TESTING OF ROMDAS BUMP INTEGRATOR

by

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Introduction

Highway and Traffic Consultants Ltd. (HTC) have developed and marketed the ROMDAS system for measuring roads. ROMDAS uses a personal computer to collect a range of data including roughness.

The standard roughness meter was a TRL Bump Integrator (BI), manufactured by CNS Farnell. However, it has been found that on smooth pavements this BI was not sufficiently sensitive to provide adequate results. HTC therefore developed the ROMDAS BI which has a user-selectable sensitivity with a maximum setting approximately 10 times that of the TRL BI.

In order to verify that the ROMDAS BI was giving equivalent results to the TRL BI a controlled test was done using the ROMDAS Prototype 1 BI and a CNS Farnell TRL Bump Integrator (SN 96033). The test was done using a lathe which could be set to different speeds. A eccentric connection was installed on the lathe which provided an impluse to the BI wire, causing the drum to rotate and generating pulses.

The BI were each connected to a ROMDAS which recorded 20 data points for each instrument at each speed. The data points corresponded to 100 m sampling intervals at a nominal speed of 50 km/h. A ROMDAS tester was used to generate the speed pulses, while the BI on the lathe generated the roughness meter pulses.

TRL BI Results

Table 1 shows the summary data for the TRL BI. Annex A contains the raw data.

Table 1: TRL BI Measurements

Run	Lathe Speed (RPM)	Simulated Speed (km/h)	Speed Standard Deviation	Mean BI Count (per 100 m)	BI Count Standard Deviation	Standard. BI Count (per 100 m)	Standard. BI Count Standard Deviation
1	30	50.9	3.7	10.9	0.6	10.8	1.0
2	40	50.5	3.3	14.8	1.2	14.7	1.4
3	93	51.3	3.5	34.1	0.9	33.4	2.7
4	125	50.8	3.5	46.1	1.2	45.5	3.2
5	230	51.2	3.7	81.4	2.1	79.9	6.9
6	300	52.7	2.9	111.0	1.8	105.6	6.3

It will be observed that there was some variations in the vehicle speeds between each run. This is because the pulse generator used by the ROMDAS simulator has some inherent variations. To test the implications of this the data were standardised to a speed of 50 km/h using the relationship:

ST_BI = BI * 50/SPEED

where ST_BI is the standardised BI in counts/100 m
BI is the raw BI in counts/100 m
SPEED is the simulated speed in km/h

Figure 1 and Figure 2 show the TRL BI measurements against RPM. There is a strong linear relationship for both analyses:

BI = 0.3645 RPM + 0.0043 R^2 = 1

ST_BI = 0.3481 RPM + 0.8585 R^2 = 1

Due to the nature of the measurements we would expect the intercept to be close to 0. This is the case with the raw BI data but not with the standardised data. Since we are dealing with small integer numbers, when the data are standardised the standard deviation increases and this influences the regression results.

The higher standard deviation at higher RPM may be due to vibrations in the connections having an impact.

