SURFACE SYSTEMS & INSTRUMENTS, INC.
Custom Test Equipment • Mobile Technology Solutions

California	Kansas
1845 Industrial Drive	307 Plymate
Auburn, California 95603	Manhattan, Kansas 66502
Telephone: (415) 383-0570	Telephone: (785) 539-6305
Facsimile: (415) 358-4340	Facsimile: (785) 539-6210

smoothroad.com

ZERO-SPEED INERTIAL PROFILER

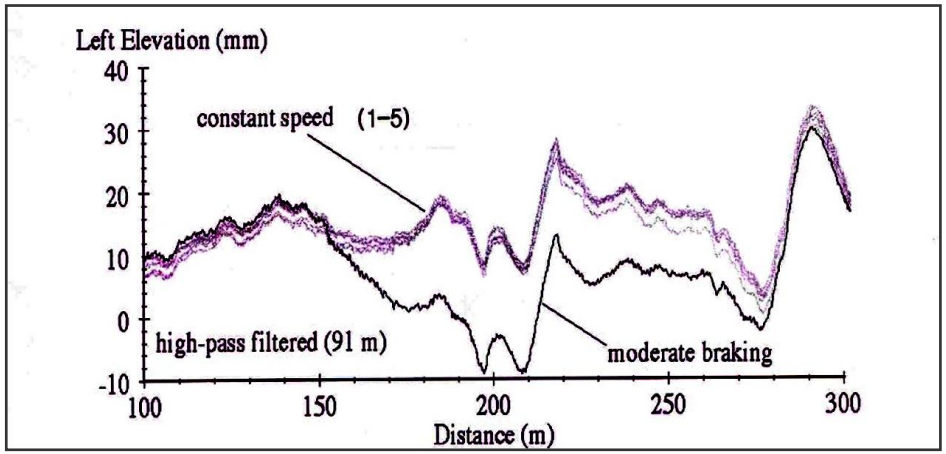
Surface Systems & Instruments, Inc. (SSI) has released its “zero-speed” inertial profiling system, which can measure accurate and repeatable pavement profiles from a dead stop, throughout host vehicle stops, and without lead-in or run-out sections. On same-surface testing, the zero-speed system, operated with speed changes and vehicle stoppages, performs equivalent to conventional inertial profilers operated at a constant speed, as demonstrated below. The zero-speed upgrade is available on SSI’s CS9100 mid-mount configuration, the CS9300 front/rear mount systems, or on the CS9500 full lane width scanning system. The zero-speed functionality is also available on the SSI CS8700 lightweight and CS8600 ultralight systems. The proprietary design of the zero-speed system is covered by a pending patent application.

▲CS9300 Front/Rear Mount Zero-Speed Configuration▲

FIGURE 1

▲CS9100 Mid-Mount Zero-Speed Configuration▲

Background: Measuring accurate longitudinal profiles and reporting IRI at low speeds and through host vehicle stoppages has long been a goal among innovators of inertial profiler technology. For example, FHWA backed pooled funds group TPF-5(354) (Improvement of Profile Measurement Quality) has among its priorities the "Implementation of Urban/Low Speed Profile Measurement." Also, "Low Speed and Urban International Roughness Index (IRI) Measurement" was among the priorities of the previous pooled funds group TPF-5(063)(Improving the Quality of Pavement Profiler Measurement). Until now, commercially available inertial profiling systems, relying on single axis accelerometers, have a required a significant forward speed to collect valid pavement profile data. The minimum speed varies among manufacturers but is typically in the range of 5-20 mph. With conventional inertial profilers, speed changes or vehicle stoppages during data collection introduce anomalies and gaps in the data, as depicted in Figure 2 below.



▲Standard Inertial Profiler: Impact of Vehicle Stoppages▲ **FIGURE 2** ▲Standard Inertial Profiler: Impact of Braking and Speed Changes▲

These limitations take away from the effectiveness of typical inertial profilers in urban area collections and under project conditions where fluctuating operating speeds and vehicle stoppages are often routine. As shown in Figure 3, the profiles from the zero-speed system, collected with vehicle stoppages during each run, demonstrate high repeatability and stable IRI reporting.

FIGURE 3: Zero Speed Profiler with Vehicle Stoppage vs. Certified IP Operated at Constant Speed
▲IRI Waveband Correlation: 98% • IRI Values: Within 2%▲

Data Comparisons & Validation: A CS9100 mid-mount system instrumented with the zero-speed option was compared with a DOT certified inertial profiler on multiple surface types. The graphs below depict accuracy, repeatability and IRI number comparisons from the same surface profiles.

Comparison of Same Surface Ride Statistics. Figure 4 shows the IRI values for the zero-speed device and the certified profiler.

