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Study on Prediction of Surface Texture Characteristics by Frictional Noise of the Pavement

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Abstract:
Background*: There is a strong correlation between road friction and accident risk. According to the world health organization, road traffic accident results in the death of over 1.2 million people Road friction, its measurement and relation to traffic accident risks, is a problem that has engaged thousands of road engineers throughout the world, hence there is a need to evaluate the surface texture characteristics in easiest and simplest way on the go. The term tyres/road frictional noise denotes the noise emitted from a rolling tyres as a result of the interaction between the tyres and the road surface.*
Materials and Methods*: The frictional noise is measured with the help of test vehicle. The test vehicle speed was set to 50kmph and the noise is measured for a length of 100 meter. The locations were selected in such a way that there is minimum traffic on the road, so that external sound while recording is minimized. The Gross Vehicle Weight (GVW) of testing vehicle is 16200kg. During measurements tire pressure for rear tires were kept at 110psi. The surface texture characteristics of pavement are measured with the help of sand patch test, The Sand Patch test was conducted at the road location where frictional noise measurement was carried out. Total 3 tests were conducted for each 100 meter road section. The test results are as follows. For each test the diameter of sand patch was measured 3 times i.e. D1, D2, D3 and average of them (D) is taken for further analysis part. The results were taken up to three digits of accuracy. Sand was taken in a container having 65 mm diameter and 90 mm depth, and hence volume of sand used during each test was 298647.65 mm^3. The results of the frictional noise measurement and sand patch test are then correlated and regression analysis is then carried out. The regression model is then validated by comparing Regression model estimated surface texture depth and observed field texture depth.*
Results*: Correlation Coefficient "r" which is a measure of linear association is 0.948, and hence there is strong relationship between variables.The regression line expression is; Texture depth (mm) = -11.39934+0.17789* frictional noise measurement (dB).In the graph ofRegression model estimated surface texture depth and observed field texture depth, it is observed that all data points are close to the 45 degree line, indicating a good match between field texture depth and estimated texture depth.*
Conclusion:*For 1dB increase in average frictional noise level, average texture depth of pavement (mm) increases by 0.17789 mm.89.9% of the variation in the frictional noise isexplained by the texture depth (mm) of the pavement.*
Keywords*: Skid Resistance; Pavement surface roughness; Frictional Noise; Sand Patch Test; Sound Meter; Regression; Correlation.*

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I. Introduction

Many different types of equipment have been developed and used to measure pavement characteristics, and their differences can be significant.There are number of instruments and tests are available worldwide to evaluate the skid resistance characteristics. For friction testing alone, there are several commercially produced devices that can operate at fixed or variable slip, at speeds up to 100 mi/hr (161 km/hr), and under variable test tire conditions, such as load on the vehicle, size of the vehicle, tyre tread design, and tyre inflation pressure. Pavement surface texture, which includes micro-texture, macro-texture and mega-texture, can be measured in a variety of ways, including rubber sliding contact devices, volumetric techniques, and water drainage rate techniques, but amongst these tests sand patch test is cost effective and convenient to conduct without disturbing the traffic on a road.

II. Methodology

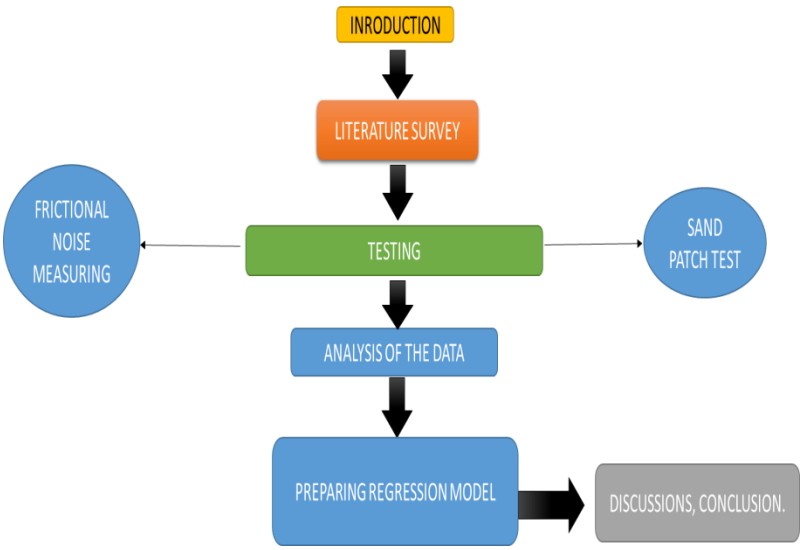

Fig. 1: Flow chart of methodology

The regression model is prepared with the data collected by conducting sand patch test and pavement friction noise data sets.Noise measurement is made with the help of National Institute for Occupational Safety and Health (NIOSH) sound level meter mobile application. Average texture depth is determined by conducting sand patch test.

