IRI Validation Test During Quality Control Operation Using Error Estimation

By

Amnon Ravina, *M.Sc.*

Geokom LTD – Civil Engineering & Geology

P.O.B 7402 Haifa 31076, Israel

Tel: 972-4-8581999, Fax: 972-4-8574448, E-mail: office@geokom.co.il

Irit Sahar, *B.Sc.*

Yotam Engineering LTD – Consulting & Pavement Design

P.O.B 7665 Haifa 31076, Israel

Tel: 972-4-8570091, Fax: 972-4-8570690, E-mail: office@yotam-eng.co.il

Arieh Sidess, *D.Sc*

Yotam Engineering LTD – Consulting & Pavement Design

P.O.B 7665 Haifa 31076, Israel

Tel: 972-4-857.0091, Fax: 972-4-8570690, E-mail: office@yotam-eng.co.il

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ABSTRACT

Roughness measurements have financial impact, on the cost & benefit of the project. Therefore, it is essential to be able to validate these tests using a simple and a practical procedure. This paper presents a method to validate the results of repeated International Roughness Index (IRI) measurements using simple analysis.

It has been found, that two additional test runs, are sufficient for evaluating the error & accuracy of the IRI measurement in cases of debates. A validation is achieved if the error of the measurement is small.

The Cross Israel Highway (CIH) project specifies IRI requirements for the roughness of the pavement. The specifications define the distribution of the results. The IRI performance of this road is the highest being achieved in Israel.

Implementing the method of defining the accuracy/error of the repeated testing and validating the original test, eliminated the dispute about the quality of the IRI measurement.

Keywords: Roughness, IRI, Quality Assurance, Quality Control, Repeatability, Precision, Bias, Validation Test, Error Calculations and Confidence Interval.

INTRODUCTION

Roughness measurements of Asphalt Concrete (AC) surface during construction or rehabilitation, as part of the Quality Control (QC) procedures, is being implemented in more and more projects around the Globe. The specifications of roughness criteria, usually includes fines and bonuses following the performance of the contractor. Since the roughness measurements have financial impact, sometimes crucial, on the cost & benefit of the project, it is occasionally required to perform, when requested, series of simple repeated testing operations to establish the claim of the authority for the fine – or to approve the claim of the contractor for the bonus.

There are some procedures to confirm and validate profiling equipment (such as ASTM E-950 [1], AASHTO PP49-03 [2]). These procedures are utilized for the initial confirmation of the profiler and for the periodical certification. All procedures include numerous repeated measurements under controlled conditions. When the equipment is accurate and well calibrated It is un-necessary and impractical to fully perform those procedures in an on going project when only a simple validation test is required to remove the doubts on the quality of the measurement.

The following paper suggests a short validation test procedure for repeated tests, whenever these are required in cases of debates.

DEFINITIONS

The **International Roughness Index** – (IRI) is a worldwide common statistical practice to quantify the serviceability of a measured longitudinal surface. The IRI simulates the vertical movements of the vehicle assuming an 80-km/h ride. It is reported in m/km [or in/mile] units.

Repeatability of profiler apparatus is the ability of the equipment to deliver the same values when the same exact profile is being measured, over and over again.

The repeatability is defined by calculating all the standard deviations of multiple observed values at each one of the specified locations along the measured pavement profile path.

The **precision** of a pavement profile measuring system is expressed as the mean of multiple repeatability Standard Deviations (SD) of the observed values at the multiple specified locations along the measured pavement profile [1].

Bias in the measurement of pavement profile, is the consistent difference between the mean value of repeat pavement profile measurements (at specified locations along the measured pavement profile) and the accepted reference value for those specified locations.

The bias in the measurement of longitudinal profile shall be the average of the individual biases at the multiple specified locations along the longitudinal profile measurement.

An accepted **reference value** for a specified location along the measured pavement profile shall be derived from an accepted **reference** pavement **profile** measuring method such as the static measurement.

The **confidence interval** (Ci90) is the interval, sourced from t-statistic test, which includes within its boundaries at 90% significance level all the values that are similar to the original one. The Ci90 can also be defined as the value of random error of the measurement at a point.

ACCURACY REQUIREMENTS

The **precision & bias** requirements for class I profiler according to the ASTM E-950 [1], are based on tightly controlled **ten repeated** profile measurements, as follows:

The precision shall not exceed 0.38 mm (0.015 in.) & the bias must not exceed 1.25 mm (0.050 in.).

AASHTO PP49-03[3] describes the field performance requirements for the profiling system to be used for QC of surface smoothness. The requirements stipulated are intended to address the need for accurate, precise, uniform and comparable profile measurements during construction. The approval of the profiling systems is based on series of well controlled **ten repeated tests** that combine true profile and IRI measurements as follows:

The precision, of the true profile measurement must not exceed 0.89mm (35 mils). The accuracy is evaluated through the average of point-by-point differences establishing two parameters, (μ_1) must be within ± 0.5mm (20 mils), and the bias (μ_2) must not exceed 1.5mm (60 mils).

The AASHTO procedure determines, in addition, the requirements for the quality of the actual IRI report of the profiler. The repeatability of the IRI measurement is being determined using precisions calculations of the total test section, 160 m (0.1 mile), these must not exceed 0.048m/km (3.0 in/mile). To evaluate the accuracy of the IRI measurement from the test data, the IRI value of the total length of the tests section must be within 0.1m/km (6 in/mile) from the reference profile.

