SUITABILITY OF ALTERNATIVE PAVEMENT ROUGHNESS STATISTICS TO DESCRIBE DYNAMIC AXLE LOADS OF HEAVY VEHICLES

by

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ABSTRACT

This is an experimental study of the interaction between dynamic axle load of heavy vehicles and pavement roughness. The main objective of the study is to determine the type of pavement roughness statistic that best describes this interaction. The experiment involved dynamic axle load measurements performed by the instrumented vehicle developed by the Vehicle Dynamics Laboratory of the National Research Council of Canada and pavement roughness measurements made by a Surface Dynamics Profilometer. Five levels of pavement roughness, three levels of vehicle speed and two vehicle suspension types were tested.

The pavement roughness statistics were calculated on the basis of the pavement roughness profile measured in the left and the right wheel paths at 6-inch intervals. They were calculated at 50-meter intervals, using the elevation of the right wheel path as well as the average elevation of the right and left wheel paths. These respectively are the quarter-car type, (IRI and HRI), the Root Mean Square Vertical Acceleration, (RMSVAa and RMSVAr) and the Mean Absolute Vertical Acceleration, (MAVAa and MAVAr).

It was shown that there is no unique pavement statistic providing the best fit between pavement roughness and dynamic axle load variation over the range of vehicle speeds tested. The highest correlation with the RMS of the dynamic load was shown for the HRI and the MAVAa for the rubber and the air suspensions, respectively. It was concluded that the IRI statistic might not be ideally suited for describing the dynamic behaviour of a particular suspension type.

The exponential relationships fitted to the Root Mean Square of the dynamic axle load demonstrated the differences in the dynamic behaviour of the rubber and the air suspension. The relative magnitude of the exponents of the vehicle speed variable for the two suspensions tested demonstrated the sensitivity of the rubber suspension to vehicle speed, (i.e., values 1.109 and 0.396 for the rubber and the air suspensions, respectively). Finally, linear relationships were fitted between IRI/HRI and the pavement profile statistics RMSVA and MAVA.

1. INTRODUCTION

Recently, there has been a great deal of interest in studying the interaction between pavement roughness and dynamic axle load generated by heavy vehicles. Dynamic axle loads have been measured on board vehicles using various instrumentation arrangements. Tests covered a variety of suspension types, levels of pavement roughness and vehicle operating conditions, (eg., vehicle speed, tire inflation pressure and so on).

Furthermore, efforts have been made recently to quantify pavement roughness and develop a universally acceptable pavement roughness statistic. The much publicized International Roughness Experiment recommended the International Roughness Index (IRI) as the most rigorous statistic that could be used universally.

The study at hand brings together the two elements of the problem, that is dynamic axle load and pavement roughness. It provides an experimental evaluation of a number of alternative pavement roughness statistics in terms of their suitability to describe dynamic axle load variation of two suspension types over a range of vehicle speeds.

2. BACKGROUND

The International Road Roughness experiment conducted by the World Bank, (1,2), evaluated a variety of roughness measuring devices and studied their suitability in describing pavement roughness. The study classified the roughness measuring devices into two major categories, profilometer-type and response-type. The former yield the true elevation of pavement points at regular intervals along the wheel paths. Common examples of such devices are the American Surface Dynamics Profilometer (3) and the French APL (4). Response type devices yield a statistic of the response of a vehicle to the pavement longitudinal profile. Common examples of such devices are the Mays Ride Meter (MRM), (5) and the Pavement Universal Roughness Device (PURD), (6). The principal of operation these devices was documented by Butler (7). The study proposed the so called International Roughness Index (IRI) which is obtained by simulating the response of a quarter-car model of standard mechanical characteristics travelling over the measured pavement profile of the right wheel path at prescribed speed. A variation of the IRI statistic has been used which consists of a pair of these quarter car models travelling over the right and the left wheel paths, respectively. The resulting response of this half-car is referred to as the Half-Car Index (HRI), (8).

A number of studies have been carried out recently dealing with the factors affecting the dynamic axle loads generated by heavy vehicles. Work by Sweatman (9) examined the effect of the various vehicle parameters affecting dynamic axle loads. Factors such as axle configuration, suspension type and tire inflation pressure and vehicle speed were considered in conjunction with pavement roughness. Dynamic axle loads were measured with a wheel-force transducer mounted on the hub of the vehicles tested. It was established that both suspension type and vehicle speed significantly affect dynamic axle load variation. The general form of the relationship proposed between the dynamic axle load, the pavement roughness and the vehicle speed is:

$$DLC = a + b\,V R^{0.5} \tag{1}$$

where, DLC is the Dynamic Load Coefficient defined as the coefficient of variation of the dynamic load, V is the vehicle speed (km/h) and R is the pavement roughness measured by a NAASRA device (in/mi), (12). Values for the coefficients a and b were established through regression for each of the suspension types tested.

Work by Woodrooffe et al (10,11) examined the dynamic load behaviour and the load sharing characteristics of a number of multiple heavy vehicle suspensions. For this purpose, the axles of a six-axle articulated tanker truck were instrumented with a combination of strain gauges and accelerometers. The dynamic load of each axle was calculated by summing the load component obtained through calibration from the bending strain of the axles plus the product of the mass of the wheel assembly multiplied by its acceleration. Pavement roughness was measured using a MRM and the output was converted to Riding Comfort Index (RCI) by the following relationship:

$$RCI = 9.63 - 0.02MRM \tag{2}$$

where, the MRM was expressed in in/mi and was calculated at 80-meter intervals, (i.e., 0.02 miles). An example of the relationships developed between the standard deviation of dynamic load and MRM is given in Figure 1 for several of the suspension types tested.

A study by Papagiannakis et al examined the impact of dynamic axle loads on flexible pavement performance (13,14). The instrumented vehicle developed by Woodrooffe et al (10,11) was used for the dynamic load measurements. The experiment took place in June 1987 and involved five levels of pavement roughness, three levels of vehicle speed and two suspension types, namely air and rubber.