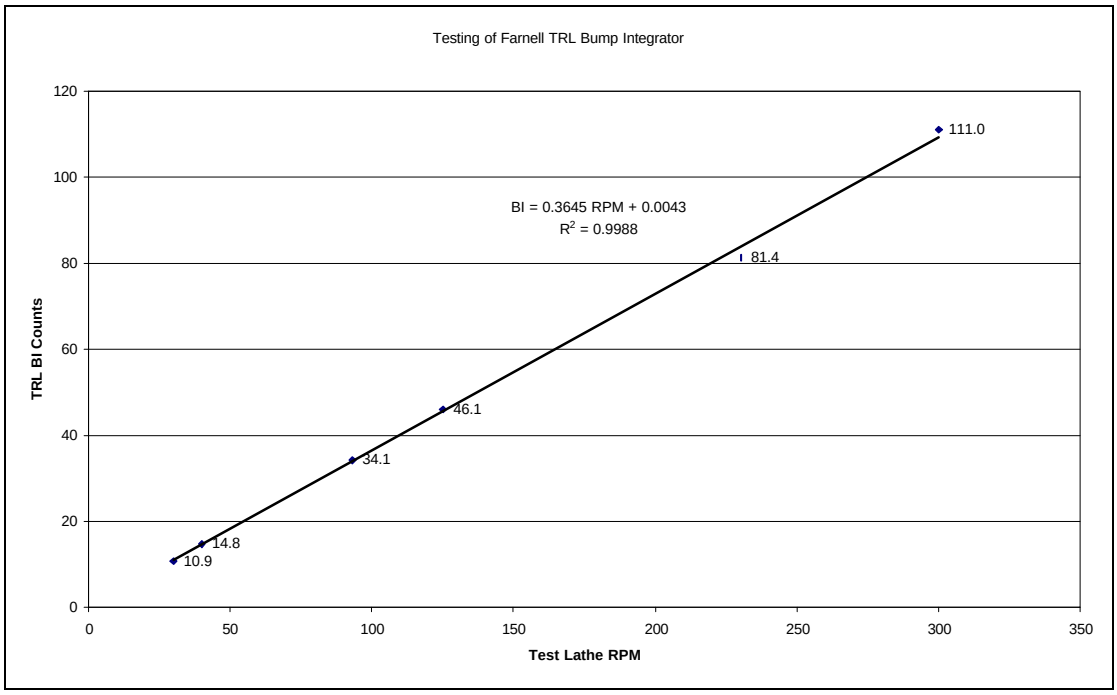

Figure 1: TRL BI Counts vs RPM

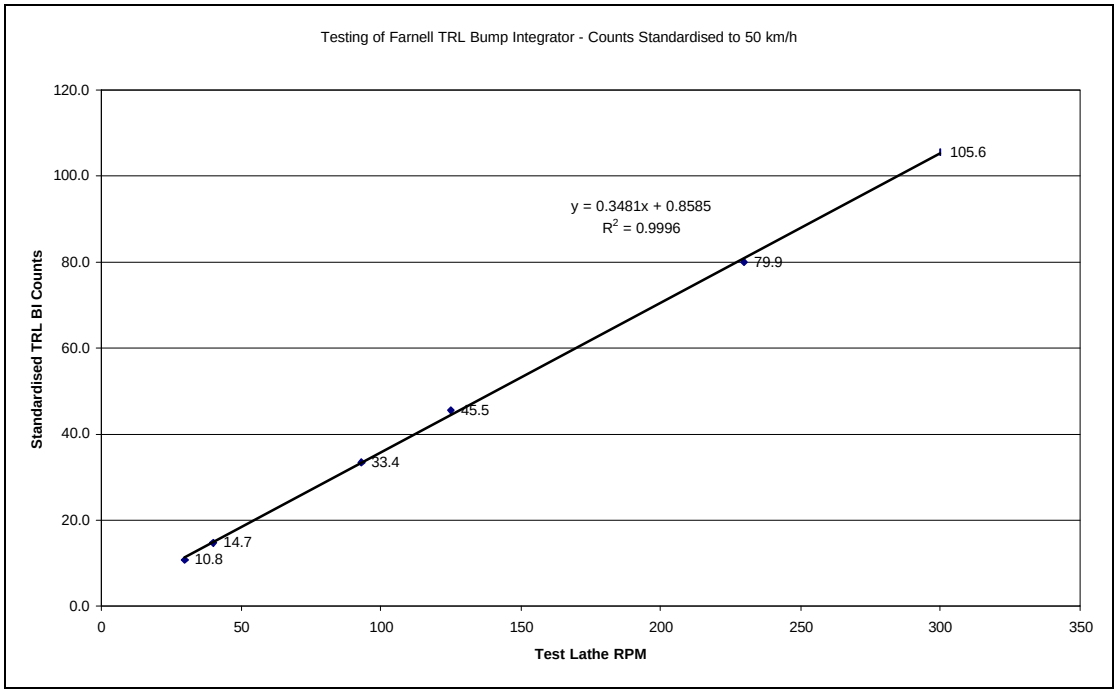

Figure 2: TRL BI Standardised Counts vs RPM

ROMDAS BI RESULTS

Table 2 shows the ROMDAS BI measurements. Annex B contains the raw data. It did not prove possible to get reliable results at the highest lathe speed due to an internal limitation of ROMDAS where a minimum time between signals is required. This limitation will be removed from the production ROMDAS units used with the ROMDAS BI but is required for the TRL BI to remove false signals.