ACCURACY CALCULATION OF THE IRI FIELD REPEATABILITY TEST

In the construction of the Cross Israel Highway (CIH) some IRI criteria were established as an acceptance tests for the asphalt layers. All the tests were performed by a well calibrated equipment (Dynatest RSP 5051 L3.2) that was tested by the manufacturer (following ASTM E-950) and successfully performed all the field tests by the operator (following AASHTO PP49-03).

Any QC test or other measurement during a construction project, should has the ability to be repeated or reproduce within defined boundaries, in cases of debate between the contractor and the enterpriser. The same roll should have been implied to the IRI measurements. Even with a well-calibrated profiler, variation can take place due to path sampling and driver skills. If there are financial fines or bonuses involve, the contractor or the enterpriser should be always entitled to perform additional independent test. However, it is impractical to perform a tightly controlled accuracy test over any section within which some results, at certain points, may be questionable.

To establish the field repeatability criterion a statistical data processing was required. A dozen sections with repeated IRI testing were collected during the routine QC measurements. Some sections were monitored with axial tracer and static measurements and with the rest of the sections no extra assisting measures were used, apart from the Road Surface Profiler (RSP) operator's experience. The sections were 300 m long. Each section was checked 10 times (9 additional checks to the first measurement) over approximately the same path. A statistical analysis was performed to each wheel path and to the center of the car, which combines a total of 36 test sections. Table 1 (A through C) and Fig 1 present a layout of a spreadsheet, as an example of one section analysis, to calculate the statistical parameters of the "IRI Field

Repeatability Test". Such an analysis was applied to each and every one of the above-mentioned sections as follows:

(1) Table 1A, specifies each precise sample (10 meters long) with a represented IRI in each of the 10 runs.

(2) The "simple statistic" table, at table no. 1a, includes: Average IRI, SD, Coefficient of Variance (CV) and the Range of reported IRI, for each sample at a point. The mean of each of the mentioned above parameters are calculated at the bottom of this table.

(3) The "Bias statistics", at Table 1C, includes the bias of each run in relation to the reference value (The average IRI of the 10 runs is considered, for this example, to be the agreed IRI for each sample i.e. the reference value).

(4) The "confidence interval" at Table 1C, presents the confidence interval at 90% significance level for each sample as the additional runs (#) are accumulated. Ci90(2) is the confidence interval at 90% significance level of the original run and the two (2) additional repeated tests.

(5) Beneath, marked as Figure 1, is the table and graph presenting the change in the random error, Ci90 vs. the additional runs. The 90, 80 and 50 percentiles are marked for each additional run for the total 300 m long test section.

    The 3rd and on additional runs are hardly influencing the random error, therefore the 90% percentile of the Ci90(2) was determined to be the value for monitoring the repeatability.

(6) At Table 1B, every sub-section, 100 m long and the complete test section, 300 m. long is being analyzed. In this table the average IRI, SD and Ci90 is calculated for each run.

In addition, the distribution and the frequency of IRI values that fall below a specification's requirements are presented.

The "average comparison" is a t-statistic test conducted to each run at every subsection:

The statistical test checks whether the average IRI ± Ci90 of a specific additional run, is being included within the boundaries of the average IRI value of the subsection.

The Dynatest test marked on this table checks whether the average IRI ± 0.1 of a specific additional test is being included within the boundaries of the average IRI value of the subsection.

(7) The "longitudinal section analysis" table, on the right side of this table on Table 1B, presents the average IRI of the sub-section, the SD, CV, Range and the total precision & bias calculated.

It is possible to observe the partial contribution of each sub-section to the test sections' conclusions due to the longitudinal division of each test section (300m) to sub-sections (100m).

It has been seen in all the measurements that ten-repeated measurements were found to be precise and accurate according to any measure. Figures no. 2A and 2B illustrates the distribution of the Ci90(2) vs. the measured IRI value, at each sample. The measurements in these figures were performed over a base asphalt course and a binder course respectively. It is clear that the Ci90(2) is a random value and it is independent of the actual measured IRI value.

Moreover, it was determined, with reference to the vast amount of test sections, that the Ci90(2) is a measure to predict the total quality of the IRI's tenth repeated measurements. If the 90% percentile of the Ci90(2) is less then 0.25 m/km, it is confident that the error after the 9^{th} additional run (when a total of 10 runs are made), Ci90(9) will withstand the AASHTO criteria for the IRI accuracy test.

Therefore, when evaluating the error of an IRI measurement, 2 additional runs, in addition to the original measurement, were found to be sufficient to determine the validation of any field measurement.

VALIDATION TEST PROCEDURE

From the field repeatability test presented above, it was concluded that in order to prove the validation of an IRI test, two additional runs of the test, are sufficient. The third additional run contributes very little to the reduction in the random error.

In the light of the above, a validation test procedure came to practice. Table no. 3A and Figure no. 3B illustrates a spreadsheet that presents the validation test procedure for the left wheel:

The analysis is conducted for each wheel separately. A test section of 300 m length is divided to sub-sections of 100m each. Every sub-section is composed of 10m length samples. For each sample there is an IRI value of the original run and two additional runs. The values at a point are used to calculate the average of the additional runs and average & SD of all the runs. The difference between each additional run to the original one is presented for each sample and the Ci90(2) is calculated.

The next table is similar to the one presented in Table 1, the “IRI field repeatability test” procedure, only here the similarity comparison is done with the original IRI test as a reference run instead of the average agreed IRI.

