R&T UPDATE
Concrete Pavement Research & Technology

COARSE-TEXTURED PAVEMENTS AND LIGHTWEIGHT PROFILERS: PART 1

The smoothness or ride quality of a pavement is the user's primary determination of pavement quality. Smoother pavements have been shown to perform longer and at a better service level. Historically, pavement smoothness has been measured immediately after construction using a California-type profilograph. However, recent years have seen an increased desire to use laser-type profilers for construction quality and acceptance as well as long-term pavement performance monitoring.

A relatively new category of equipment, lightweight inertial profilers, are increasingly used for construction control and verification. However, the accuracy, repeatability, and reproducibility of these devices have not been adequately addressed.

Repeatability refers to how well a given profile device can generate the same measurement on the same segment of road under the same conditions. Reproducibility refers to how well two or more profile devices can generate the same measurement on the same segment of road under the same conditions. Repeatability and reproducibility of profile devices are key issues to both the contractor and the owner or specifying agency in regard to compliance with ride quality specifications, incentive and disincentive pay, extent and location of remedial diamond grinding, and so on.

Profile indices such as the International Roughness Index (IRI) are based on profile measurements conducted on both new and in-service pavements. The qualification of roughness, as determined by an index value calculated from a profile created by lightweight profilers, will not necessarily agree with the perceptions of the traveling public. Coarse surface textures such as transverse and longitudinal tining, and the presence of transverse joints, strongly influence the calculated profile index although they have little or no effect on true ride quality.

The Lightweight Profiler Experiment

In order to address the issues of surface texture and its corresponding effect on profile index and the repeatability and reproducibility of current profiling equipment, a comprehensive ride quality experiment was devised. Phase I of the experiment was conducted on July 9 and 10, 2002 at four locations in southeastern Michigan, each site representing a different pavement surface texture. The location of the test sites and corresponding pavement information are presented in Table 1.

Four categories of profile measurement devices participated in Phase I of the experiment as well as a rod and level survey to establish a reference pavement profile. Specific information regarding the devices evaluated is presented in Table 2.

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Table 1. Test site location and relevant pavement information.

Test Designation	Location	Pavement Type	Surface Texture	Notes
Site 1	Access road to Capital City Airport Lansing, Mich.	Dense graded asphalt	Typical of high-fines AC surface course	IRI ≈ 150 in./mi. (moderately rough)
Site 2	I-75 near Bay City, Mich.	Jointed reinforced concrete 27 ft. joint spacing (new construction)	Longitudinal tining	IRI ≈ 90 in./mi. (smooth)
Site 3	Access road to General Motors Proving Grounds Milford, Mich.	Jointed plain concrete 23.5 ft. joint spacing	Broom finish	IRI ≈ 135 in./mi. (moderately smooth)
Site 4	M-5 extension near Novi, Mich.	Jointed plain concrete 15 ft. joint spacing (new construction)	Transverse tining, randomly spaced	IRI ≈ 60 in./mi. (smooth)

Table 2. Profile measurement devices used in the experiment.

Device Classification	Equipment Type or Manufacturer
Static	Rod and Level
Walking Speed Profiler	SurPro 1000
	ARRB Walking Profiler
Lightweight Inertial Profiler	International Cybernetics Corp. [ICC]
	Dynatest/KJL 6400
	Surface System Instruments [SSI]
	Ames Engineering Lightweight Inertial Surface Analyzer (LISA), 3 devices
High Speed Inertial Profiler	Michigan DOT
	Dynatest RSP 5051
	Surface System Instruments [SSI]
Profilograph	James Cox and Sons

Profile Determination

The ride quality experiment was designed to evaluate the performance of lightweight profilers. However, three additional categories of profile measuring equipment were included to compare results under controlled conditions. Of specific interest was the performance of the lightweight profilers compared with the high-speed inertial profilers on heavily textured concrete pavements. The lightweight profilers are generally used at the time of construction and the high speed profilers used for network pavement management data collection. However, since the results of the light-weight profilers are often verified by the use of a high-speed unit and long-term pavement perform-ance is assessed through a combination of both devices, agreement in the measured profiles are crucial.

A true pavement profile is the most desirable basis for comparing profile measurement devices. Rod and level surveys have traditionally been used to generate reference profiles although the time and expense of performing these surveys limit their use in a practical sense. Other devices such as DipStick, SurPro 1000, and the ARRB Walking Profiler have also been used to generate reference profiles. Whether a rod and level survey or a profiling device is used, the results may not represent a true profile due to the ways in which the data are collected and analyzed. For instance, a level rod has a relatively large footprint compared with the laser footprint of a profiler. Therefore, the true profile at any given location may vary due to the bridging of the level rod versus the pinpoint measurement of the laser. For purposes of the Phase I experiment, the rod and level survey was selected as the reference profile subject to the stated limitations. Surveys were performed at sites 1, 2, and 4 within 2 weeks of the profiler measurements.

