R&T UPDATE
Concrete Pavement Research & Technology

Coarse-Textured Pavements and Lightweight Profilers: Part 2

LEAVE YOUR PROFILER AT HOME ON LONGITUDINALLY-TINED PAVEMENT

Last month's R&T Update discussed the impact of coarse surface texture (i.e. tining, diamond grinding, or open-graded) on the smoothness of a pavement measured with laser-type profilometers such as lightweight or high-speed inertial profilers. This month's issue will focus on the impact of coarse surface texture on California-type profilograph index numbers, when simulated using a laser-type profiler.

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.

Because lightweight profilers are faster, easier to use and transport, and less bulky than California profilographs, paving contractors are increasing their use for construction quality control, even when specifications require smoothness numbers to be reported as profile index (PI) readings from a California profilograph. Lightweight profilers are able to simulate the California profilograph response through on-board computer software simulation. However, it is not the simulation process which is at question, but the accuracy of the profile from which the index value is calculated.

The smoothness or ride quality of a pavement is often a factor in whether or not a contractor receives full pay for the pavement. Contractors are also required to profile the pavement to determine if there are any rough spots or "must-grinds" that are out of tolerance. In short, the impact of smoothness is directly related to a paving contractor's bottom line. In similar fashion, the device or quality of the device used to measure the pavement smoothness can also affect the pay factor as well.

The Lightweight Profiler Experiment

The lightweight profiler experiment was explained in detail in last month's edition of R&T Update. The experiment was devised to address the issues of surface texture and its corresponding effect on profile index and the repeatability and reproducibility of current profiling equipment. 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 four textures tested included dense graded asphalt, longitudinal tined concrete, broom-finished concrete, and transverse tined concrete.

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. The device types included walking speed profilers, lightweight profilers, and high-speed profilers (see Part 1 of this R&T Update, Number 4.08, August 2003 for more details on the four sites and thirteen different devices tested).

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The impetus of this research came when contractors noticed different results when running two lightweight profilers, one behind the other. Table 1 below lists the results from that initial experiment, PI simulation using a lightweight profiler and the use of a manual California-type profilograph on both transverse tining and longitudinal tining.

Table 1. Comparison between lightweight profiler and profilograph. (2)

I-75 NB, Sta. 16+960 to 18+380
Transverse Tining

Lot	PI simulated from profiler (in./mi.)	Profilograph (in./mi.)
1	26.37	25.02
2	21.45	19.16
3	20.86	19.64
4	25.98	20.82
5	20.86	20.03
6	20.86	22.41
7	25.00	22.25
8	24.41	24.71
Avg.	23.22	21.76

I-94 EB, Sta. 11+195 to 12+350
Longitudinal Tining

Lot	PI simulated from profiler (in./mi.)	Profilograph (in./mi.)
1	42.12	30.56
2	28.74	22.09
3	31.29	18.45
4	32.28	19.96
5	33.26	21.62
6	32.67	24.47
7	35.82	21.62
Avg.	33.74	22.68

The smoothness specification in place in Michigan at the time this individual comparison was made can be summarized as follows:

- Profile Index, 0.0-in. blanking band
- PI < 18 in./mi. = bonus (exact amount determined according to a formula)
- 18 < PI < 30 = full pay
- PI > 30 in./mi. = must-grind to below 30 in./mi.

Therefore, according to the results of this head-to-head comparison, the use of the lightweight profiler on the longitudinal tining results in unnecessary grinding.

Profile Determination and Simulation

For the comprehensive profiler experiment, three runs were made with each device, and each of the three different profiles were used to simulate the profile index. Profile measurements were made over predetermined distances and following as close as practical to 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. (1)

The goal of the analysis was to compare the profiles generated by the laser profilometers to assess their repeatability. In other words, the goal of the analysis was to show how a profiler might possibly indicate must-grinds on the first run, and then a bonus situation on a second run, or bonus on the first run versus only full pay on the second, etc.

Manual Trace Reduction

Originally, profilographs recorded pavement response by drawing a trace on a long strip of paper. Afterward, an engineer analyzed the trace and derived an overall roughness score manually. This was done by identifying scallops, which are protrusions above or below a reference line, and summing their heights. The sum is then normalized by the longitudinal distance, and result is PI, usually expressed in units of in/mi or m/km.

Manual trace reduction involves six important aspects: the blanking band, scallop rounding, minimum scallop height, minimum scallop width, outlining, and bump detection. These aspects will not be discussed in this R&T Update but can found in Reference 3.

Profilograph Simulation
Most highway agencies still specify smoothness using the PI scale. However, lightweight profilers are continually replacing profilographs because they are more efficient. Because they are non-contact devices, their measured "actual" profiles must first undergo a computer simulation to determine the profilograph response to the pavement conditions. Second, that profilograph trace must be analyzed to duplicate manual reduction. However, because computers can accomplish numerous calculations per second, many of the factors used in manual trace reduction are no longer needed in computer simulation. But in order to compare profilograph numbers between lightweight profilers and profilographs, many of the same inputs used in manual trace reduction are specified in computer simulation.

The profiler settings or factors that influence repeatability and reproducibility of profilograph simulation using lightweight profilers are:

- Minimum scallop height & rounding – not significant
- Low-pass filtering – highly significant
- Minimum scallop width – highly significant
- Blanking band – highly significant

Comparison

The profilers were tested for repeatability by simulating PI's for each of the three runs. Figure 1 demonstrates the wide deviation of PI using a 0.2-in. blanking band on transverse tining not only within a particular device, but also between devices.

