Data Collection Ltd.

Validation of ROMDAS Z-250 Reference Profiler

April 2002

Data Collection Ltd.
P.O. Box 348
Motueka 7161
NEW ZEALAND

Ph: +64-3-528-8212
Fax: +64-3-528-8213
info@romdas.com
www.romdas.com

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Data Collection Ltd.
P.O. Box 348
Motueka, 7161
NEW ZEALAND
Phone: +64-3-528-8212
Fax: +64-3-528-8213
info@ROMDAS.com
www.ROMDAS.com

REVISIONS

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1 Introduction

Measuring Road Roughness

Road roughness is an important attribute both for monitoring the condition of the pavement and also because of its impact on user costs. Roughness is measured using several different techniques:

- Direct measurements of the road elevations using instruments such as rod-and-level surveys or manually operated instruments designed for such measurements;
- Indirect measurements of the road elevations using non-contact sensors such as lasers or ultrasonics;
- Mechanical instruments such as the Bump Integrator.

Reference Profilers

Reference profilers are used for very accuracy direct measurements of road elevations. They are also used to validate non-contact instruments, and calibrate mechanical instruments. Referred to as **Class I** profilers[1], they represent the most accurate method for measuring roughness.

The two most commonly used reference profilers are:

- Face Dipstick®. Manufactured by the Face Company in the USA, this consists of a precision inclinometer which is manually 'walked' down the road. It is paused at each placement and a reading is taken.
- ARRB TR Walking Profiler®. Manufactured by ARRB Transport Research of Australia, this instrument is pushed along the road.

The Face Dipstick is the most widely used and accepted class 1 profiler by pavement engineers and researchers alike[2].

Z-250

Data Collection Ltd (DCL) design, manufacture, and sell a range of vehicle mounted instrumentation for the measurement of pavement condition. In response to requests from our customers, the Z-250 was developed as a low-cost reference profiler.

It is operated in a similar manner to the Face Dipstick, but the data are recorded on an industry standard iPaq Pocket PC computer. The data are also processed using the industry standard RoadRuf software.

The Z-250 samples the vertical elevation (Z) at 250 mm intervals at it is walked along the pavement, pausing for each elevation.

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1 Sayers, M., *et al.* (1986). Guidelines on Calibrating Roughness Meters. World Bank Technical Report 46. The World Bank, Washington, D.C.

2 Opus International Report No. 97-529351 Transfer Function Based Performance Specifications for Inertial Profilometer Systems. Opus Central Laboratories, Lower Hutt.

The Z-250 manual can be downloaded from www.ROMDAS.com.

Z-250 Validation

This report describes the results of validating the Z-250 against a Face Dipstick. The objective was to confirm that the Z-250 would qualify as a Class I reference profiler.

2 Experimental Procedure

Class I Standard

The definition generally accepted for a Class I reference profiler is that adopted in ASTM standard E950(94). The Class I profiler must measure the true IRI, have negligible random error, a minimum sampling interval no greater than 300mm, and have a demonstrated accuracy of better than 2% over a 320m length test section.

The profiler must also record the longitudinal profile such that this can then be used in the IRI algorithm developed by the University of Michigan.

Reference Instrument

The validation was done using the Face Dipstick owned by Transit New Zealand.

Prior to calibration it was checked against the reference spacers and calibration platform supplied by ARRB as part of their Walking Profiler kit, and the calibration spacers normally supplied with the Z250. All spacers used had traceable certification, (to international standards) of their accuracy.

Validation Sites

The validation was done in New Zealand and Fiji:

- **New Zealand**: Site 6, one of several Transit New Zealand reference sites, was chosen for the validation. This was a relatively straight site with significant vertical curvature. It was constructed approximately 15 years ago and consisted of a grade 6 chips seal or surface treatment (5mm stone) which had a recent grade 3 (15mm stone) surface treatment overlay. Measurements both before and after the surface treatment were undertaken giving results for both high and low texture surfaces. The traffic volumes on this road were very low and the pavement was in good condition with no patching.