For each section the validation results are being marked: Is the original run, reference run, valid and/or whether the average of the additional runs can be used or should be used instead.

Figure no. 3B illustrates the results. The bottom graph illustrates the results of the additional runs on top of the original one, when the X-axis is the longitudinal path. The top graph illustrates the original IRI value vs. Ci90(2).

With this information the accuracy of the measurement of the tested section and at every sub-section of 10 m long can be quickly evaluated, when necessary to resolve debates.

The validation procedure can be used for other fields' comparison when needed such as:

- Switching between drivers/operators.
- Quality Assurance (QA) follow-up on the quality of the measurements.

CROSS ISRAEL HIGHWAY (CIH) CASE HISTORY

The Cross Israel Highway (CIH), a project of 90 km of 6 asphalt lanes, which is currently under construction by the DE-CJV (Derech Eretz-Construction Joint Venture), specifies requirements for the roughness of the pavement using the IRI scale. Unlike the common practice, where roughness is defined as an average value for a certain longitudinal distance, the CIH specifications define the distribution of the IRI results. The IRI results are reported for every 10 m sections over a distance of 300 m' lane. The specified distribution is as follows:

Wearing Course

100% of the measurement records must be below IRI = 2.3 m/km.

80% of the measurement records must be below IRI = 1.8 m/km.

50% of the measurement records must be below IRI = 1.4 m/km.

Binder Course

100% of the measurement records must be below IRI = 2.6 m/km.

80% of the measurement records must be below IRI = 2.1 m/km.

50% of the measurement records must be below IRI = 1.6 m/km.

Base-asphalt - Top Layer

100% of the measurement records must be below IRI = 3.0 m/km.

80% of the measurement records must be below IRI = 2.5 m/km.

50% of the measurement records must be below IRI = 1.8 m/km.

By defining the distribution the specification limits the appearance of local bumps and depressions. When the pavement does not meet the specs, a fine is being implemented and in extreme cases the contractor has to scarified the layer and repave it.

The validation procedure was applied on approximately 1% of the measurements. The subcontractors ordered about half of the repeated measurements. The rest of the repeated tests were applied as an internal QA tests. The validity of the first measurement was approved in all these tests.

Implementing the method of defining the accuracy/error of the repeated testing and validating the original test, eliminates the dispute about the quality of the IRI measurement. It was in spite the fact that the requirements were aimed for a high standard, which combines heavy fines for rejects. The IRI performance of the road is the highest being achieved in Israel. It is comparable with the European & American criteria.

The validation test was also used to test the skills of a newly trained operator before practicing actual measurements.

CONCLUSIONS & RECOMENDATIONS

A simple and reliable procedure is required for practicing repeated IRI testing, when these are being used as an acceptance tests with specific QC criteria.

A validation test procedure that defines the error of the IRI measurement, yielded from two additional runs, presents sufficient information to evaluate the quality and the accuracy of the IRI measurement. This can be achieved assuming that the equipment is well calibrated and the operator is trained to perform the test.

In a validation test, when the 90% percentile of the Ci90(2) is higher then 0.25 m/km, the initial measurement (i.e. the original, reference IRI) should be disqualified and be replaced by the average of the two additional runs. One can define some other limits on the Ci90(2) such as the 50% percentile.

A validations test procedure that uses only 2 additional runs is a convenient measure for QA application, to test the quality of the IRI measurements. In an on going large project such as CIH, when the rate of measurements is intensive, validation test over 1% of the sections being tested was found to be sufficient for QA purposes. The enterpriser should determine in his specifications the rate and intensity of QA testing.

If a disqualification of a reference section appears during the Quality Assurance practicing test of the IRI measurement, then the IRI measurements by the system being tested should be halted. A full repeatability test procedure should be performed to re-approve the profile measuring system.

The validation test was found to be a convenient practice to test a newly trained operator. Both, the chief operator and the newly trained operator have to achieve accurate measurements with comparable error that exist within the same defined limits.

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Table No.1a: IRI Field Repeatability Test

