R&T UPDATE
Concrete Pavement Research & Technology

REPEATABILITY TESTING OF A MODIFIED AMES LISA PROFILER FOR USE ON TINED CONCRETE

An experiment was recently conducted which evaluated the repeatability of two modified versions of a Lightweight Inertial Surface Analyzer (LISA) on coarse-textured concrete pavement. The LISA is a lightweight profiler produced by Ames Engineering. The modifications were implemented by Ames Engineering in a direct effort to improve the repeatability of profile measurement on coarse-textured pavement. This was done as a follow-up of and in response to a broader study of lightweight profiler repeatability and reproducibility sponsored by ACPA and the Michigan Concrete Paving Association. In the ACPA study, the participating profilers, as a group, exhibited unacceptable reproducibility on tined concrete.

The purpose of this follow-up experiment was to rate the repeatability of two modified versions of the Ames LISA and potentially qualify them as sufficiently repeatable for use on longitudinally and transversely tined concrete pavement. The qualification was based on comparison of profile measurements, using the same analysis methods as in the original ACPA study.

Test Sites

The profile measurements took place in Boone County, Iowa on October 17, 2003. Testing began at 9 AM and was completed by 11:30 AM. This was a sunny day with scattered clouds. The temperature was 40°F at 7:30 AM, and increased to 65°F by noon. The test site was on County Road E-57 west of Iowa 17, just west of the Town of Luther, approximately 10 miles southwest of Ames. The site included three test segments: (1) concrete with a light (smooth) turf drag, (2) transversely tined concrete, and (3) longitudinally tined concrete.

Each of the three test segments was 528 feet long with more than 500 feet available for run-up and run-off. The measurement track of interest was located 3 feet off the right edge of the pavement and was delineated with a keel mark every 15 feet. Operators were able to set guide markers over the edge line.

The longitudinally tined segment had a 3/4 inch uniform spacing, a depth of about 1/8 inch, and uniform appearance. It was a new pavement constructed in the fall of 2003 with skewed joints spaced 15 feet apart. The transversely tined segment had “random” spacing that repeated on a 1 foot interval. The individual tine spacings ranged from 5/8 inch to 1 ½ inches. It was an older pavement (20 years) which had several quarter-sized popouts in its surface. The joints were skewed and spaced 15 feet apart. The segment with a smooth turf drag was a very old pavement (more than 30 years) that was still in very good condition, with the exception that several quarter-sized popouts appeared on the surface. This pavement had right angle saw cut joints, spaced 40 feet apart.

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Profilers Tested

Two Ames LISA models were used. The first was a standard (unmodified) Ames LISA owned and operated by the Iowa Department of Transportation. This device is designated as profiler configuration number 1. It served as the experimental control, to help show the level of improvement provided by the modified device. The second was an experimental profiler owned and operated by Ames Engineering. The profiler was modified to include two optional configurations. These are designated as profiler configuration numbers 2 and 3.

Profiler Comparison

The main focus of this experiment was repeatability of profile measurement. Direct profile comparison is necessary in any study of the repeatability of profilers, because index values may compare favorably due to compensating error. Profile comparison will reveal these instances. An objective method of assessing profile agreement called cross correlation was used for this purpose. This is the same method that was used in the original ACPA profile measurement study. A good rating by this method provides a reasonable expectation that the profiles and summary index values will agree on the same type of pavement in the field.

The cross correlation method provides a rating of agreement ranging from -100 to 100, where a value of 100 indicates perfect agreement. Any disagreement in overall roughness level or profile shape will degrade the value. The method can also be customized to emphasize the most relevant profile features. This is done by applying a filter to the profiles before they are compared. In this study, the output of the IRI filter was used as the main indicator of profile agreement. The original ACPA study sought a value of 95 for repeatability of IRI filter output. This is still considered the ideal benchmark for profiler repeatability. Three other filters, emphasizing long, medium, and short wavelength contents were also studied for diagnostic purposes.

The table below provides a summary of the cross correlation level observed for IRI filter output. In the table, the repeatability ratings are the average of all possible comparisons for a given profiler in a given road segment. Since each profiler configuration measured each site five times, the values in the table are the average of 10 comparisons. The next table provides the repeatability ratings for long (25-125 foot), medium (5-25 foot), and short (1-5 foot) wavelengths.

Repeatability Rating for IRI Filter Output

Ames Profiler Configuration	Smooth Turf Drag	Transverse Tining	Longitudinal Tining
1	93	94	60
2	96	98	85
3	97	97	88

Repeatability Rating in Various Wavelength Ranges

Ames Profiler	Smooth Turf Drag			Transverse Tining			Longitudinal Tining		
Configuration	L	M	S	L	M	S	L	M	S
1	97	92	77	99	92	72	81	53	30
2	97	95	84	98	98	89	92	81	61
3	95	97	88	99	97	88	92	87	72

L – Long Wavelengths M – Medium Wavelengths S – Short Wavelengths

International Roughness Index Results

Each profiler configuration measured each segment five times. The table below lists the average International Roughness Index (IRI) measured by each configuration on each site. The table also lists the standard deviation of each group of measurements, first in inches per mile, and then as a percentage of the average IRI.