- **Fiji:** The FRUP calibration sites at Princes Rd and Sekoula Rd. were used. These sites were chosen as they have IRI ranging from 2 – 10 IRI m/km. All three sites were surface treatment types with low texture. Pavement condition varied from good to poor, with considerable areas of patching on the rougher sections. The 100m sections within each site were, however, homogeneous.

Site Measurements

At each site 300m long wheel paths were marked out as follows:

- A reference tape measure (fibre glass surveyors tape) was used to mark out 50m subsections along the pavement and a string line was placed on the wheel path between the 50m marks.

- At approximate 1m intervals site marks were painted to guide the profilers and hence profile the same pavement section.
- The string line was then moved along the pavement and the pavement marked in this manner for the entire 300m. This provided a wheel path guideline from which the measurements were taken.
- Profile measurements were made with both instruments, and repeat profiles using the Z-250 were also collected from the some sites.

3 Data Analysis

IRI Statistic

The IRI was calculated using the UMTRI RoadRuf software for each 100m section surveyed with both devices within each 300m site. Note 100m is the standard reporting interval for many road condition monitoring surveys and therefore it is reasonable to validate the instrument at this reporting interval.

Comparison of Means

The mean roughness from the Z-250 for Fiji was 4.89, versus 4.91 for the Dipstick. The standard deviations were 2.37 and 2.40 respectively. A comparison of means test (t-test) was done using these data. This showed that the means were not significantly different at 99% confidence.

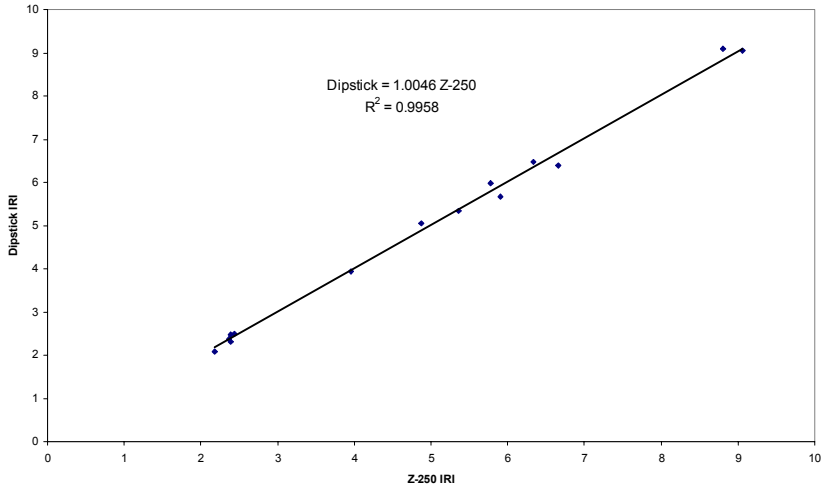
100 m IRI Results

Ideally, the 'true' roughness of each site would be estimated by performing several repeat runs with the Dipstick, and taking the average. The Z-250 data would then be compared against this. However, time constraints did not permit this to be done.

As shown below, the two instruments had excellent correlation. The relationship between Dipstick IRI and Z250 IRI is defined by the equation:

$$DIPSTICK = 1.0046\ Z\text{-}250$$

where DIPSTICK is the Dipstick 100 m IRI m/km
Z-250 is the Z-250 100 m IRI m/km



Assuming that both instruments are measuring the true IRI for the site then the average of the two measurements would represent the "true"

roughness.

In all but three cases, the Z250 100m IRI was within 2% of the true site IRI, and only exceeded the 2% tolerance by 0.02, 0.01, and 0.01 IRI. Remembering that this is the 100m IRI and the 2% error limit for Class 1 profilers applies to a 320m site length, then we would expect that all data would be within the required 2% tolerance if we were to calculate the 300m IRI.