Table 2: ROMDAS BI Measurements

Run	Lathe Speed (RPM)	Simulated Speed (km/h)	Speed Standard Deviation	Mean BI Count (per 100 m)	BI Count Standard Deviation	Standard. BI Count (per 100 m)	Standard. BI Count Standard Deviation
1	30	50.3	2.3	121.7	3.8	121.3	7.4
2	40	51.2	2.1	160.9	7.3	157.2	7.1
3	93	51.0	2.5	377.4	3.0	370.8	18.5
4	125	51.4	2.6	555.7	10.4	542.4	30.4
5	230	51.4	2.5	976.0	23.1	952.2	64.1

As with the TRL BI measurements there was some variations in the vehicle speeds between each run, but they were less in this test.

Figure 3 and Figure 4 show the TRL BI measurements against RPM. There is a strong linear relationship for both analyses:

BI = 4.3087 RPM - 8.0679 R^2 = 1

ST_BI = 4.1953 RPM -5.8492 R^2 = 1

The negative intercepts represent deviations of less than 2.5% (since there were 360 pulse/rev from the BI) so should not be viewed as having a major impact on the results.

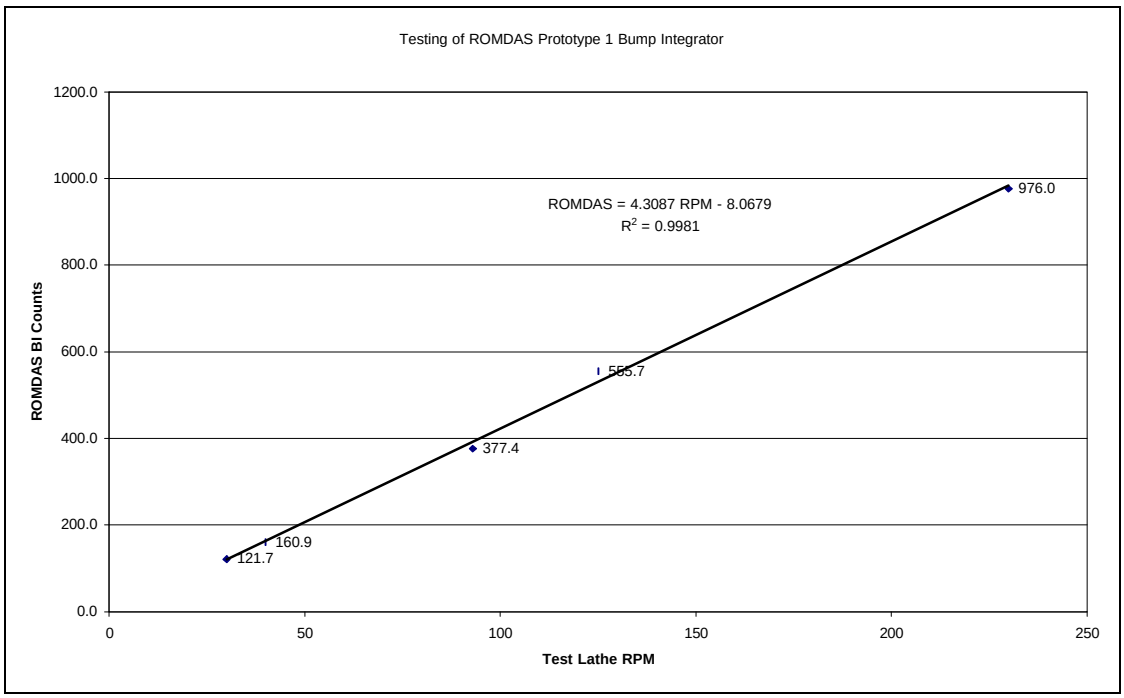

Figure 3: ROMDAS BI Counts vs RPM

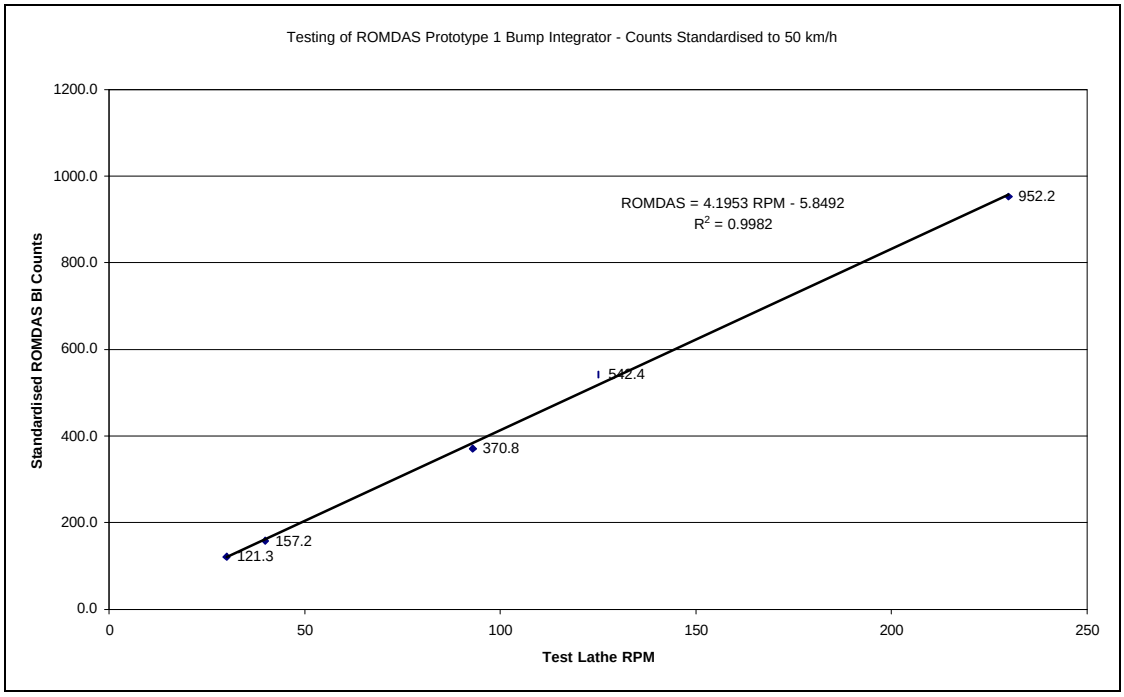

Figure 4: ROMDAS Standardised BI Counts vs RPM

Comparison of ROMDAS and TRL BI