Strain and acceleration measurements on board the vehicle were made only on the right-hand side of the axles and therefore, dynamic axle load had to be calculated by multiplying by 2 the load measured for the right half of the axle. Pavement roughness was measured by a Surface Dynamics Profilometer yielding pavement profile elevation at 6-inch intervals in both left and right wheel paths. Regression equations were fitted to the standard deviation of the dynamic load versus pavement roughness and vehicle speed data for the air and the rubber suspensions, (Equations 3 and 4, respectively). The standard deviation of the dynamic load was calculated over the entire length of the test sections, while the HRI statistics calculated at 50-meter intervals were averaged to reflect the roughness of the test sections.

$$\mathbf{SD} = 0.087\,\mathbf{V}^{0.398}\,\mathbf{R}^{0.725}$$

$$(\mathbf{r}^2 = 0.80,\ \mathbf{t}_1 = 1.73,\ \mathbf{t}_2 = 2.69,\ \mathbf{t}_3 = 4.34) \quad (3)$$

$$\mathbf{SD} = 0.005\,\mathbf{V}^{1.265}\,\mathbf{R}^{0.671}$$

$$(\mathbf{r}^2 = 0.90,\ \mathbf{t}_1 = 1.25,\ \mathbf{t}_2 = 7.81,\ \mathbf{t}_3 = 6.71) \quad (4)$$

Where, **SD** is the standard deviation of the dynamic load, (kN), **R** is the average HRI pavement roughness, (in/mi) and **V** is the vehicle speed, (km/h). The statistic **t**, defined as the ratio of the magnitude of the coefficient divided by its standard error, indicated that the coefficients of both speed and roughness are statistically significant. Equations 3 and 4 revealed that the rubber suspension is much more sensitive to vehicle speed than the air suspension, yielding higher variation in dynamic load under the same pavement roughness conditions.

3. OBJECTIVES-METHODOLOGY

The objectives of the study are to:

(i) Select the most suitable pavement roughness statistic to describe the dynamic load variation generated by the axle of heavy vehicles over a range of pavement roughness and vehicle speeds.

(ii) Develop regression equations to describe the relationship between dynamic axle load, pavement roughness and vehicle speed for the two suspension types tested.

(iii) Develop relationships between the pavement roughness statistics analyzed for future reference.

The study at-hand expands on the experimental results by Papagiannakis et al, (13, 14), by performing a more detailed analysis of the same data set. The objectives listed above are addressed by analyzing the dynamic load and pavement roughness data at 50-meter intervals, instead of calculating statistics over the full length of the test sections. Furthermore, alternative pavement roughness statistics are considered in order to select the one best suited to describe dynamic axle load variation.

4. DATA ANALYSIS AND DISCUSSION

Pavement roughness and dynamic load statistics were calculated in 50-meter intervals. The variation in dynamic axle load was indexed by its Root Mean Square (RMS) calculated as shown below:

$$RMS = \left(\frac{\sum_{i=k}^{i=k+n} (DL_i - W)^2}{n} \right)^{0.5} \qquad (7)$$

where, DL_i is one of the n dynamic load measurements obtained in each 50-meter interval and W is the static axle load. The RMS was considered to be more representative of the load variation than the standard deviation because the average value of the load calculated in 50-meter intervals can be substantially different than the static load.

Two categories of pavement roughness statistics were analyzed, namely, simulated vehicle response statistics and pavement profile statistics. The IRI and the HRI were included in the first category and were calculated according to References 2 and 8, respectively. The second category included statistics based simply on the measured pavement profile. These are the Root Mean Square Vertical Acceleration (RMSVA) and the Mean Absolute Vertical Acceleration (MAVA). These were calculated according to Equations 6 and 7, (Joseph et al, 1986) for the right wheel path as well as the average of the right and the left wheel paths, hence the acronyms RMSVAr, MAVAr and RMSVAa, MAVAa, respectively.

$$\mathrm{RMSVA} = \left(\sum_{i=2}^{i=n-1} \frac{(Y_{i+1} + Y_{i-1} - 2*Y_i)^2}{(n-2)\Delta s^4} \right)^{0.5} \tag{6}$$

$$\mathrm{MAVA} = \sum_{i=2}^{i=n-1} \frac{|Y_{i+1} + Y_{i-1} - 2*Y_i|}{(n-2)\Delta s^2} \tag{7}$$

Where, Y_i, is the pavement profile elevation at point i. Tables 2 through 7 summarize the pavement roughness statistics calculated at 50-meter intervals.

The statistical analysis of the dynamic load and pavement roughness data was carried out in two stages. First, the relationship between dynamic axle load variation and alternative pavement roughness statistics was explored. Second, the relationship between alternative pavement roughness statistics was examined.

4.1 Relationship between Dynamic Load and Pavement Roughness

Table 8 lists the correlation values between the RMS of the dynamic axle load, (i.e., variable names AIR and RUBBER for the air and rubber suspensions, respectively) and the pavement roughness statistics calculated in 50-meter intervals. In general, it can be seen that the RMS of the dynamic load of the rubber suspension demonstrates higher correlation to vehicle speed than to the roughness statistics analyzed. On the contrary, the RMS of the dynamic load of the air suspension demonstrates higher correlation to the roughness statistics analyzed than the vehicle speed. This verifies the trend observed earlier (13,14), in relation to the relative sensitivity of the two suspensions to vehicle speed. The statistics that demonstrated the highest correlation with the RMS of the Dynamic load were the HRI for the rubber suspension and the MAVAa for the air suspension. These were selected to express pavement roughness, R, in the relationships that were developed. The general form of the relationship proposed by Papagiannakis et al (13,14), was followed for this purpose, (i.e., Equations 3 and 4). The resulting equations are:

$$RMS = 0.008 V^{1.109} R^{0.682}$$

$$(r^2 = 0.6317, t_1 = 2.00, t_2 = 11.31, t_3 = 15.50) \quad (8)$$

$$RMS = 0.879 V^{0.396} R^{1.049}$$

$$(r^2 = 0.68, t_1 = 4.60, t_2 = 7.62, t_3 = 18.73) \quad (9)$$

where, V is the vehicle speed in km/h. The calculated coefficients are highly significant indicating that the selected form of the relationship is indeed appropriate. The higher sensitivity of the rubber suspension to vehicle speed can be visualized by comparing the exponential coefficients of the variable V in Equations 8 and 9. The quality of fit of the two equations, (i.e., r^2 values of 0.632 and 0.6833, respectively) is quite acceptable considering the simplified approach taken in modelling the interaction between dynamic load and pavement roughness. Indeed, it has been demonstrated that the impact of the pavement roughness of each 50-meter increment may extend over to the following increments, (17). This suggests that a forward moving average treatment of the calculated dynamic axle load statistics may have yielded a better fit to the proposed statistical models. Figures 3 and 4 illustrate the observed versus fitted RMS values of the dynamic load according to Equations 8 and 9 for the highest vehicle speed tested, (i.e., 80 km/h). The wide spread of the observed RMS values is apparent.