2.1 Study Location: Frictional noise measurement and sand patch test are conducted to collect field data at various locations of Jamner City, Dist. Jalgaon (MH). All the pavements on which testing is carried out were flexible pavements.

2.2 Objectives of the study:

1. To study various skid resistance characteristics measurement methods.
2. To measure the surface texture depth with the help of sand patch method.
3. To measure the frictional noise of the pavement surface.
4. To formulate the model based on correlation between surface texture depth and frictional noise.
5. To validate the formulated model.
6. To predict the surface texture characteristics of the pavement by frictional noise; with the help of formulated model.

2.3 Frictional Noise Measurement: Noise measurement is made with the help of National Institute for Occupational Safety and Health (NIOSH) sound level meter mobile application, which is developed in collaboration by EA LAB, Inc. under MOU agreement between NIOSH and EA LAB. Some study shows that certain sound measurement apps for Apple.inc smartphones may be considered accurate and reliable for use in certain noise measurements.TATA 1613 truck which is fitted with fire fighting body is used as a test vehicle for sound level measurement.The truck is having dual wheel assembly.

Fig. 2: TATA 1613 fire fighting truck

Fig.3: Picture showing dual wheel assembly

2.4 Sand Patch Test:

Sand patch test is also known as sand circle method. This test procedure determines the average texture depth of a paved surface using sand, to give the volume of voids. The test procedure is as follows

1) Ensure that the area to be tested is dry and free from detritus. Brush any fine material from the surface.

2) Fill the cylinder with sand and tap lightly until the sand in the cylinder completely becomes compact, and carefully strike off the surface with the straight edge or metal scale.

3) Pour out the sand in a conical heap in the centre of the area to be tested.

4) Using the straight-edge,spread the sand into a circular patch so that the surface depressions are filled to the level of the tops of the stones. The tops of the larger stones should only just be visible through the sand layer.

5) Measure the diameter of the patch twice, to be more precise diameter should be measure thrice;average the measurements to give D, the sand circle diameter.The average texture depth may be calculated by the following formula.

Texture Depth (mm) = $4V/\pi D^2$

WhereD = average diameter of sand patch circle (mm)

V = volume of sand used (mm^3)

Fig.4: surface unevenness **Fig.5**: Sand Patch Dia. Measurement **Fig.6**: patchillustrating D_1,D_2,D_3

III. Data Collection and Analysis

3.1 Frictional Noise Measurement The data was collected at various locations of Jamner city. The test vehicle speed was set to 50kmph and the noise is measured for a length of 100 meter. The locations were selected in such a way that there is minimum traffic on the road, so that external sound while recording is minimised. The Gross Vehicle Weight (GVW) of testing vehicle is 16200kg. During measurements tire pressure for rear tires were kept at 110psi.

Table no 1: Frictional Noise Measurement on various road surfaces.

Sr. no	Road Name	Road width (M)	Maximum level (dB)	Minimum Level (dB)	Average level (dB)
1	Samrod Road	6	68	62	65
2	Sonbardi Road	6	69	65	67
3	Waki Road	6	70	66	68
4	Hiverkheda Road	9	73	67	70
5	Bhusawal Road	12	75	66	70.5
6	Khadgaon Road	6	76	66	71
7	Fattepur Road	9	77	68	72.5
8	Jalgaon Road	12	78	68	73
9	Ganpati Nagar Main Road	9	79	69	74
10	Old Bodwad road (GovindMaharajChowk to old Bodwad Naka)	6	81	70	75.5
11	Lahasar Road	6	83	71	77
12	Koduli Road	6	85	74	79.5
13	MIDC Road	9	85	79	82

3.2 Sand Patch Test The Sand Patch test was conducted at the road location where frictional noise measurement was carried out. Total 3 tests were conducted for each 100 meter road section. The test results are as follows. For each test the diameter of sand patch was measured 3 times i.e. D1, D2, D3 and average of them (D) is taken for further analysis part. The results were taken up to three digits of accuracy. Sand was taken in a container having 65 mm diameter and 90 mm depth, and hence volume of sand used during eachtest was 298647.65 mm^3.