Table 3 shows the summary statistics for the TRL and ROMDAS BI data. The data are:

- **BI** Mean BI counts/100 m
- **95% Conf** 95% Confidence Intervals (1.96 x Standard Deviation)
- **% Conf** 95% Confidence Intervals as % of the Mean
- **S.E.** Standard Error of the Estimate (Standard Deviation/SQRT(20))
- **%S.E.** Standard Error as % of the Mean

Table 3: Comparison of TRL and ROMDAS BI

Run	TRL BI					ROMDAS BI				
	BI	95% Conf	% Conf	S.E.	% S.E.	BI	95% Conf	% Conf	S.E.	% S.E.
1	10.9	1.3	11.5	0.14	1.3	121.7	7.5	6.2	0.86	0.7
2	14.8	2.3	15.8	0.27	1.8	160.9	14.2	8.9	1.62	1.0
3	34.1	1.8	5.2	0.20	0.6	377.4	5.8	1.5	0.66	0.2
4	46.1	2.3	5.1	0.27	0.6	555.7	20.4	3.7	2.33	0.4
5	81.4	4.1	5.1	0.47	0.6	976.0	45.2	4.6	5.16	0.5

The data in Table 3 show that the ROMDAS BI performed better than the TRL BI in the tests. The 95% confidence intervals were in the range of 1.5 - 8.9 per cent against 5.1 - 15.8 per cent. It is interesting that the greatest variations arose with both devices and Run 2 which suggests that there was some inherent variations in the lathe speed influencing the results.