4.2 Relationship between Alternative Pavement Roughness Statistics

Table 9 lists the correlation values between the pavement roughness statistics analyzed. As expected, high correlations were observed between identical statistics calculated for the profile of the right wheel path and the average of the profiles of right and left wheel paths. Furthermore, high correlation was shown between the RMSVA and the MAVA statistics. Comparing the roughness statistics of the two categories, namely simulated vehicle response and pavement profile, higher correlation was found between IRI/HRI and RMSVAr/RMSVAa than IRI/HRI and MAVAr/MAVAa. Linear regression equations were fitted to the experimental data to express the pavement profile statistics as a function of the simulated vehicle response statistics, (Equations 10 to 13). The observed and fitted data of these relationships are shown in Figures 5 through 8.

$$RMSVAr = 1.522 + 0.040 IRI$$

$$(r^2 = 0.578,\ t_1 = 2.93,\ t_2 = 9.79) \quad (10)$$

$$MAVAr = 1.971 + 0.015 IRI$$

$$(r^2 = 0.435,\ t_1 = 7.42,\ t_2 = 7.35) \quad (11)$$

$$RMSVAa = 0.727 + 0.032 HRI$$

$$(r^2 = 0.766,\ t_1 = 2.83,\ t_2 = 15.14) \quad (12)$$

$$MAVAa = 1.178 + 0.014 HRI$$

$$(r^2 = 0.690,\ t_1 = 8.78,\ t_2 = 12.48) \quad (13)$$

5. CONCLUSIONS AND FURTHER STUDY

There seems to be no unique pavement statistic providing the best fit between pavement roughness and dynamic axle load variation over the range of vehicle speeds tested. This appears to be the result of the particular frequency content of individual suspensions. The highest correlation with the RMS of the dynamic load was shown for the HRI and the MAVAa for the rubber and the air suspensions, respectively. As a result, the universally recommended IRI statistic might not be ideally suited for describing the dynamic behaviour of a particular suspension type.

The relationships fitted to RMS of the dynamic axle load data versus the selected pavement roughness statistics followed the general exponential form proposed in previous studies. The relative magnitude of the exponents of the vehicle speed variable for the two suspensions tested demonstrated the sensitivity of the rubber suspension to vehicle speed, (i.e., values 1.109 and 0.396 for the rubber and the air suspensions, respectively).

Study of the pavement roughness statistics calculated, revealed a higher correlation between IRI/HRI and RMSVAr/RMSVAa than between IRI/HRI and MAVAr/MAVAa. The regression equations produced can be used to convert the IRI statistic usually calculated to pavement profile statistics such as the RMSVA and the MAVA.

Future study of the interaction between dynamic load and pavement roughness must take into account the fact that the dynamic load impact of a particular roughness feature on the pavement may extend over a considerable pavement length down the road. This can be accounted for by calculating the forward moving average of the dynamic axle load statistic over the section increments analyzed. Regression analysis should follow the "smoothing" of the dynamic load series obtained in this fashion.

The conclusion that the IRI is not ideally suited to describe the relationship between pavement roughness and dynamic axle load raises another question. Is the IRI best suited to describe the relationship between pavement roughness and pavement user's ratings such as the Present Serviceability Rating and the Riding Comfort Rating, (18)? It is crucial to address this question by conducting pavement serviceabilty ratings by panels of users and relate them to alternative pavement roughness statistics.

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Figure 1: Standard Deviation of the Dynamic Load versus Riding Comfort Index, (After Ref. 10)

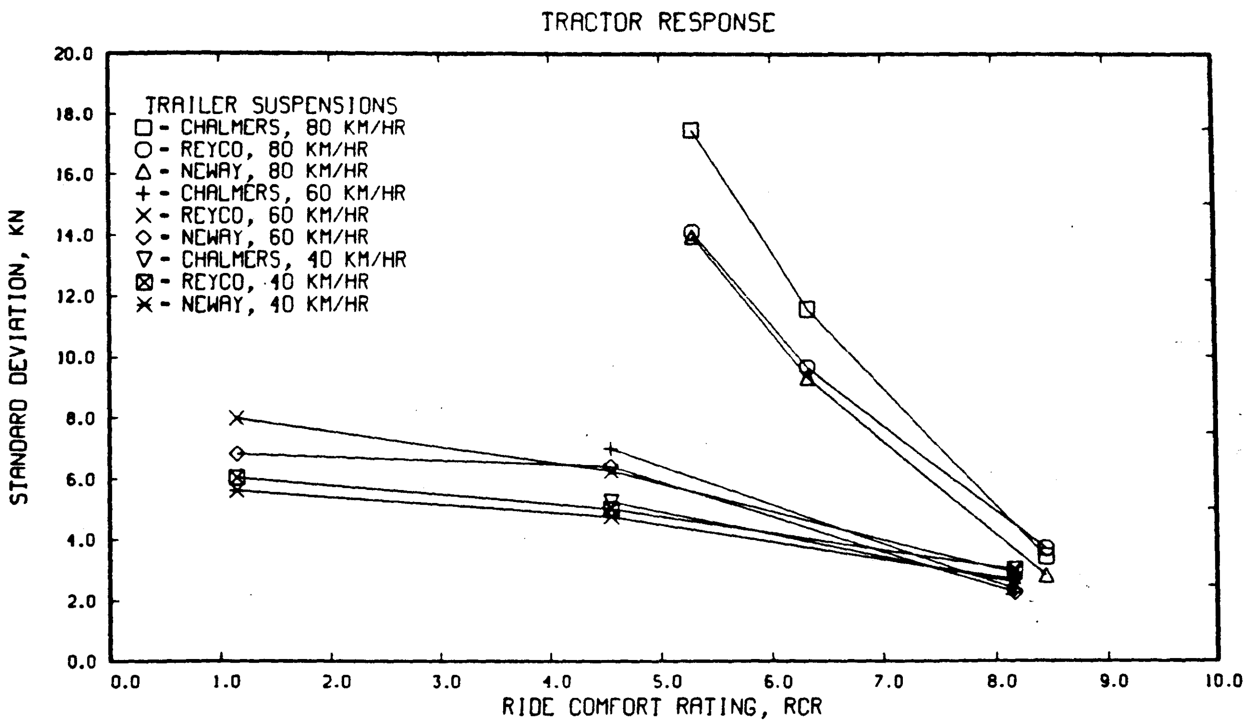

Figure 2: Standard Deviation of the Dynamic Load versus Vehicle Speed
for HRI Roughness Level of 201 in/mi, (After Ref. 14)