Table no 2: Average texture depth calculations

Sr. no	Road Name	Road width (M)	D in mm	Texture Depth(mm) = $4V/\pi D^2$
1	Samrod Road	6	740	0.694
2	Sonbardi Road	6	706	0.763
3	Waki Road	6	677	0.829
4	Hiverkheda Road	9	642	0.922
5	Bhusawal Road	12	630	0.958
6	Khadgaon Road	6	615	1.005
7	Fattepur Road	9	580	1.130
8	Jalgaon Road	12	537	1.318
9	Ganpati Nagar Main Road	9	494	1.558
10	Old Bodwad road (GovindMaharajChowk to old Bodwad Naka)	6	449	1.886
11	Lahasar Road	6	409	2.273
12	Koduli Road	6	364	2.869
13	MIDC Road	9	320	3.713

Table no 3: Average Texture depth (mm) and average frictional noise level (dB) at various locations.

Sr. no	Road Name	Texture Depth(mm) = 4V/πD2	Average level (dB)
1	Samrod Road	0.694	65
2	Sonbardi Road	0.763	67
3	Waki Road	0.829	68
4	Hiverkheda Road	0.922	70
5	Bhusawal Road	0.958	70.5
6	Khadgaon Road	1.005	71
7	Fattepur Road	1.13	72.5
8	Jalgaon Road	1.318	73
9	Ganpati Nagar Main Road	1.558	74
10	Old Bodwad road (GovindMaharajChowk to old Bodwad Naka)	1.886	75.5
11	Lahasar Road	2.273	77
12	Koduli Road	2.869	79.5
13	MIDC Road	3.713	82

3.3 Correlation analysis Correlation is used to know whether the variables under study are correlated or not, and if yes what is the strength of their association.Correlation Coefficient "r" is a measure of strength of their association.In this case Correlation Coefficient "r" is 0.948Correlation analysis is conducted with the use of Microsoft excel, the output of the analysis is as follows.

Table no 4: output of the Correlation analysis from Microsoft excel.

	Texture Depth(mm) = 4V/πD2	Average level (dB)
Texture Depth(mm) = 4V/πD2	1	
Average level (dB)	0.94845343	1

3.4 Regression analysis: Regression gives the functional relationship between variables in the form of y= f(x) + c and a model to make future projection.

Table no 5: Summary output of regression analysis

SUMMARY OUTPUT	
Regression Statistics	
Multiple R	0.94845343
R Square	0.899563909
Adjusted R Square	0.890433355
Standard Error	0.305083841
Observations	13

Table no 6:Anova of regression analysis

ANOVA					
	df	SS	MS	F	Significance F
Regression	1	9.170084	9.170084	98.52238265	7.96E-07
Residual	11	1.023838	0.093076		
Total	12	10.19392			

Table no 7: Various coefficients of regression analysis

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-11.39934842	1.305556	-8.73141	2.81665E-06	-14.2729	-8.52584	-14.2729	-8.52584
Average level (dB)	0.177893682	0.017922	9.925844	7.96343E-07	0.138447	0.21734	0.138447	0.21734

Table no 8: Residual output of regression analysis

RESIDUAL OUTPUT		
Observation	Predicted Texture Depth(mm) = 4V/πD2	Residuals
1	0.163740908	0.530259
2	0.519528272	0.243472
3	0.697421954	0.131578
4	1.053209318	-0.13121
5	1.142156159	-0.18416
6	1.231103	-0.2261
7	1.497943523	-0.36794
8	1.586890364	-0.26889
9	1.764784046	-0.20678
10	2.031624569	-0.14562
11	2.298465092	-0.02547
12	2.743199297	0.125801
13	3.187933501	0.525066

The regression line expression is; Texture depth = -11.39934+0.17789* frictional noise measurement.
Where; Texture depth is measured in mm
Frictional noise is measured in dB

IV.Model Validation

The regression model developed in the earlier section is validated using the data collected at the remaining Roads. The estimated texture depth (mm) is evaluated with the help of regression equation which was developed in the earlier section i.e. Texture depth (mm) = -11.39934 + 0.17789* frictional noise measurement (dB); the field texture depth (mm) is measured on site.

Finally estimated pavement surface texture depths and field observed pavement surface texture depths are compared. The graph is plotted between these two surface texture depths in order to observe the nature of the graph. Trend line in graph inclined at 45^0indicates a good model.

4.1 Frictional Noise Measurement Frictional noise is measured similarly as discussed in the section 3.1 of this paper, for the remaining major roads of Jamner city.