First Binder Asphalt Course 08/11/01 Right Wheel

Code	Station 1	Station 2	T2_R1	T2_R2	T2_R3	T2_R4	T2_R5	T2_R6	T2_R7	T2_R8	T2_R9	T2_R10	Simple Statistics Avr	StDev	CV	Range
5406	321000	320990	0.88	0.90	0.84	0.88	0.88	0.85	0.82	0.97	0.86	0.82	**0.87**	0.044	5.1%	**0.15**
5406	320990	320980	0.80	0.91	0.87	0.84	0.93	0.90	0.93	0.92	0.92	0.89	**0.89**	0.043	4.8%	**0.13**
5406	320980	320970	1.33	1.54	1.46	1.60	1.48	1.40	1.57	1.61	1.60	1.52	**1.51**	0.094	6.2%	**0.28**
5406	320970	320960	0.74	0.57	0.79	0.68	0.66	0.65	0.63	0.62	0.76	0.88	**0.70**	0.093	13.4%	**0.31**
5406	320960	320950	1.63	1.53	1.50	1.63	1.38	1.31	1.43	1.53	1.60	1.41	**1.50**	0.110	7.4%	**0.32**
5406	320950	320940	0.69	0.63	0.68	0.67	0.7	0.66	0.63	0.90	0.75	0.71	**0.70**	0.078	11.2%	**0.27**
5406	320940	320930	0.95	0.96	0.68	0.83	0.79	0.73	0.82	1.04	0.75	1.06	**0.86**	0.133	15.5%	**0.38**
5406	320930	320920	1.58	1.54	1.43	1.59	1.58	1.51	1.63	1.63	1.60	1.61	**1.57**	0.062	3.9%	**0.20**
5406	320920	320910	1.36	1.55	1.58	1.42	1.7	1.66	1.58	1.57	1.57	1.54	**1.55**	0.100	6.4%	**0.34**
5406	320910	320900	0.94	1.02	1.04	1.03	0.97	1.02	0.96		0.96	0.93	**0.99**	0.042	4.2%	**0.11**
5406	320900	320890	0.87	0.88	0.90	0.86	0.88	0.91	0.90	0.89	0.79	1.10	**0.90**	0.079	8.7%	**0.31**
5406	320890	320880	0.70	0.72	0.65	0.55	0.56	0.63	0.63	0.66	0.70	0.61	**0.64**	0.057	9.0%	**0.17**
5406	320880	320870	0.99	0.90	0.89	0.77	0.92	0.84	0.92	0.91	0.92	0.99	**0.91**	0.065	7.2%	**0.22**
5406	320870	320860	0.69	0.54	0.71	0.64	0.67	0.63	0.60	0.56	0.65	0.63	**0.63**	0.054	8.5%	**0.17**
5406	320860	320850	0.71	0.75	0.73	0.75	0.79	0.81	0.73	0.78	0.70	0.61	**0.74**	0.056	7.7%	**0.20**
5406	320850	320840	0.48	0.46	0.51	0.48	0.47	0.52	0.49	0.54	0.58	0.62	**0.52**	0.052	10.0%	**0.16**
5406	320840	320830	1.01	1.01	0.93	1.03	0.98	0.99	0.93	0.94	0.93	1.10	**0.99**	0.055	5.6%	**0.17**
5406	320830	320820	0.80	0.72	0.75	0.86	0.89	0.76	0.79	0.75	0.82	0.76	**0.79**	0.054	6.8%	**0.17**
5406	320820	320810	0.62	0.73	0.65	0.64	0.64	0.62	0.66	0.67	0.62	0.74	**0.66**	0.044	6.6%	**0.12**
5406	320810	320800	0.66	0.69	0.75	0.67	0.63	0.67	0.64	0.66	0.64	0.66	**0.67**	0.034	5.1%	**0.12**
5406	320800	320790	1.12	1.10	1.15	1.11	1.13	1.14	1.16	1.08	1.11	1.23	**1.13**	0.042	3.7%	**0.15**
5406	320790	320780	0.72	0.75	0.76	0.75	0.73	0.76	0.82	0.79	0.80	0.84	**0.77**	0.039	5.1%	**0.12**
5406	320780	320770	0.98	0.82	0.95	0.82	1.06	1.05	0.83	0.99	0.87	0.89	**0.93**	0.093	10.0%	**0.24**
5406	320770	320760	0.89	0.86	0.88	0.76	0.78	0.76	0.92	0.96	0.82	0.91	**0.85**	0.071	8.3%	**0.20**
5406	320760	320750	0.96	1.07	0.99	0.98	0.95	1.09	0.96	1.06	1.09	0.89	**1.00**	0.069	6.9%	**0.20**
5406	320750	320740	1.37	1.47	1.73	1.51	1.52	1.59	1.23	0.92	1.61	1.23	**1.42**	0.237	16.7%	**0.81**
5406	320740	320730	1.60	1.64	1.78	1.73	1.66	1.69	1.56	1.54	1.74	1.51	**1.65**	0.091	5.6%	**0.27**
5406	320730	320720	0.89	0.90	0.81	0.84	0.77	0.90	0.77	0.72	0.89	0.89	**0.84**	0.066	7.9%	**0.18**
5406	320720	320710	0.50	0.57	0.68	0.55	0.57	0.72	0.59	0.55	0.60	0.50	**0.58**	0.071	12.1%	**0.22**
5406	320710	320700	1.12	1.13	1.11	1.12	1.08	1.13	0.93	1.04	1.15	1.07	**1.09**	0.065	5.9%	**0.22**
												Average:	**0.96**	0.073	7.8%	**0.23**