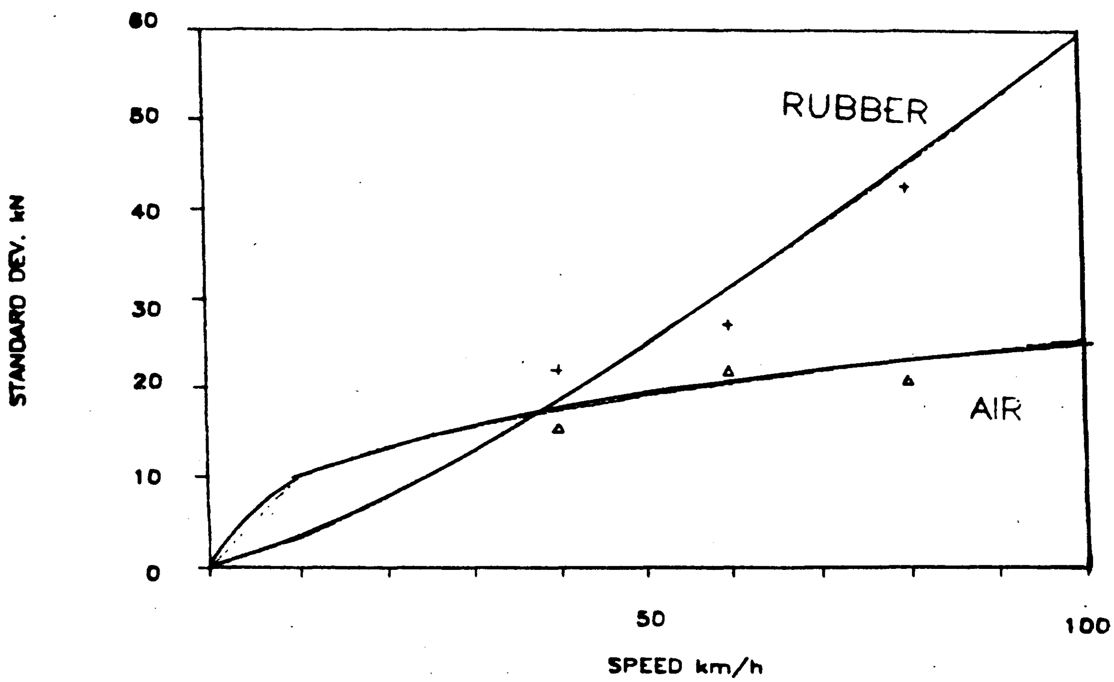

Figure 3: RMS of the Dynamic Load versus Pavement Roughness for the Rubber Suspension, (80 km/h)

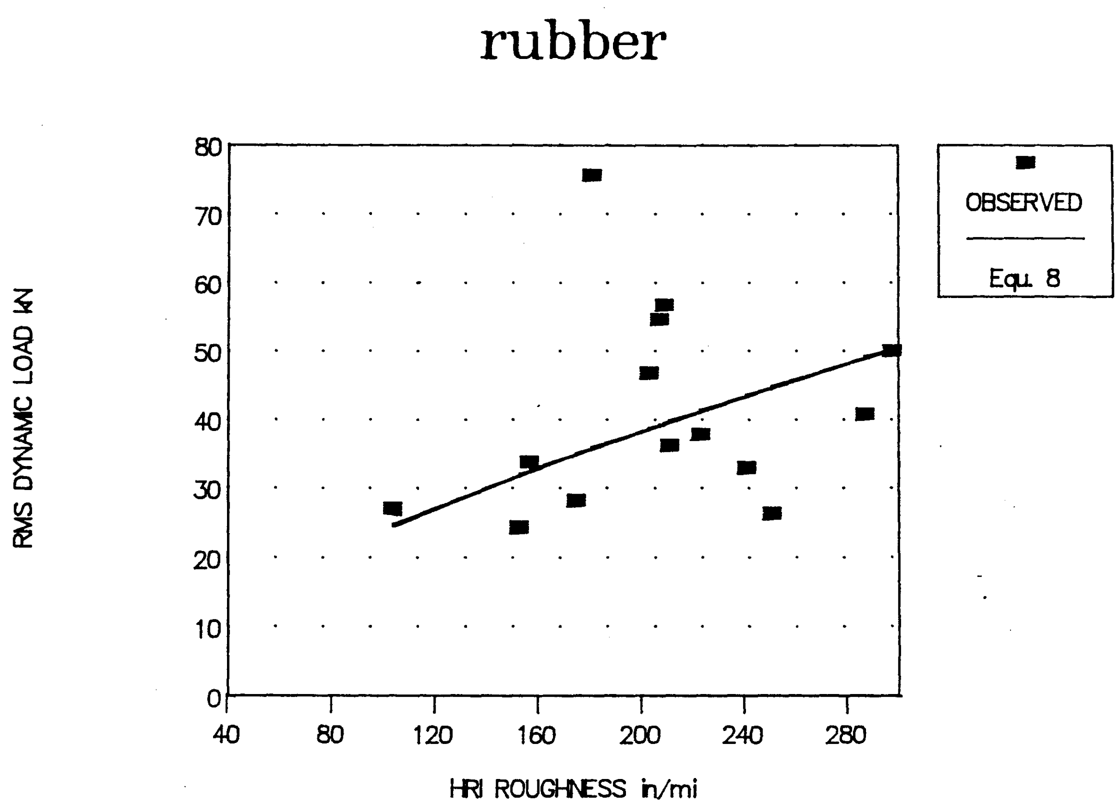

Figure 4: RMS of the Dynamic Load versus Pavement Roughness for the Air Suspension, (80 km/h)