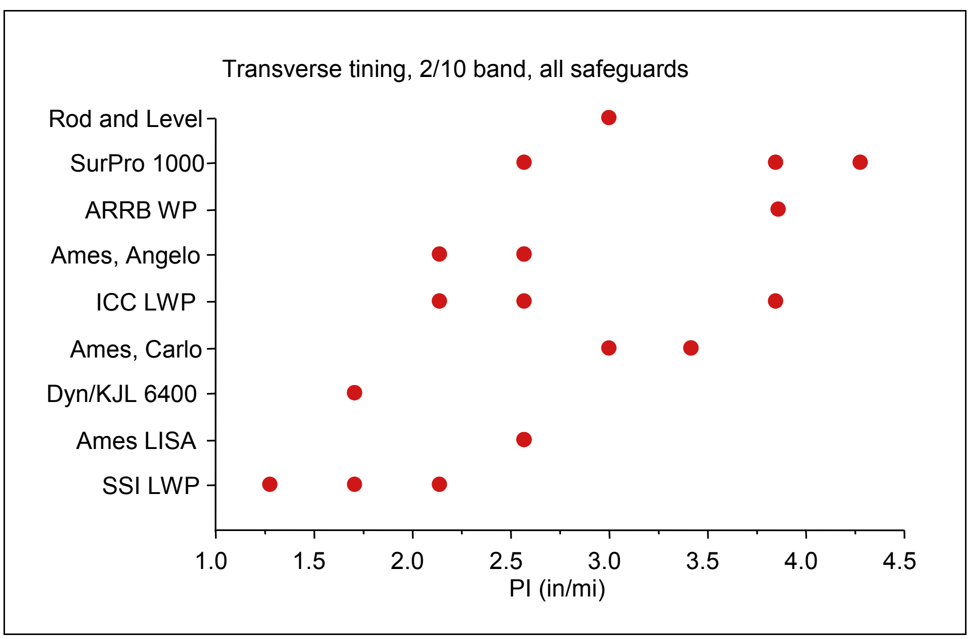

Figure 1. Graphic showing non-repeatability using lightweight or walking profilers (1)

Figure 2 demonstrates an even wider spread on longitudinal tining, with a 0.0-in. blanking band. Note where 30 in./mi. appears on the graph, which is where the cutoff occurs in the Michigan DOT specification between full pay and must-grinds.

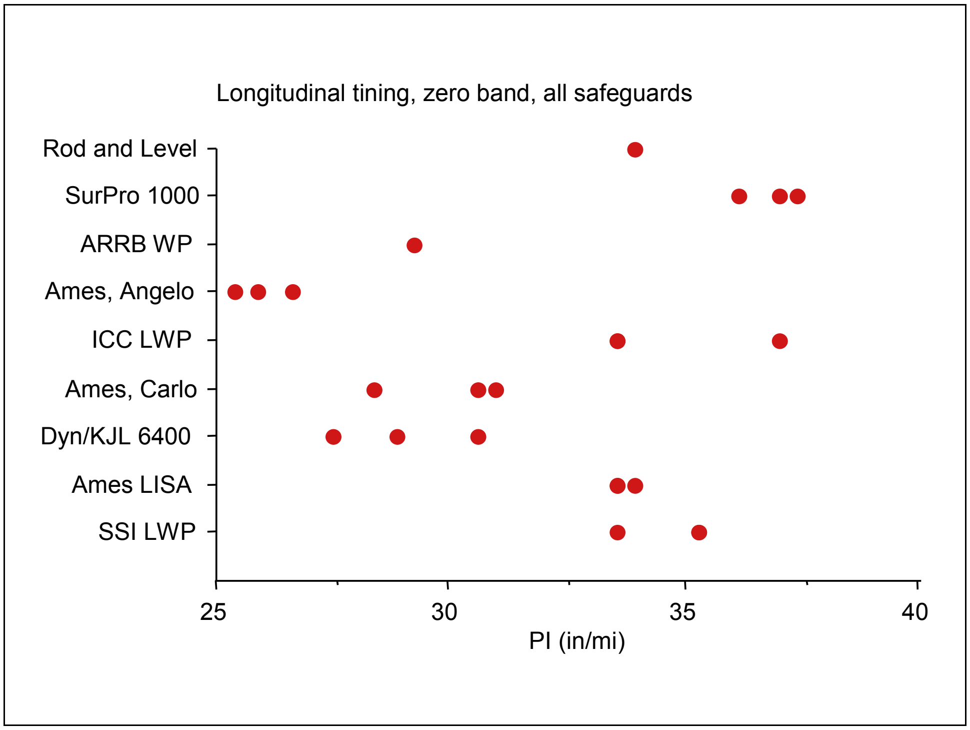

Figure 2. Graph showing non-repeatability using lightweight or walking profilers (1)

Summary – What does a contractor need to know about profilers?

The primary conclusion of the study on profiler simulation is that the devices tested did not reproduce each other's simulated PI measurements, nor were the PI simulations repeatable on coarse-textured pavements. The errors are less egregious on transverse tined pavements, as well as when evaluated with a 0.2 in. blanking band. However, contractors should be aware of these potential errors and carefully consider whether to employ lightweight profilers for PI measurement when working under incentive specifications on transverse tined pavement. The errors are significant enough on longitudinally tined pavements that ACPA recommends the use of manual profilographs instead of non-contact profilers at this time.

ACPA is working in cooperation with the laser and profiler manufacturers to correct the source of the errors, improve the profiler equipment, and increase accuracy of PI simulation for coarse-textured pavements. These improvements may be ready for the 2004 construction season.

References

1. Karamihas, S.M., Assessment of Profiler Performance for Construction Quality Control with Simulated Profilograph Index, submitted for presentation at the 83rd Annual Meeting of the Transportation Research Board, July 2003.
2. Data from Michigan Concrete Paving Association, 2003.
3. Operation of California Profilographs and Evaluation of Profiles, California Test Method 526, 1978 and 2002.

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