Table No.1b: Longitudinal Section Analysis

												Longitudinal Section Analysis Avr	StDev	CV	Range
0-100	AVR	1.09	1.12	1.09	1.12	1.11	1.07	1.10	1.20	1.14	1.14	**1.12**	0.036	3.2%	**0.13**
	StDev	0.35	0.39	0.37	0.40	0.39	0.37	0.41	0.38	0.40	0.34				
	Ci90	0.18	0.20	0.19	0.21	0.20	0.19	0.21	0.21	0.21	0.18				
	X<2.6	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%				
	X<2.1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%			**Section Bias**	**0.072**
	X<1.6	90%	100%	100%	90%	90%	90%	90%	78%	100%	90%			**Section Precision**	**0.080**
Average	Statistics	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK				
Comparison	Dynatest	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK				
100-200	AVR	0.75	0.74	0.75	0.73	0.74	0.74	0.73	0.74	0.74	0.78	**0.74**	0.016	2.2%	**0.06**
	StDev	0.17	0.16	0.13	0.16	0.17	0.15	0.15	0.14	0.12	0.20				
	Ci90	0.09	0.08	0.07	0.08	0.09	0.08	0.08	0.07	0.06	0.11				
	X<2.6	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%				
	X<2.1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%			**Section Bias**	**0.039**
	X<1.6	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%			**Section Precision**	**0.055**
Average	Statistics	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK				
Comparison	Dynatest	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK				
200-300	AVR	1.02	1.03	1.08	1.02	1.03	1.08	0.98	0.97	1.07	1.00	**1.03**	0.042	4.1%	**0.12**
	StDev	0.31	0.33	0.38	0.36	0.35	0.33	0.28	0.26	0.36	0.28				
	Ci90	0.16	0.17	0.20	0.19	0.18	0.17	0.14	0.14	0.19	0.14				
	X<2.6	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%				
	X<2.1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%			**Section Bias**	**0.067**
	X<1.6	100%	90%	80%	90%	90%	90%	100%	100%	80%	100%			**Section Precision**	**0.084**
Average	Statistics	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK				
Comparison	Dynatest	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK				
0-300	AVR	0.95	0.96	0.97	0.95	0.96	0.96	0.94	0.96	0.98	0.97	**0.96**	0.013	1.3%	**0.04**
	StDev	0.31	0.34	0.34	0.36	0.34	0.33	0.33	0.33	0.36	0.31				
	Ci90	0.09	0.10	0.10	0.11	0.10	0.10	0.10	0.10	0.11	0.09				
	X<2.6	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%				
	X<2.1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%			**Section Bias**	**0.059**
	X<1.6	97%	97%	93%	93%	93%	93%	97%	93%	93%	97%			**Section Precision**	**0.073**
Average	Statistics	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK				
Comparison	Dynatest	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK				
Percentile100		1.63	1.64	1.78	1.73	1.70	1.69	1.63	1.63	1.74	1.61				
Percentile80		1.16	1.20	1.21	1.18	1.18	1.17	1.17	1.07	1.23	1.23				
Percentile50		0.89	0.90	0.88	0.84	0.89	0.88	0.87	0.92	0.87	0.89				

Table No.1c:IRI Field Repeatability Test, Bias Statistics Ci(90)

Bias Statistics										Confidence Interval (90)								
AV-R1	AV-R2	AV-R3	AV-R4	AV-R5	AV-R6	AV-R7	AV-R8	AV-R9	AV-R10	Ci90(1)	Ci90(2)	Ci90(3)	Ci90(4)	Ci90(5)	Ci90(6)	Ci90(7)	Ci90(8)	Ci90(9)
0.010	0.030	0.030	0.010	0.010	0.020	0.050	0.100	0.010	0.050	0.016	0.029	0.021	0.016	0.015	0.018	0.027	0.024	0.023
0.091	0.019	0.021	0.051	0.039	0.009	0.039	0.029	0.029	0.001	0.090	0.053	0.038	0.039	0.033	0.030	0.027	0.025	0.022
0.181	0.029	0.051	0.089	0.031	0.111	0.059	0.099	0.089	0.009	0.173	0.101	0.096	0.074	0.065	0.060	0.058	0.054	0.049
0.042	0.128	0.092	0.018	0.038	0.048	0.068	0.078	0.062	0.182	0.140	0.110	0.078	0.061	0.051	0.045	0.040	0.040	0.049
0.135	0.035	0.005	0.135	0.115	0.185	0.065	0.035	0.105	0.085	0.082	0.065	0.056	0.077	0.088	0.076	0.066	0.062	0.057
0.012	0.072	0.022	0.032	0.002	0.042	0.072	0.198	0.048	0.008	0.049	0.031	0.022	0.020	0.017	0.017	0.050	0.046	0.041
0.089	0.099	0.181	0.031	0.071	0.131	0.041	0.179	0.111	0.199	0.008	0.151	0.108	0.086	0.077	0.065	0.072	0.066	0.069
0.010	0.030	0.140	0.020	0.010	0.060	0.060	0.060	0.030	0.040	0.033	0.074	0.060	0.049	0.041	0.041	0.039	0.035	0.032
0.193	0.003	0.027	0.133	0.147	0.107	0.027	0.017	0.017	0.013	0.156	0.113	0.086	0.099	0.089	0.076	0.066	0.058	0.052
0.046	0.034	0.054	0.044	0.016	0.034	0.026	0.986	0.026	0.056	0.066	0.050	0.038	0.032	0.026	0.025	0.025	0.023	0.023
0.028	0.018	0.002	0.038	0.018	0.012	0.002	0.008	0.108	0.202	0.008	0.015	0.014	0.011	0.013	0.011	0.010	0.020	0.041
0.059	0.079	0.009	0.091	0.081	0.011	0.011	0.019	0.059	0.031	0.016	0.034	0.062	0.058	0.047	0.040	0.035	0.033	0.030
0.085	0.005	0.015	0.135	0.015	0.065	0.015	0.005	0.015	0.085	0.074	0.052	0.074	0.059	0.050	0.043	0.038	0.033	0.034
0.058	0.092	0.078	0.008	0.038	0.002	0.032	0.072	0.018	0.002	0.123	0.088	0.062	0.049	0.040	0.036	0.035	0.031	0.028
0.026	0.014	0.006	0.014	0.054	0.074	0.006	0.044	0.036	0.126	0.033	0.019	0.016	0.022	0.025	0.022	0.020	0.020	0.029
0.035	0.055	0.005	0.035	0.045	0.005	0.025	0.025	0.065	0.105	0.016	0.024	0.017	0.014	0.016	0.013	0.016	0.021	0.027
0.025	0.025	0.055	0.045	0.005	0.005	0.055	0.045	0.055	0.115	0.000	0.044	0.036	0.029	0.023	0.025	0.023	0.022	0.029
0.010	0.070	0.040	0.070	0.100	0.030	0.000	0.040	0.030	0.030	0.066	0.038	0.050	0.053	0.045	0.038	0.034	0.031	0.028
0.039	0.071	0.009	0.019	0.019	0.039	0.001	0.011	0.039	0.081	0.090	0.054	0.040	0.031	0.028	0.023	0.021	0.019	0.023
0.007	0.023	0.083	0.003	0.037	0.003	0.027	0.007	0.027	0.007	0.025	0.044	0.033	0.033	0.027	0.025	0.021	0.020	0.018
0.013	0.033	0.017	0.023	0.003	0.007	0.027	0.053	0.023	0.097	0.016	0.024	0.018	0.014	0.013	0.013	0.016	0.014	0.022
0.052	0.022	0.012	0.022	0.042	0.012	0.048	0.018	0.028	0.068	0.025	0.020	0.014	0.012	0.011	0.020	0.019	0.018	0.020
0.054	0.106	0.024	0.106	0.134	0.124	0.096	0.064	0.056	0.036	0.132	0.081	0.070	0.077	0.072	0.066	0.059	0.053	0.048
0.036	0.006	0.026	0.094	0.074	0.094	0.066	0.106	0.034	0.056	0.025	0.015	0.049	0.044	0.041	0.042	0.044	0.040	0.037
0.044	0.066	0.014	0.024	0.054	0.086	0.044	0.056	0.086	0.114	0.090	0.054	0.040	0.035	0.040	0.035	0.033	0.033	0.036
0.048	0.052	0.312	0.092	0.102	0.172	0.188	0.498	0.192	0.188	0.082	0.176	0.125	0.097	0.081	0.099	0.145	0.132	0.123
0.045	0.005	0.135	0.085	0.015	0.045	0.085	0.105	0.095	0.135	0.033	0.090	0.068	0.053	0.043	0.047	0.048	0.045	0.048
0.052	0.062	0.028	0.002	0.068	0.062	0.068	0.118	0.052	0.052	0.008	0.047	0.035	0.040	0.036	0.036	0.040	0.037	0.035
0.083	0.013	0.097	0.033	0.013	0.137	0.007	0.033	0.017	0.083	0.058	0.086	0.062	0.048	0.056	0.048	0.042	0.037	0.037
0.032	0.042	0.022	0.032	0.008	0.042	0.158	0.048	0.062	0.018	0.008	0.009	0.007	0.014	0.013	0.045	0.040	0.037	0.034
0.055	**0.045**	**0.054**	**0.051**	**0.047**	**0.059**	**0.049**	**0.105**	**0.054**	**0.076**	**0.058**	**0.060**	**0.050**	**0.045**	**0.041**	**0.039**	**0.040**	**0.038**	**0.038**