Table 9: Frictional Noise Measurement on various road surfaces for data validation

Sr. no	Road Name	Road width (M)	Maximum level (dB)	Minimum Level (dB)	Average level (dB)
1	Railway Station Road	12	71	60	65.5
2	Pachora Road	12	72	60	66
3	ITI Colony Road	9	75	63	69
4	Vivekanandnagar Road	6	78	64	71
5	Jijaunagar Road	6	80	67	73.5
6	SupariBaug main Road	9	86	73	79.5

4.2 Surface Texture Measurement

The estimated texture depth (mm) is evaluated with the help of regression equation which is developed in the earlier section i.e. Estimated Texture depth (mm) = -11.39934 + 0.17789* frictional noise measurement (dB), and Field texture depth is actually measured on the site by conducting sand patch test; similar to as it was carried out for model formation purpose.

Table 10: Calculations of Estimated Texture depth (mm)

Sr. no	Road Name	Road width (M)	Average level (dB)	Estimated Texture depth (mm) =-11.39934 + 0.17789* frictional noise measurement (dB)	Estimated Texture depth (mm)
1	Railway Station Road	12	65.5	= -11.39934 + 0.17789*65.5	0.252
2	Pachora Road	12	66	= -11.39934 + 0.17789*66	0.341
3	ITI Colony Road	9	69	= -11.39934 + 0.17789*69	0.875
4	Vivekanandnagar Road	6	71	= -11.39934 + 0.17789*71	1.231

5	Jijaunagar Road	6	73.5	= -11.39934 + 0.17789*73.5	1.675
6	SupariBaug main Road	9	79.5	= -11.39934 + 0.17789*79.5	2.743

Table 11: Calculations of Observed Field Texture depth (mm)

Sr. no	Road Name	Road width (M)	D in mm	Observed Field Texture Depth(mm) = $4V/\pi D^2$
1	Railway Station Road	12	1200	0.264
2	Pachora Road	12	1050	0.345
3	ITI Colony Road	9	658	0.878
4	Vivekanandnagar Road	6	556	1.230
5	Jijaunagar Road	6	477	1.671
6	SupariBaug main Road	9	372	2.747

Table 12: Comparison ofEstimated Texture depth and observed Field Texture Depth

Sr. no	Road Name	Road width (M)	Estimated Texture depth (mm)	Observed Field Texture Depth(mm) = $4V/\pi D^2$
1	Railway Station Road	12	0.252	0.264
2	Pachora Road	12	0.341	0.345
3	ITI Colony Road	9	0.875	0.878
4	Vivekanandnagar Road	6	1.231	1.230
5	Jijaunagar Road	6	1.675	1.671
6	SupariBaug main Road	9	2.743	2.747

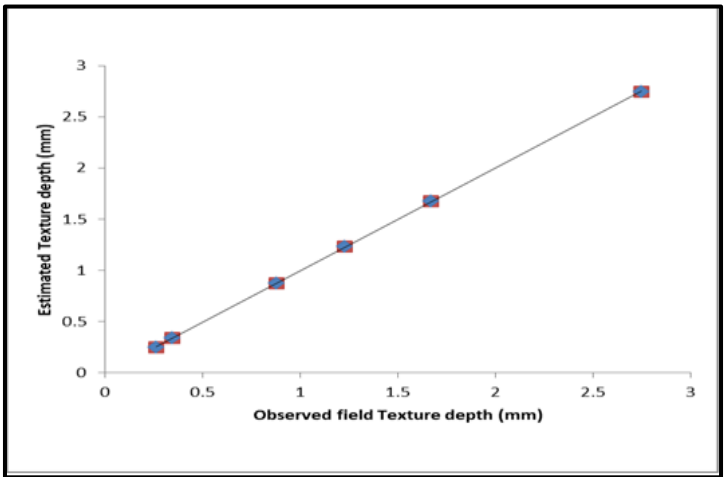

Fig. 7: Relation between estimated pavement surface texture depth & field observed pavement surface texture depth

It was observed that all data points were close to the 45 degree line, indicating a good match between field texture depth and estimated texture depth.

V. Conclusion

1. Correlation is used to know whether the variables under study are correlated or not, and if yes what is the strength of their association.
2. The correlation between average frictional noise and Average texture depth are positively correlative.
3. Correlation Coefficient "r" which is a measure of linear association is 0.948, and hence there is strong relationship between variables.
4. 89.9% of the variation in the frictional noise is explained by the texture depth (mm) of the pavement.
5. Regression gives the functional relationship between variables in the form of y= f(x) + c and a model to make future projection.
6. Significance F-value is 7.96343E-07 and P-values are 2.81665E-06 and 7.96343E-07 which are less than 0.05.
7. The regression line expression is; Texture depth(mm) = -11.39934+0.17789* frictional noise measurement
8. For 1dB increase in average frictional noise level, average texture depth of pavement (mm) increases by 0.17789 mm.

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