The standard errors are another measure of confidence in the results. Here, the ROMDAS BI also performed better than the TRL BI with the standard errors in the range of 0.2 - 1.0 per cent against 0.6 - 1.8 per cent.

The results were similar with the standardised speeds with the ROMDAS confidence intervals in the range 8.8 to 13.2 versus 13.9 - 18.6 for the TRL BI; the standard errors 1.0 - 1.5 for ROMDAS versus 1.6 - 2.1 for the TRL BI.

Figure 5 shows the TRB vs ROMDAS BI values for the same runs. The relationship between the two instruments was:

ROMDAS = 12.23 TRL - 19.58 R^2 = 1

Ideally, the intercept should be 0. Further runs at lower speeds would be required to confirm why this arises. However, since the ROMDAS BI has about 10 times the sensitivity of the TRL BI, it is not surprising that there are some variations when the counts are low.

Conclusions

The analysis showed that the ROMDAS BI provides more repeatable results than the TRL BI. There is a strong linear relationship between the two instruments. It should therefore be possible to use the ROMDAS BI in place of the TRL BI and obtain equivalent, or better, results. Combined with the increased sensitivity of the ROMDAS BI over the TRL BI this should result in improved roughness measurements.

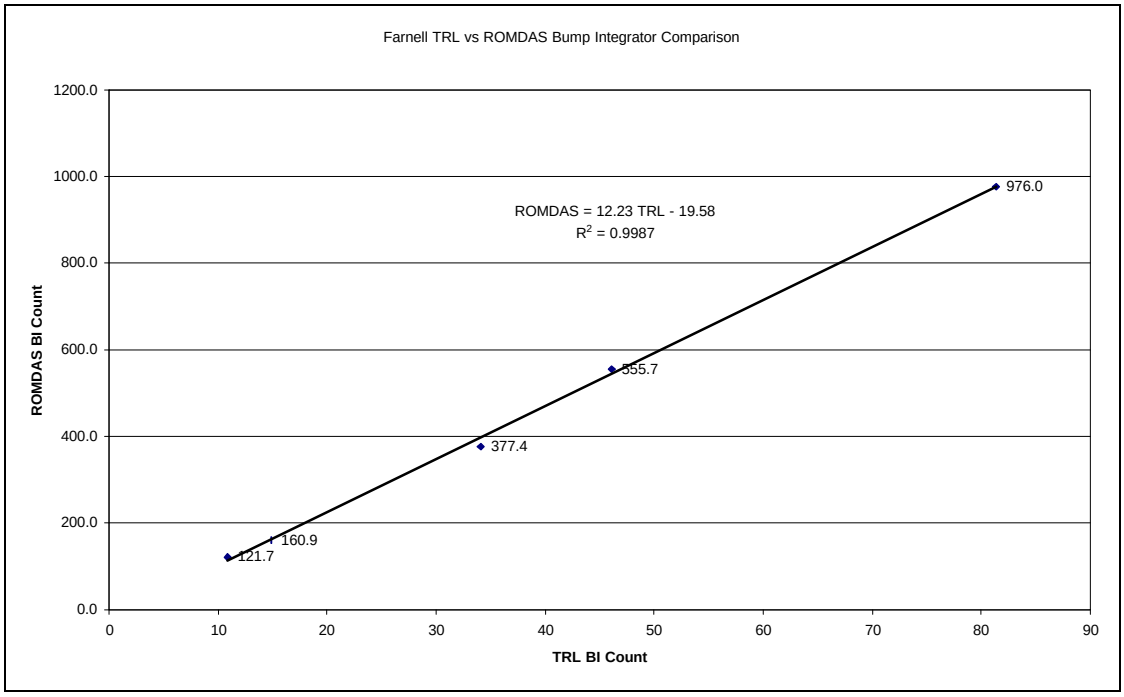

Figure 5: TRL vs ROMDAS BI Counts

Annex A - TRL BI Data

Chainage	TRL BI Data by Lathe Speed											
	30 RPM		40 RPM		93 RPM		125 RPM		230 RPM		300 RPM	
	BI	Speed	BI	Speed	BI	Speed	BI	Speed	BI	Speed	BI	Speed
100	11	49	15	48	34	48	47	55	81	48	109	55
200	10	56	16	54	34	48	47	55	83	48	111	51
300	11	49	14	48	33	51	46	48	81	48	111	48
400	10	49	14	48	35	55	48	48	84	44	112	48
500	11	49	15	54	33	55	46	48	79	48	112	49
600	12	48	15	55	34	55	47	48	80	54	110	55
700	12	55	14	48	33	55	45	48	79	48	112	48