Figure No.1: Random Error Distribution

Percentile Calculations

	R1	R2	R3	R4	R5	R6	R7	R8	R9
Percentile100	0.132	**0.110**	0.087	0.078	0.077	0.067	0.066	0.059	0.053
Percentile80	0.090	0.089	0.071	0.064	0.058	0.050	0.052	0.047	0.048
Percentile50	0.041	0.051	0.044	0.042	0.040	0.037	0.036	0.033	0.034

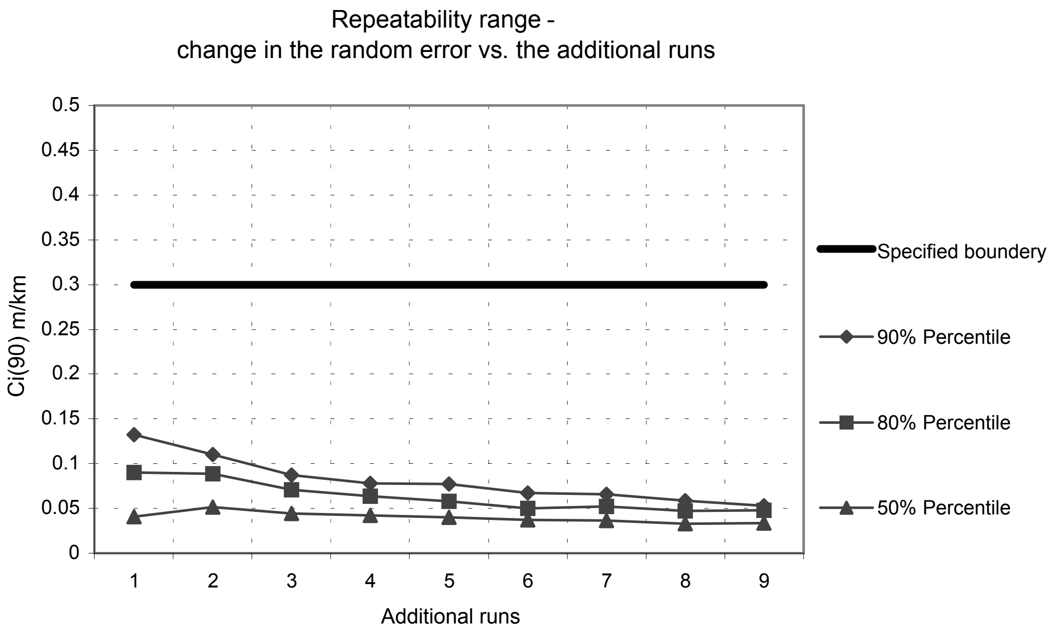

Figure No.2A: Random Error Distribution, Ci(90)vs. the IRI value
On top of Base Asphalt Layer