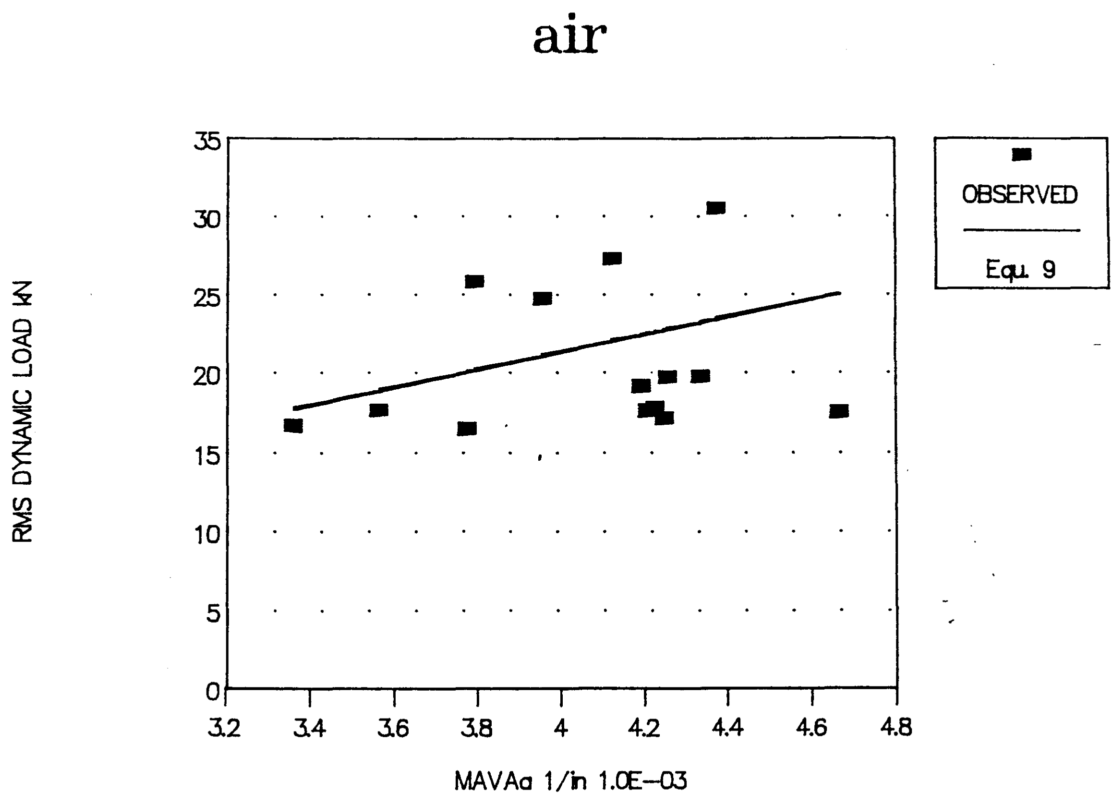

Figure 5: RMSVAr versus IRI, (i.e., fitted data from Equation 10)

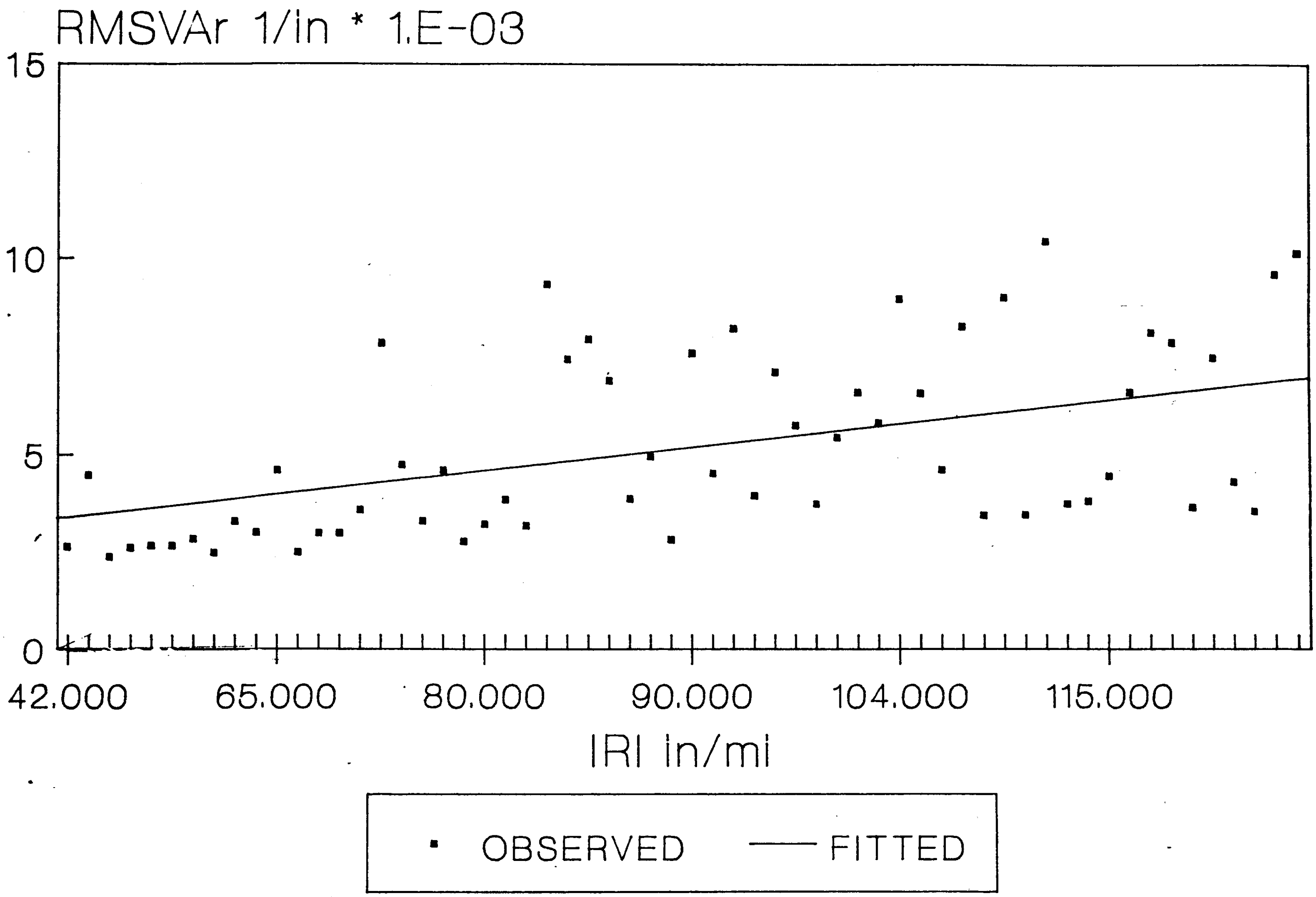

Figure 6: MAVAr versus IRI, (i.e., fitted data from Equation 11)