800	11	55	14	55	34	48	48	48	85	48	110	55
900	11	48	16	55	35	48	45	48	83	55	111	55
1000	11	55	15	48	35	55	47	55	81	55	109	51
1100	11	49	14	55	34	55	45	55	82	51	113	55
1200	11	49	14	48	34	48	45	48	84	55	109	55
1300	11	49	15	48	35	48	47	48	79	55	113	55
1400	11	56	16	55	33	55	46	55	81	51	108	48
1500	11	56	13	48	33	55	46	55	83	48	114	54
1600	10	49	15	48	36	48	44	55	78	55	109	55
1700	12	48	16	48	33	48	47	55	83	55	109	55
1800	11	49	13	48	35	48	44	48	78	55	112	54
1900	10	56	14	51	35	48	46	48	83	48	111	54
2000	10	44	18	48	34	55	45	48	80	55	114	54
Mean	10.9	50.9	14.8	50.5	34.1	51.3	46.1	50.8	81.4	51.2	111.0	52.7
Standard Deviation	0.6	3.7	1.2	3.3	0.9	3.5	1.2	3.5	2.1	3.7	1.8	2.9

Annex B - ROMDAS BI Data

Chainage	ROMDAS BI Data by Lathe Speed											
	30 RPM		40 RPM		93 RPM		125 RPM		230 RPM		300 RPM	
	BI	Speed	BI	Speed	BI	Speed	BI	Speed	BI	Speed	BI	Speed
100	117	53	155	50	377	54	562	52	1016	46	Not Run	
200	127	49	164	52	378	54	547	54	966	52	Due To ROMDAS	
300	122	51	170	54	378	52	580	50	976	50	Timing Limitation	
400	119	53	160	50	377	50	557	54	1024	50		
500	125	47	155	50	373	50	544	48	988	52		
600	121	51	160	54	379	50	549	50	974	48		
700	124	46	162	50	379	50	556	50	944	50		
800	124	50	175	54	377	50	565	54	987	54		
900	124	50	156	50	377	54	556	52	974	50		
1000	124	52	155	54	372	50	552	52	955	54		
1100	121	54	154	48	375	54	553	52	962	50		
1200	124	52	155	48	381	50	560	54	971	54		
1300	125	49	176	54	376	50	541	48	964	54		
1400	123	53	161	50	383	46	553	50	959	54		
1500	124	48	155	54	382	54	560	54	979	50		
1600	123	50	156	52	373	50	570	50	1007	48		
1700	120	52	154	50	378	54	538	54	941	54		
1800	120	50	171	50	378	50	567	45	959	54		
1900	110	50	167	50	380	52	544	50	1009	50		
2000	117	46	156	50	374	46	560	54	964	54		
Mean	121.7	50.3	160.9	51.2	377.4	51.0	555.7	51.4	976.0	51.4		
Standard Deviation	3.8	2.3	7.3	2.1	3.0	2.5	10.4	2.6	23.1	2.5		