File	Profile	IRI (in/mi)
0speed_10mph_01 T1	LElev.	89.35
0speed_30mph_01 T1	LElev.	88.89
0speed_40mph_Stop_20mph_01 T1	LElev.	88.23
0speed_60mph_01 T1	LElev.	87.87
Inertial_40mph_01 T1	LElev.	87.16
Inertial_40mph_02 T1	LElev.	88.50
Inertial_40mph_03 T1	LElev.	87.64

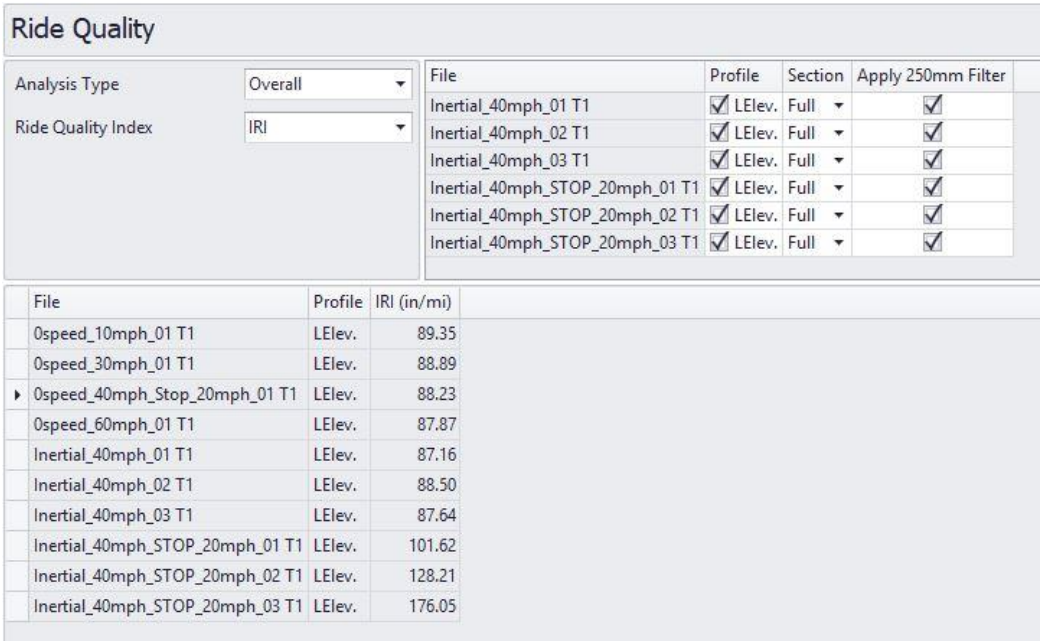


FIGURE 4: ▲Zero-Speed vs Standard Inertial Profiling System: Same Surface IRI Comparison▲

Repeatability & Accuracy Comparison. Figures 5 and 6 below show a ProVal comparison of same surface data from the zero-speed device with q certified profiler. For simplicity, the accuracy comparison is based on the certified profiler's data instead of a reference profiling device that would be used to certify inertial profilers. Since the zero-speed profiler functions like a typical inertial profiler at normal collection speeds, it will pass existing equipment certification tests. DOT and AASHTO standards may be revised as necessary to validate the zero-speed system's ability to collect data through vehicle stoppages and without run-up or run-out sections.

Accuracy - Left

Comparison	Correlation (%)	Shape Coefficient	Roughness Coefficient	Offset (ft)	Basis IRI (in/mi)	Comparison IRI (in/mi)	IRI Difference (%)
0speed_10mph_02 T1	98.31	0.994	98.95	-0.1	88.50	87.93	-0.64
0speed_30mph_04 T1	98.95	1.000	99.00	-0.3	88.50	87.75	-0.84
0speed_60mph_03 T1	97.92	0.999	98.06	0.0	88.50	86.71	-2.03
0speed_40mph_Stop_20mph_01 T1	94.60	0.997	94.85	0.6	88.50	88.23	-0.31

FIGURE 5: ▲Zero-Speed vs Standard Inertial Profiling System: Accuracy Results▲

Repeatability - Left

Basis	Comparison	Correlation (%)	Shape Coefficient	Roughness Coefficient	Offset (ft)	Basis IRI (in/mi)	Comparison IRI (in/mi)	IRI Difference (%)
0speed_30mph_01 T1	0speed_30mph_02 T1	98.32	0.988	99.51	0.0	88.89	89.34	0.51
0speed_30mph_01 T1	0speed_30mph_03 T1	99.17	1.000	99.18	0.1	88.89	89.45	0.63
0speed_30mph_01 T1	0speed_30mph_05 T1	98.16	0.988	99.39	0.1	88.89	89.75	0.97
0speed_30mph_02 T1	0speed_30mph_03 T1	97.87	0.988	99.06	0.0	89.34	89.45	0.12
0speed_30mph_02 T1	0speed_30mph_05 T1	99.43	1.000	99.46	0.0	89.34	89.75	0.46
0speed_30mph_03 T1	0speed_30mph_05 T1	98.18	0.988	99.40	0.0	89.45	89.75	0.34

FIGURE 6: ▲SSI Zero-Speed vs Standard Inertial Profiling System: Repeatability Results▲

Waveband Comparison. The performance of the zero-speed system in the wavebands of interest is presented in Figure 7. As shown, SSI's zero-speed system can generate longitudinal profiles that rival reference profiler performance for repeatability and accuracy in all wavebands of interest.