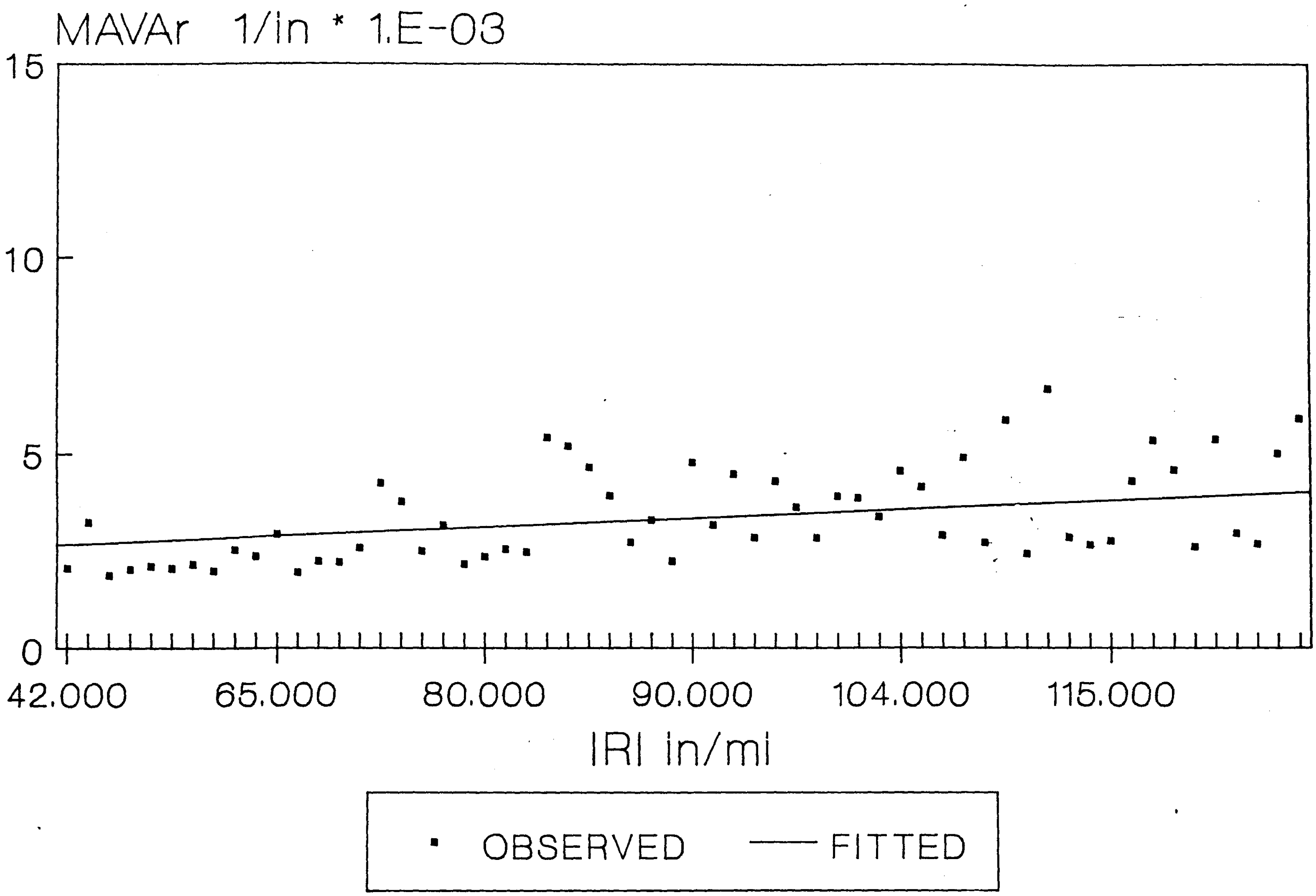

Figure 7: RMSVAa versus HRI, (i.e., fitted data from Equation 12)

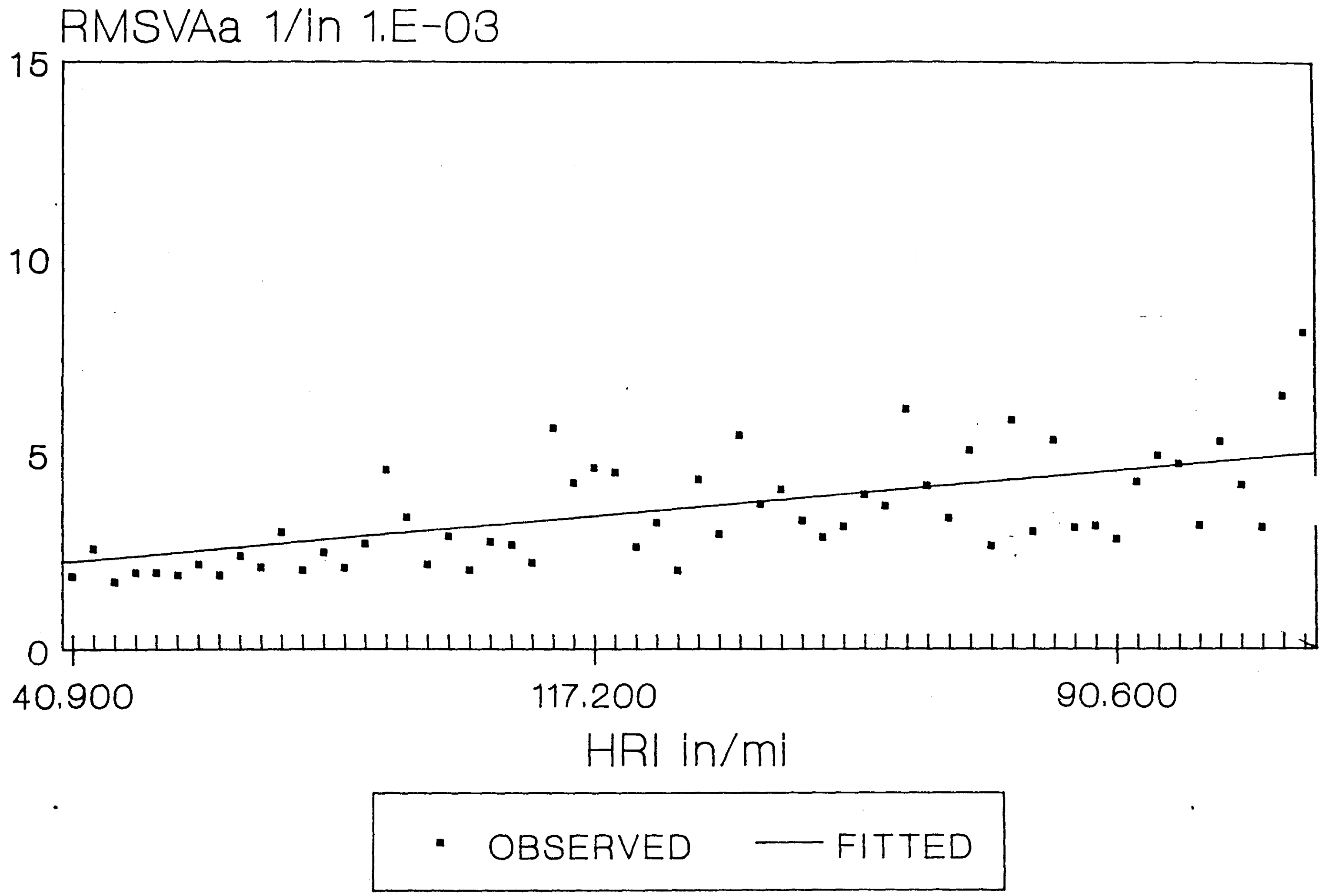

Figure 8: MAVAa versus HRI, (i.e., fitted data from Equation 13)