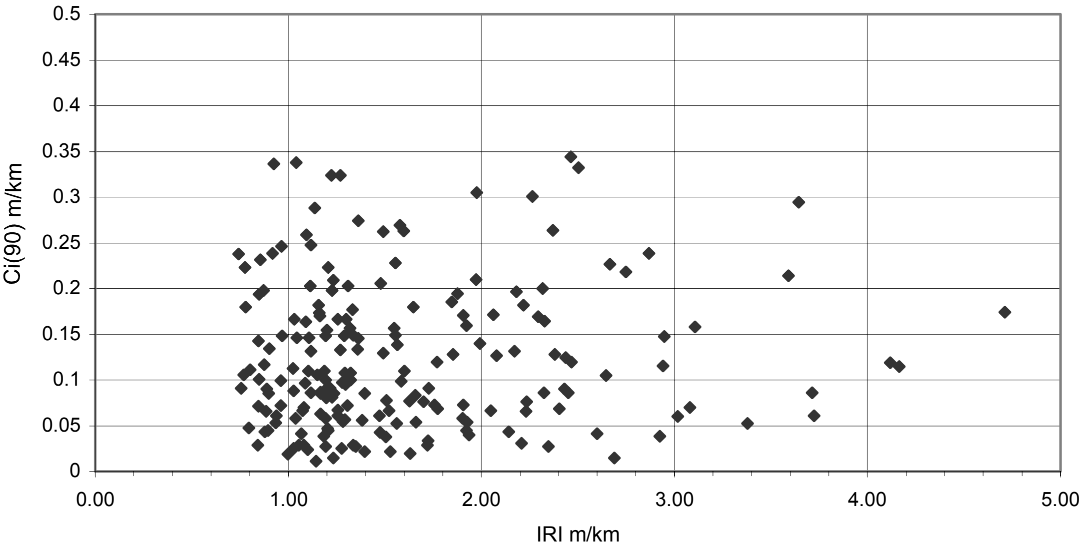

Figure No.2B: Random Error Distribution, Ci(90)vs. the IRI value
On top of Binder Asphalt Course

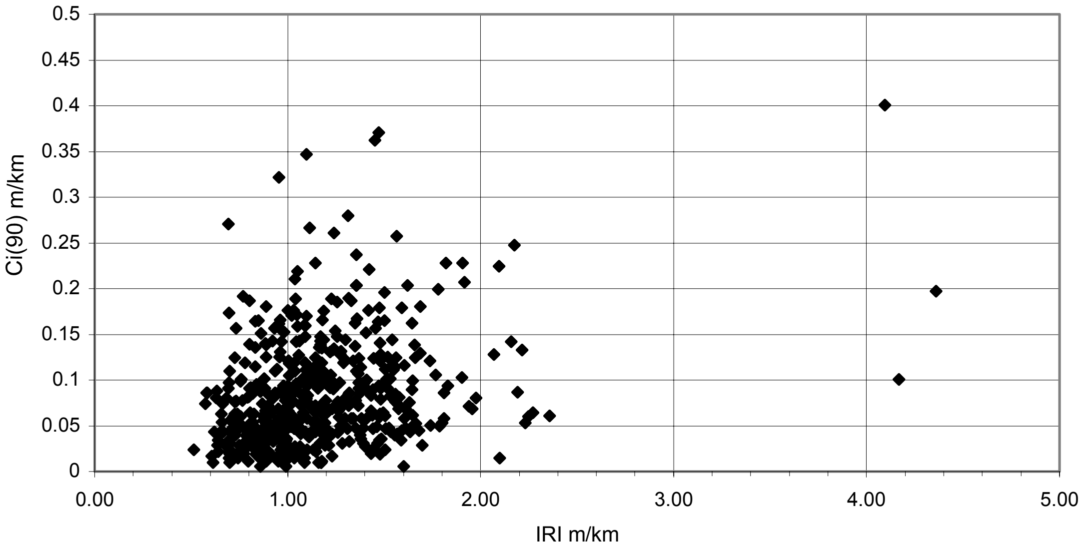

Table No.3a: Validation Test Procedure

Similarity comparison between original and additional runs -Validation test

0.3 Certification requirements

Second Binder Ac Course

Road	Carriage	Lane	Layer code	Layer	Original test's date	Additional test's date	Reason
No.6	Right	Left	3	Binder Ac	16/ 09/ 01	19/ 11/ 01	Self check