1-5ft

Repeatability - Left

Basis	Comparison	Correlation (%)	Shape Coefficient	Roughness Coefficient	Offset (ft)	Basis IRI (in/mi)	Comparison IRI (in/mi)	IRI Difference (%)
0speed_30mph_01 T1 - BWBP	0speed_30mph_02 T1 - BWBP	98.34	0.992	99.16	0.0	24.53	24.75	0.90
0speed_30mph_01 T1 - BWBP	0speed_30mph_03 T1 - BWBP	97.30	0.985	98.82	0.0	24.53	24.56	0.13
0speed_30mph_01 T1 - BWBP	0speed_30mph_05 T1 - BWBP	98.83	0.996	99.25	0.0	24.53	24.70	0.69
0speed_30mph_02 T1 - BWBP	0speed_30mph_03 T1 - BWBP	95.91	0.977	98.21	0.0	24.75	24.56	-0.76
0speed_30mph_02 T1 - BWBP	0speed_30mph_05 T1 - BWBP	98.46	0.996	98.88	0.0	24.75	24.70	-0.21
0speed_30mph_03 T1 - BWBP	0speed_30mph_05 T1 - BWBP	97.24	0.981	99.16	0.0	24.56	24.70	0.55

5-25ft

Profiler Certification: Detailed Results

Repeatability - Left

Basis	Comparison	Correlation (%)	Shape Coefficient	Roughness Coefficient	Offset (ft)	Basis IRI (in/mi)	Comparison IRI (in/mi)	IRI Difference (%)
0speed_30mph_01 T1 - BWBP (1)	0speed_30mph_02 T1 - BWBP (1)	97.60	0.980	99.58	0.0	73.44	74.50	1.44
0speed_30mph_01 T1 - BWBP (1)	0speed_30mph_03 T1 - BWBP (1)	98.76	0.995	99.24	0.1	73.44	73.83	0.53
0speed_30mph_01 T1 - BWBP (1)	0speed_30mph_05 T1 - BWBP (1)	97.39	0.979	99.46	0.1	73.44	74.60	1.57
0speed_30mph_02 T1 - BWBP (1)	0speed_30mph_03 T1 - BWBP (1)	97.59	0.985	99.10	0.0	74.50	73.83	-0.90
0speed_30mph_02 T1 - BWBP (1)	0speed_30mph_05 T1 - BWBP (1)	99.41	0.999	99.51	0.0	74.50	74.60	0.13
0speed_30mph_03 T1 - BWBP (1)	0speed_30mph_05 T1 - BWBP (1)	97.81	0.984	99.42	0.0	73.83	74.60	1.04

25-125ft

Profiler Certification: Detailed Results

Repeatability - Left

Basis	Comparison	Correlation (%)	Shape Coefficient	Roughness Coefficient	Offset (ft)	Basis IRI (in/mi)	Comparison IRI (in/mi)	IRI Difference (%)
0speed_30mph_01 T1 - BWBP (2)	0speed_30mph_02 T1 - BWBP (2)	96.53	0.971	99.43	0.0	36.21	35.13	-2.98
0speed_30mph_01 T1 - BWBP (2)	0speed_30mph_03 T1 - BWBP (2)	97.18	0.980	99.17	0.1	36.21	35.17	-2.89
0speed_30mph_01 T1 - BWBP (2)	0speed_30mph_05 T1 - BWBP (2)	96.13	0.968	99.28	0.1	36.21	34.88	-3.68
0speed_30mph_02 T1 - BWBP (2)	0speed_30mph_03 T1 - BWBP (2)	98.42	0.991	99.35	0.1	35.13	35.17	0.09
0speed_30mph_02 T1 - BWBP (2)	0speed_30mph_05 T1 - BWBP (2)	99.26	0.998	99.52	0.0	35.13	34.88	-0.73
0speed_30mph_03 T1 - BWBP (2)	0speed_30mph_05 T1 - BWBP (2)	98.30	0.988	99.48	-0.1	35.17	34.88	-0.82

FIGURE 7: ▲Waveband Performance of Zero-Speed Inertial Profiling System▲