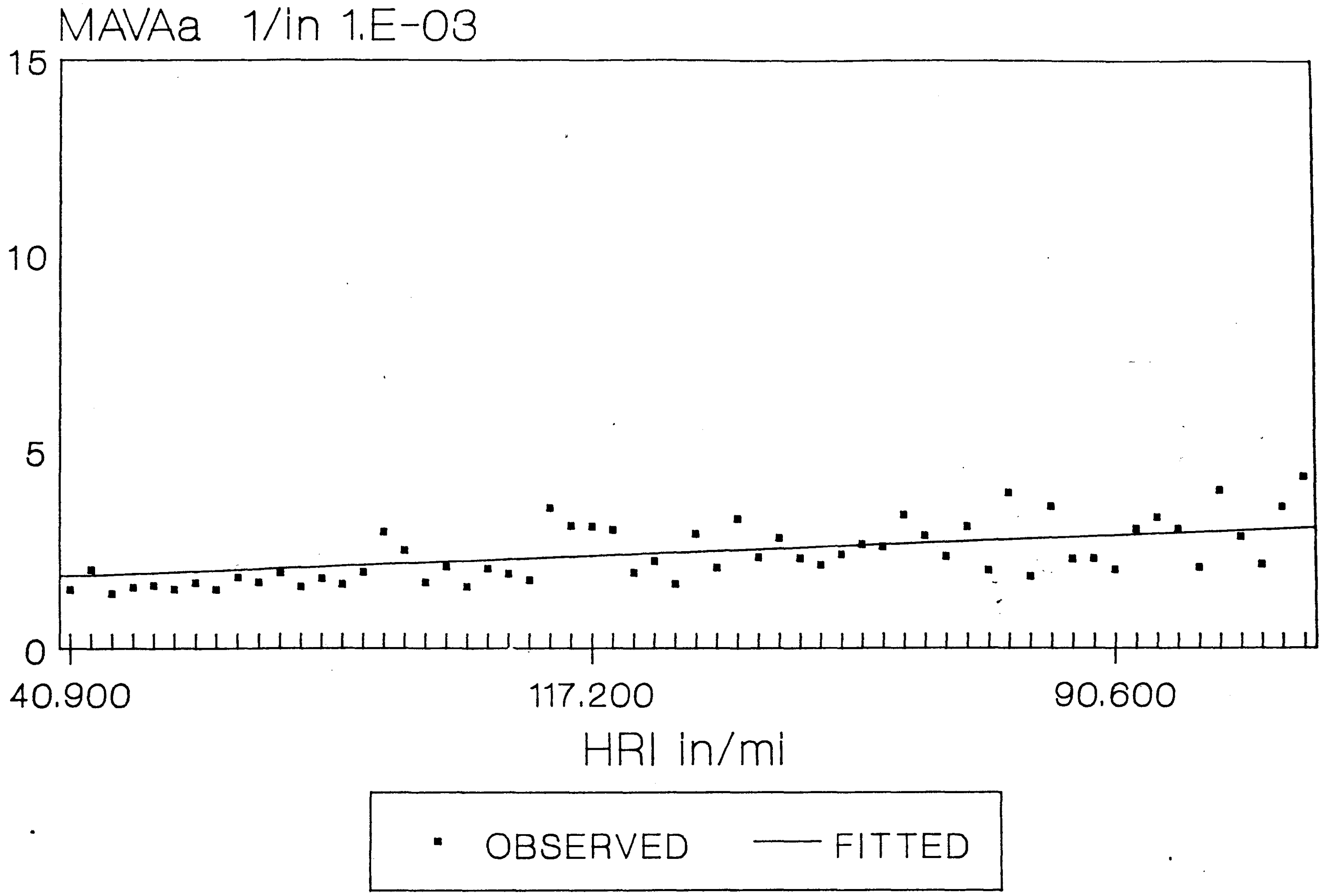

Table 1
Aggregate Dynamic Load Statistics, (After Ref. 13)

RUN #	SECTION NUMBER	HRI in/mi	SPEED km/h	LENGTH (m)	S.DEV. (kN) RUBBER	S.DEV. (kN) AIR
29			40		8.04	8.07
30	1	56	60	746.17	10.87	6.94
31			80		14.28	7.40
21			40		11.06	9.44
22	2	87	60	760.74	18.76	8.66
24			80		28.17	11.01
13			40		10.86	10.40
14	3	96	60	769.08	14.49	11.30
12			80		30.11	13.67
3			40		14.76	12.60
4	4	115	60	518.59	16.81	19.07
40			80		33.57	19.46
16			40		22.15	15.65
17	5	201	60	677.98	27.06	22.11
20			80		42.55	21.08

Table 2
Half-Car Ride Index (Average of Two Wheel Paths), HRI, (in/mi)

INTERVAL(m)	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5
0 - 50	35.2	70.7	81.6	117.2	165.1
50 - 100	48.7	69.4	87.9	108.6	170.3
100 - 150	60.5	101.1	90.6	138.3	179.7
150 - 200	38.2	94.0	97.9	128.6	162.4
200 - 250	45.7	89.1	90.8	87.7	181.5
250 - 300	51.8	74.8	115.7	93.2	115.3
300 - 350	45.2	93.5	83.1	86.9	155.3
350 - 400	66.2	76.8	100.1	136.6	168.6
400 - 450	62.4	108.8	67.6	168.1	315.7
450 - 500	70.2	160.4	103.2	97.1	208.3
500 - 550	40.9	80.6	86.3	108.5	228.8
550 - 600	53.2	73.7	99.0		204.6
600 - 650	85.2	68.3	97.0		297.0
650 - 700	61.5	106.9	114.4		261.7
700 - 750	85.9	62.5	107.3		
750 - 800		62.8	115.6		

Table 3
International Roughness Index (Right Wheel Path), IRI, (in/mi)