Summary of IRI Results

Site	Ames Profiler Configuration	International Roughness Index		
		Average (in/mi)	St. Dev. (in/mi)	Normalized St. Dev. (%)
Smooth Turf Drag	1	85.0	1.5	1.7
	2	86.4	0.4	0.5
	3	85.7	0.3	0.4
Transverse Tining	1	130.5	0.7	0.6
	2	128.2	1.0	0.8
	3	129.8	1.4	1.1
Longitudinal Tining	1	87.6	2.8	3.2
	2	69.8	2.0	2.8
	3	67.6	2.0	2.9

All three configurations provided very repeatable IRI values on the segment with a smooth turf drag and the transversely tined segment. The configurations also agree with each other extremely well on these segments. On the longitudinally tined site, all three configurations still exhibited good repeatability, but the modified configurations did not agree with the original configuration at all.

Overall:

- All three configurations showed a low standard deviation on the smooth turf drag and transverse tined sites.
- All profilers showed the highest standard deviation on the longitudinally tined site, although the standard deviation was not critically high.
- The IRI values produced by configurations 2 and 3 were 18 to 20 in/mi lower than those produced by configuration 1 on the longitudinally tined site. It is suspected that much of this reduction is due to their ability to prevent contamination of the profile by coarse texture. This is a successful step in the direction of improving lightweight profilers for use on coarse-textured pavement.

The IRI values produced by configurations 2 and 3 were 18 to 20 in/mi lower than those produced by configuration 1 on the longitudinally tined site. This is a successful step in the direction of improving lightweight profilers.

The third observation is very important. Profilers misinterpret longitudinal tining when the narrow footprint of conventional height sensors drifts slowly into and out of the troughs. This causes texture to erroneously appear as features that would adversely affect ride quality. Configurations 2 and 3 may have successfully reduced this type of error to an acceptable amount.

Conclusions

Smooth Turf Drag:

- IRI filter output showed good repeatability with the unmodified profiler (#1) and excellent repeatability with both modified configurations (#2 and #3).

- The level of repeatability, 96 and 97, indicates that enhanced profilers (#2 and #3) can be expected to provide consistent IRI results on concrete pavement with a smooth turf drag finish.
- All three profiler configurations measured long wavelength content with excellent repeatability and medium wavelength content with good or excellent repeatability. The two enhanced configurations (#2 and #3) showed slight improvement in the medium wavelength range and significant improvement in the short wavelength range.

Transverse Tining:
- IRI filter output showed good repeatability with the unmodified profiler (#1) and excellent repeatability with both modified configurations (#2 and #3).
- The level of repeatability, 98 and 97, indicates that modified profilers (#2 and #3) can be expected to provide consistent IRI results on transversely tined concrete pavement.
- All three profiler configurations measured long wavelength content with excellent repeatability, and the two modified configurations (#2 and #3) showed noticeable improvement in the medium and short wavelength range.

Longitudinal Tining
- IRI filter output showed poor repeatability with the unmodified profiler (#1) and fair repeatability with profiler configuration 2.
- In profiler configuration 3, the IRI repeatability rating was 88. A recent research study reported that a rating of 88 means that a profiler can be expected to provide IRI values within 10 percent on multiple runs over the same type of pavement. This rating is not ideal, but it is a tremendous improvement.
- The unmodified profiler did not measure any wavelength range with good repeatability. Both modified configurations improved repeatability in all wavelengths, but configuration 3 improved matters much more than configuration 2 in the medium and short wavelength ranges.
- The longitudinally tined segment used in this experiment was more challenging than the longitudinally tined site used in the original ACPA experiment. Note that the unmodified Ames profiler achieved a repeatability rating of only 60 on this segment. The same make and model of profiler achieved a rating of 87 in the original experiment on a longitudinally tined test site in Michigan.

Recommendation

While this recent experiment found that slight improvements are still necessary on the modified LISA for it to meet ACPA's repeatability standard for coarse longitudinal textures (e.g. longitudinal tining), ACPA encourages contractors wishing to improve the reliability of their surface profile measurements to consider a modified LISA profiler. As of the beginning of 2004, Ames Engineering, Inc. is the only lightweight profiler manufacturer that has demonstrated improved equipment for smoothness profiling of coarse-textured pavement. The modified LISA profiler meets the repeatability standard for transverse tining, and Ames Engineering, Inc. has also made great strides in improving LISA for longitudinal tining.

References

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