Longitudinal Profile

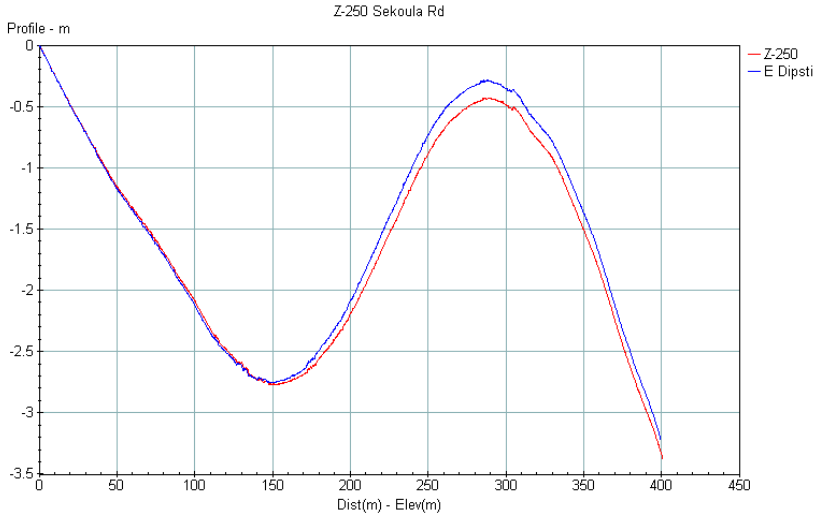
While the calculation of IRI is one test of a good profiler, it is also important to look at the frequency response of the profiler as this can also have a detrimental effect on the accuracy if pavements of a particular roughness wavelength are being surveyed.

Longitudinal profile data can be imported into the RoadRuf program and selectively filtered and viewed for any variation in amplitude of the longitudinal profile plot. While this is only a subjective procedure it is possible to review the frequency response using the method adopted by the Austroads guide and reviewed in Opus report described above in the footnote. If significant variation is observed then this process would be recommended.

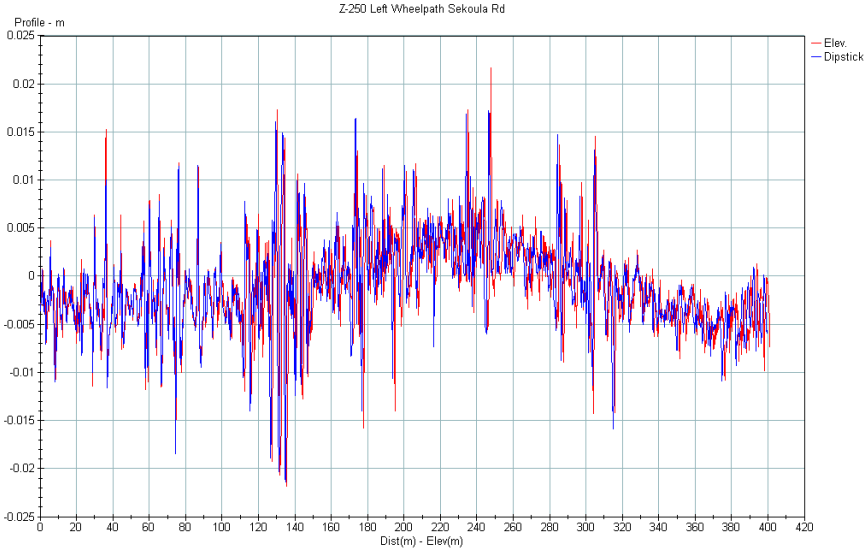
Figures 1 through 4 below shows the unfiltered and filtered longitudinal profiles. Filtering using the UMTRI RoadRuf software at 50, 10, and 5m filters respectively for both the Dipstick and the Z-250. These filtering frequencies were chosen for the following reasons:

- Pavement wavelength is calculated for pavement roughness with wavelengths between 0.5 and 50m, therefore filtering out wavelengths longer than this shows all the data considered in the IRI calculation.
- IRI can be considered as a band pass filter with two response peaks 10-20m and 2-5m respectively. Filtering at 10 and 5m allows us to view the data with the most significant influence on IRI.