Profile measurements were made over predetermined distances and following as close as practical a predetermined right wheelpath alignment. The equipment was operated at normal operating speeds and according to established testing protocols by trained personnel. The raw profile data were recorded for each device by the respective operators and given to the project team prior to leaving each site.

Data Analysis

The goal of the analysis was to compare the profiles generated by each of the devices and assess both their repeatability and reproducibility relative to the other devices. The repeatability of each device was determined by comparing profiles from repeated tests. These “back-to-back” tests were performed as closely as possible to the original alignment. Shifting of the profiles to account for slightly different beginning and endpoints was performed to obtain the best possible overlap of the data.

Repeatability

The analysis was focused on comparing profiles, not calculated profile indices. However, as profile indices are widely accepted, IRI values were determined for each test site and profile device. The results presented in Table 3 are intended to illustrate the repeatability of the devices and are likely indicative of what would be encountered under typical job site conditions. The results are shown as standard deviations and are a measure of variability relative to the mean or average IRI values. It should be noted that the limited amount of data does not lend itself to statistically viable results.

Table 3. Repeatability (standard deviation) of roughness index measurements.

Device	Device Type	Standard Deviation of Index Comparison			
		Site 1 Dense-graded asphalt	Site 2 Longit. tined concrete	Site 3 Broom finish concrete	Site 4 Random trans. tined concrete
LISA 1	Lightweight	0.29	0.32	1.28	2.03
LISA 2	Lightweight	0.26	6.17	0.58	2.76
LISA 3	Lightweight	0.60	2.75	*	1.11
ICC	Lightweight	1.97	4.40	1.08	3.01
Dynatest 6400	Lightweight	0.45	3.41	0.32	2.79
SSI	Lightweight	*	4.66	5.40	5.94
Mich DOT	High Speed	1.48	2.37	*	2.85
Dynatest 5051	High Speed	0.12	0.97	1.31	0.37
SSI	High Speed	0.81	6.93	0.46	4.95

An alternate method of determining repeatability uses a mathematical comparison of the results of each device. The profiles of all of the devices were compared on the basis of three wavelengths (short, medium, and long) and two filter types (IRI and RN [Ride Number]). The repeatability ratings resulting from one of these comparisons is presented in Table 4. Note that the values range from 0 to 100, with 100 being totally repeatable.

A repeatability rating of 95 or better is considered excellent, and this threshold value is used to indicate minimum acceptability. Note that the dense graded asphalt (Site 1) and the broom finished concrete (Site 3) showed relatively high levels of repeatability, while the deeply textured concrete sections did not. Other repeatability ratings based on the other four filters showed similar results and in most cases were considerably worse than the values shown in Table 4.

Table 4. Repeatability ratings (0-100) of tested devices.

Device	Device Type	Repeatability Rating			
		Site 1 Dense-graded asphalt	Site 2 Longit. tined concrete	Site 3 Broom finish concrete	Site 4 Random trans. tined concrete
LISA 1	Lightweight	**98**	83	**97**	93
LISA 2	Lightweight	**98**	79	**98**	92
LISA 3	Lightweight	**96**	87	**97**	**98**
ICC	Lightweight	**97**	78	**95**	91
Dynatest 6400	Lightweight	**98**	89	**98**	90
SSI	Lightweight	**95**	76	85	65
Mich DOT	High Speed	**96**	83	93	90
Dynatest 5051	High Speed	**100**	84	**97**	88
SSI	High Speed	**97**	72	**96**	61

Reproducibility
Reproducibility is assessed by comparing the profiles or calculated indices for each pair of devices. Using a technique referred to as cross correlation, reproducibility ratings, comparable to those shown for repeatability were calculated for each pair of devices. A threshold of 90 was established to define the minimum accepted value. With few exceptions, none of the devices were sufficiently reproducible to meet the threshold of 90 on either of the coarsely textured concrete sections. The asphalt and broom finished concrete were substantially better but still lacked desirable levels of reproducibility.

Summary

Phase I of the ride quality experiment has illustrated the need for refinement of existing profile devices to meet current and future standards of ride quality assessment. This refinement may require modification of existing hardware and/or signal processing and data analysis procedures. The lack of repeatable and reproducible results is problematic to both the State Agencies and the industry. Implementation of ride quality specifications employing non-contact profiling equipment is not recommended until these identified problems are corrected.

The full text of the ride quality experiment Phase I final report including details of the field trials, analysis, and recommendations may be found on the ACPA website, www.pavement.com.

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