INTERVAL(m)	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5
0 - 50	44.0	61.0	93.0	86.0	157.0
50 - 100	57.0	80.0	102.0	164.0	223.0
100 - 150	71.0	132.0	115.0	137.0	241.0
150 - 200	55.0	93.0	139.0	109.0	251.0
200 - 250	51.0	111.0	104.0	128.0	203.0
250 - 300	64.0	97.0	105.0	93.0	104.0
300 - 350	53.0	113.0	88.0	73.0	175.0
350 - 400	70.0	88.0	99.0	84.0	153.0
400 - 450	66.0	108.0	77.0	118.0	329.0
450 - 500	76.0	141.0	85.0	101.0	181.0
500 - 550	42.0	72.0	104.0	87.0	211.0
550 - 600	54.0	83.0	95.0	93.0	207.0
600 - 650	80.0	80.0	97.0		287.0
650 - 700	42.0	110.0	118.0		209.0
700 - 750	90.0	65.0	90.0		
750 - 800		73.0	110.0		

Table 4
Root Mean Square Vertical Accel. (Average of Two Wheel Paths), RMSVAa, $(in^{-1}*10^{-3})$

INTERVAL(m)	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5
0 - 50	1.714	2.381	2.917	4.624	8.086
50 - 100	1.872	2.733	3.631	5.806	7.849
100 - 150	2.065	3.135	2.795	5.293	8.057
150 - 200	2.161	3.688	4.157	5.853	7.51
200 - 250	1.954	3.075	3.321	4.712	7.542
250 - 300	2.088	2.844	5.072	5.477	6.152
300 - 350	1.95	3.133	3.217	4.561	6.456
350 - 400	2.458	2.594	3.114	5.65	6.481
400 - 450	2.006	2.62	2.871	4.93	8.181
500 - 550	2.148	3.094	4.236	3.934	7.819
550 - 600	1.851	2.676	4.157	4.502	7.853
600 - 650	1.887	2.19	4.068		8.447
650 - 700	2.007	2.65	3.263		7.347
700 - 750	2.563	2.977	4.25		9.754
750 - 800	1.993	2.984	4.322		
800 - 850		3.345	5.333		

Table 5
Root Mean Square Vertical Accel. (Right Wheel Path), RMSVAr, $(in^{-1}*10^{-3})$

INTERVAL(m)	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5
0 - 50	2.346	3.27	4.497	7.918	10.12
50 - 100	2.45	3.193	5.803	7.229	9.143
100 - 150	2.961	3.637	4.44	7.468	11.8
150 - 200	2.818	3.929	4.294	8.996	10.5
200 - 250	2.589	3.722	4.591	7.84	9.563
250 - 300	2.979	3.716	8.252	8.198	8.952
300 - 350	2.64	3.794	4.936	7.832	9.205
350 - 400	2.962	3.845	5.435	9.32	9.592
400 - 450	2.459	3.427	4.584	8.099	12.16
500 - 550	3.267	3.539	7.412	6.585	9.077
550 - 600	2.601	3.561	6.556	6.865	9.949
600 - 650	2.637	3.152	7.095		11.94
650 - 700	2.742	3.828	5.733		10.96
700 - 750	4.457	3.441	6.59		15.73
750 - 800	2.787	4.581	7.571		
800 - 850		4.713	10.41		

Table 6
Mean Absolute Vertical Accel. (Average of Two Wheel Paths), MAVAa, ($in^{-1}*10^{-3}$)

INTERVAL(m)	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5
0 - 50	1.865	2.526	3.163	4.631	5.883
50 - 100	1.971	2.347	3.378	4.609	4.896
100 - 150	2.203	2.589	2.743	5.366	5.978
150 - 200	2.151	2.840	2.940	5.852	5.347
200 - 250	2.026	2.825	2.888	4.566	4.719
250 - 300	2.356	2.829	4.885	4.475	4.547
300 - 350	2.103	2.636	3.292	4.237	4.698
350 - 400	2.234	2.710	3.906	5.405	4.990
400 - 450	1.933	2.703	3.158	5.331	5.050
450 - 500	2.487	2.657	5.185	3.863	4.910
500 - 550	2.050	2.572	4.132	3.910	5.139
550 - 600	2.048	2.464	4.292		5.774
600 - 650	2.151	2.548	3.624		5.915
650 - 700	3.245	2.403	4.291		7.129
700 - 750	2.216	2.932	4.776		
750 - 800		3.755	6.647		

Table 7
Mean Absolute Vertical Accel. (Right Wheel Path), MAVAr, ($in^{-1}*10^{-3}$)

INTERVAL(m)	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5
0 - 50	1.384	1.803	2.039	3.066	4.335
50 - 100	1.493	2.024	2.560	3.537	4.225
100 - 150	1.622	2.040	1.987	3.992	4.207
150 - 200	1.669	2.300	2.807	3.928	4.247
200 - 250	1.548	2.257	2.318	2.998	3.957
250 - 300	1.680	2.104	3.066	3.262	3.360
300 - 350	1.596	2.266	2.205	2.935	3.776
350 - 400	1.776	1.912	2.370	3.537	3.565
400 - 450	1.560	1.973	2.068	3.286	3.794
450 - 500	1.670	2.118	3.093	2.623	4.123
500 - 550	1.488	1.934	2.834	2.979	4.192
550 - 600	1.498	1.729	2.780		4.255
600 - 650	1.562	1.886	2.273		4.374
650 - 700	1.993	1.816	3.001		4.666
700 - 750	1.626	1.923	2.888		
750 - 800		2.467	3.569		

Table 8
Correlation between the RMS of the Dynamic Load, (Air and the Rubber Suspensions) and Pavement Roughness Statistics

	RUBBER	AIR
SPEED	0.498	0.216
IRI	0.524	0.685
HRI	0.588	0.732
RMSVAr	0.542	0.744
RMSVAa	0.578	0.756
MAVAr	0.502	0.740
MAVAa	0.553	0.786

Table 9
Correlation Between Pavement Roughness Statistics

	IRI	HRI	RMSVAr	RMSVAa	MAVAr	MAVAa
IRI	1.000					
HRI	0.918	1.000				
RMSVAr	0.760	0.834	1.000			
RMSVAa	0.844	0.875	0.958	1.000		
MAVAr	0.660	0.753	0.961	0.898	1.000	
MAVAa	0.792	0.831	0.953	0.973	0.947	1.000

SESSION 5 – PAVEMENTS 2

Chairman: Pat Ring, Transportation Research Board

Speakers

1. **Precision Without Accuracy: Heavy Trucks and Pavements Revisited**
   J.B.L. Robinson, E. Hildebrand, University of New Brunswick,
   M. Jackart, New Brunswick Department of Transportation

2. **The Response of Pavement to Heavy Loads**
   J.P. Mahoney, D.E. Newcomb, Washington State University

3. **Truck Tire Types and Road Contact Pressures**
   P. Yap, Goodyear Tire

4. **Designing Pavements for Realistic Traffic**
   J.K. Cable, S. Sermet, Iowa State University