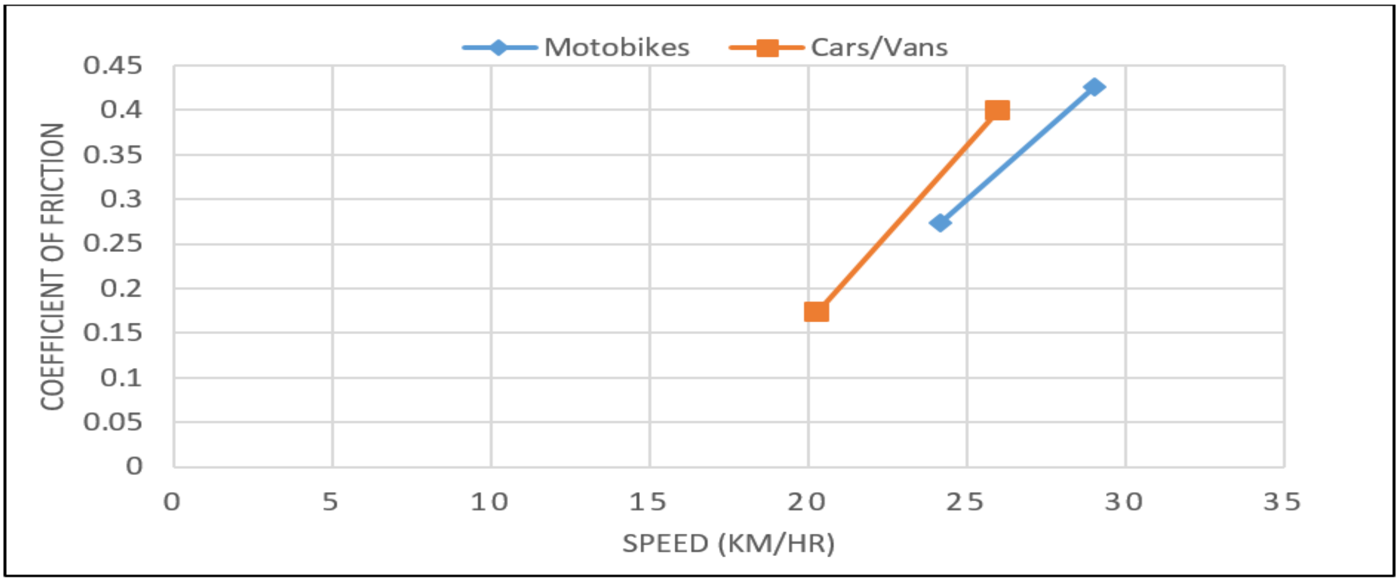

Fig 3 Average Speed vs Coefficient of Friction Required

Fig 4 Curve Section

Fig 5 Pendulum Skid Tester

Table 3 Skid Resistance Calculation for Clean Surface Initial reading of pendulum arm deflection when it swing free in air =44

State of flexible pavement	Maximum Deflection of pendulum arm when the skid mark is 5 inch	Average of maximum deflection	SRV=((Average of maximum deflection-Initial reading of pendulum arm deflection when free)/100)
Dry	100	98.2	0.542
	98		
	95		
	97		
	101		
Wet	94	95.2	0.512
	97		
	96		
	95		
	94		

Table 4 Skid Resistance Calculation for Muddy surface Initial reading of pendulum arm deflection when it swing free in air =44

State of flexible pavement	Maximum Deflection of pendulum arm when the skid mark is 5 inch	Average of maximum deflection	SRV=((Average of maximum deflection-Initial reading of pendulum arm deflection when free)/100)
Dry	82	78.4	0.344
	78		
	76		
	81		
	75		
Wet	60	65.2	0.212
	68		
	63		
	70		
	65		

- The skid resistance of the pavement is higher than the coefficient of friction when the surface is clean and dry. Similarly, there are no issues with skid resistance when the surface is wet.
- On a muddy surface, skid resistance is significantly lower than the coefficient of friction. Specifically, the skid resistance value decreases by 36.5% when the mud is dry and by 58.6% when the mud is wet.
- There is a 5.5% decrease in SRV when the clean surface is wet. For muddy surfaces, the SRV decreases by 38.4% when wet.
- Figure 1 illustrates a significant increase in traffic volume and speed on weekends, particularly on Saturdays.
- Figure 2 depicts the required coefficient of friction as speed increases.

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V. CONCLUSION

The findings indicated that the curve section is safe for driving when the surface is clean. However, the presence of mud significantly increased the risk of skidding at the average daily speed. The entire road has not been paved, with both ends of the curve section covered in mud. During the rainy season, vehicles track mud onto the paved section, increasing the likelihood of skidding and accidents. To mitigate this risk, speed limits of 20 km/hr should be posted at both ends of the curve section. Additionally, to safely maintain a speed of 25 km/hr, a superelevation of 16% should be implemented.

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