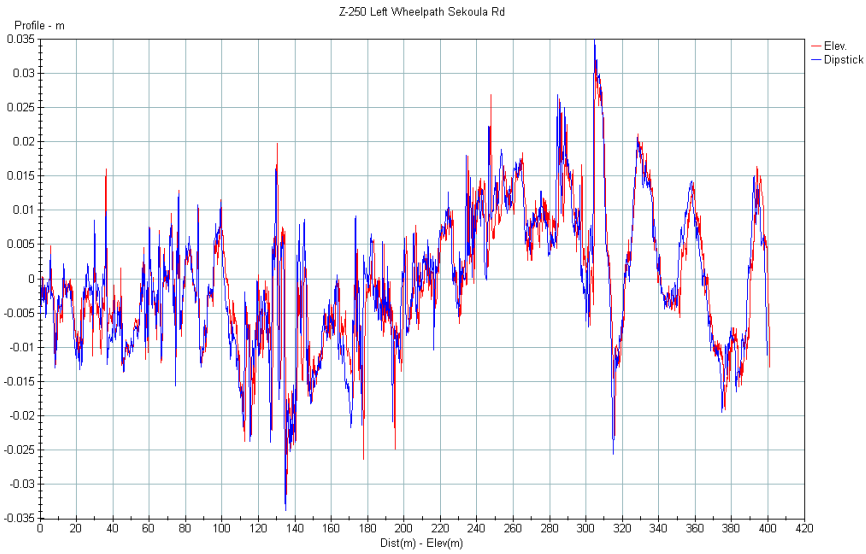
It will be noted that both instruments show a similar response for all filters.



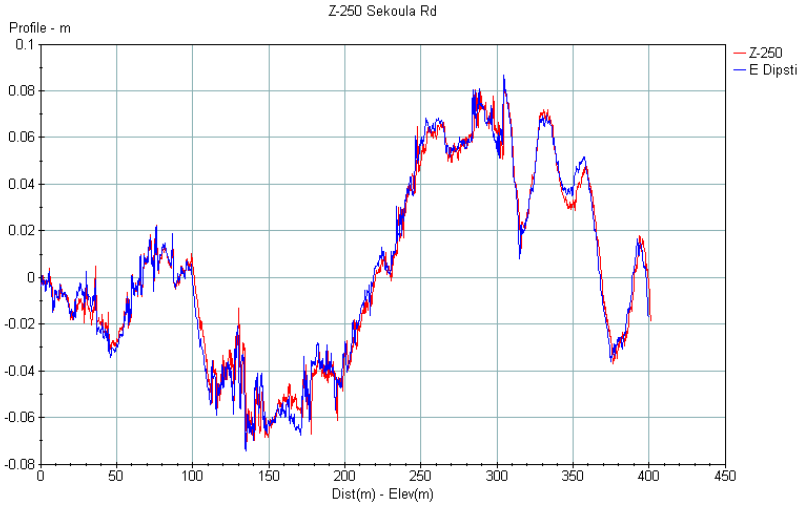
Dipstick and Z-250 Profiles – Unfiltered



Dipstick and Z-250 Profiles – Filtered at 5 m



Dipstick and Z-250 Profiles – Filtered at 10 m



Dipstick and Z-250 Profiles – Filtered at 50 m

4 Conclusions

IRI Calculations

The intended use of the Z-250 and other Class I profilers is as a reference from which other vehicle mounted equipment might be calibrated or accurate monitoring of road roughness can be made. Therefore it is essential to ensure that this equipment will give good results regardless of the surface type and surface roughness. This study considered both the surface type and roughness range in the validation:

- The validation sites selected represent different seal types and textures, in particular surface types which have shown to cause problems with the accuracy of the measured roughness were included.

- The pavement roughness ranged from 2 IRI to 10 IRI m/km, and while conditions outside these limits might be experienced it is unlikely that they would be included as equipment calibration sites.

There was no statistically significant difference in the mean roughnesses from the Z-250 and the Face Dipstick.

In all but three cases the 100m values for the Z 250 were within 2% of the mean value for a 100m section IRI calculation. These results indicate that the 2% accuracy requirement for the Class I profiler (for 320m) will be achieved.

Since the measurements were completed over several weeks at different sites this suggests that the measurements are stable over time, and that operator error effects are likely to be minimal.

Longitudinal Profile

The results indicate that both profilers are measuring the same amplitude wavelength and do not require further analysis. There is no evidence that would suggest any gain or attenuation of a particular wavelength.