Left wheel

Station	**Reference**	*AR 1*	*AR 2*	AvrIII	AvrII	StDevIII	ref- AR1	ref- AR2	Ci90(2)		
321600	**0.53**	*0.72*	*0.72*	0.66	0.72	0.11	0.19	0.19	0.10		
321610	**0.74**	*0.81*	*0.84*	0.80	0.83	0.05	0.07	0.10	0.05		
321620	**0.68**	*0.63*	*0.65*	0.65	0.64	0.03	0.05	0.03	0.02		
321630	**1.05**	*1.02*	*1.00*	1.02	1.01	0.03	0.03	0.05	0.03		
321640	**1.25**	*1.25*	*1.16*	1.22	1.20	0.05	0.00	0.09	0.05		
321650	**1.18**	*1.17*	*1.13*	1.16	1.15	0.02	0.01	0.05	0.02		
231660	**0.84**	*0.81*	*0.87*	0.84	0.84	0.03	0.03	0.03	0.03		
321670	**1.02**	*0.96*	*0.95*	0.97	0.95	0.04	0.06	0.07	0.04		
321680	**1.46**	*1.23*	*1.25*	1.31	1.24	0.13	0.23	0.21	0.12		
321690	**1.02**	*0.87*	*0.90*	0.93	0.88	0.08	0.15	0.12	0.08		
321700	**0.52**	*0.68*	*0.68*	0.63	0.68	0.09	0.16	0.16	0.09		
321710	**0.66**	*0.61*	*0.59*	0.62	0.60	0.04	0.05	0.07	0.03		
321720	**1.52**	*1.29*	*1.35*	1.39	1.32	0.12	0.23	0.17	0.11		
321730	**1.06**	*1.22*	*1.26*	1.18	1.24	0.11	0.16	0.20	0.10		
321740	**1.02**	*0.95*	*1.07*	1.01	1.01	0.06	0.07	0.05	0.06		
321750	**0.67**	*0.84*	*0.90*	0.80	0.87	0.12	0.17	0.23	0.11		
321760	**1.25**	*0.88*	*0.93*	1.02	0.90	0.20	0.37	0.32	0.19		
321770	**0.63**	*0.75*	*0.74*	0.71	0.75	0.07	0.12	0.11	0.06		
321780	**0.95**	*1.06*	*1.02*	1.01	1.04	0.06	0.11	0.07	0.05		
321790	**1.32**	*1.69*	*1.73*	1.58	1.71	0.23	0.37	0.41	0.21		
321800	**1.12**	*1.19*	*1.23*	1.18	1.21	0.06	0.07	0.11	0.05		
321810	**1.53**	*1.18*	*1.19*	1.30	1.19	0.20	0.35	0.34	0.19		
321820	**0.75**	*0.71*	*0.66*	0.71	0.69	0.04	0.04	0.09	0.04		
321830	**1.17**	*0.93*	*0.92*	1.01	0.93	0.14	0.24	0.25	0.13		
321840	**0.69**	*0.75*	*0.76*	0.73	0.75	0.04	0.06	0.07	0.04		
321850	**0.82**	*0.52*	*0.55*	0.63	0.54	0.17	0.30	0.27	0.16		
321860	**1.26**	*0.89*	*0.91*	1.02	0.90	0.21	0.37	0.35	0.20		
321870	**1.19**	*0.99*	*0.95*	1.04	0.97	0.13	0.20	0.24	0.12		
321880	**1.17**	*1.02*	*1.02*	1.07	1.02	0.09	0.15	0.15	0.08		
321890	**0.91**	*0.97*	*1.00*	0.96	0.99	0.05	0.06	0.09	0.04		
				0.97	**0.96**	**0.09**	**0.15**	**0.16**	**0.09**	0.19	90%percentile
										0.12	80%percentile
										0.07	50%percentile

Section		**Reference**	*AR1*	*AR2*	AvrIII	AvrII	
0-100	AVR	**0.98**	*0.95*	*0.95*	0.96	0.95	**Section Bias: 0.089**
	StDev	**0.28**	*0.22*	*0.19*	0.23	0.20	**Section Precision: 0.057**
	Ci90	**0.15**	*0.11*	*0.10*	0.12	0.11	
	X<2.6	**100%**					
	X<2.1	**100%**					
	X<1.6	**100%**					
Average Comparison	Stat.		*OK*		OK	OK	
	Reproduction 0.2		*OK*		OK	OK	
100-200	AVR	**0.96**	*1.00*	*1.03*	0.99	1.01	**Section Bias: 0.180**
	StDev	**0.34**	*0.33*	*0.34*	0.32	0.34	**Section Precision: 0.108**
	Ci90	**0.17**	*0.17*	*0.18*	0.17	0.18	
	X<2.6	**100%**					
	X<2.1	**100%**					
	X<1.6	**100%**					
Average Comparison	Stat.		*OK*		OK	OK	
	Reproduction 0.2		*OK*		OK	OK	
200-300	AVR	**1.06**	*0.92*	*0.92*	0.97	0.92	**Section Bias: 0.190**
	StDev	**0.26**	*0.21*	*0.22*	0.21	0.21	**Section Precision: 0.111**
	Ci90	**0.14**	*0.11*	*0.11*	0.11	0.11	
	X<2.6	**100%**					
	X<2.1	**100%**					
	X<1.6	**100%**					
Average Comparison	Stat.		*OK*		OK	NC	
	Reproduction 0.2		*OK*		OK	OK	
0-300	AVR	**1.00**	*0.95*	*0.96*	0.97	0.96	**Section Bias: 0.153**
	StDev	**0.29**	*0.25*	*0.25*	0.25	0.25	**Section Precision: 0.092**
	Ci90	**0.09**	*0.08*	*0.08*	0.08	0.08	
	X<2.6	**100%**					
	X<2.1	**100%**					**Reference is valid**
	X<1.6	**100%**					
Average Comparison	Stat.		*OK*		OK	OK	Average III is also valid
	Reproduction 0.2		*OK*		OK	OK	
Percentile100		1.53	1.69	1.73			
Percentile80		1.25	1.18	1.16			
Percentile50		1.02	0.94	0.94			

Figure No.3b: Validation Test Procedure