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ZERO-SPEED INERTIAL PROFILER

Surface Systems & Instruments, Inc. (SSI) has released a “Zero-Speed” inertial profiling system with the ability to measure accurate and repeatable pavement profiles from a dead stop, throughout speed changes 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. The Zero-Speed Profiler is available in 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 the subject of a pending patent application.



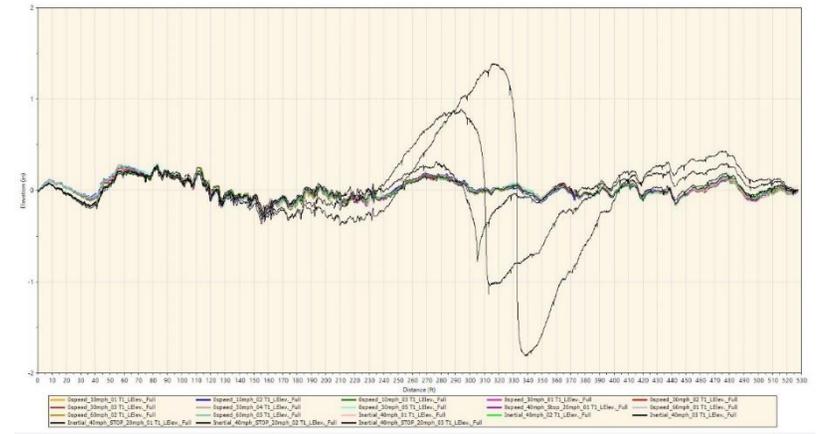
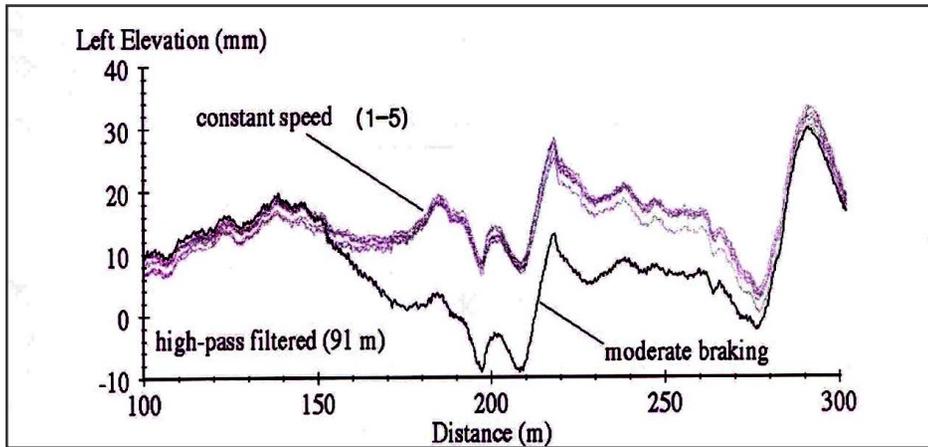
▲ CS9300 Front/Rear Mount Zero-Speed Configuration ▲



▲ CS9100 Mid-Mount Zero-Speed Configuration ▲

FIGURE 1

Background: Measuring accurate longitudinal profile and reporting IRI at low speeds or through host vehicle stoppages has long been a goal of manufacturers 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, all commercially available inertial profiling systems, relying on single axis accelerometers, have a required forward speed needed to collect valid pavement profile data. The minimum speed varies among manufacturers but is typically in the range of 5-20 mph. With current commercial inertial profilers, speed changes or vehicle stoppages during data collection introduce anomalies and gaps in the data, as depicted in Figures 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 commercial inertial profilers in urban area collections and under project conditions necessitating fluctuating operating speeds or vehicle stoppages. Significantly, SSI’s zero-speed systems can generate longitudinal profiles that rival reference profiler performance for repeatability and accuracy in all wavebands of interest. See Figure 3.



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

Ride Quality					
Analysis Type	Overall	File	Profile	Section	Apply 250mm Filter
Ride Quality Index	IRI	Inertial_40mph_01 T1	<input checked="" type="checkbox"/> LElev.	Full	<input checked="" type="checkbox"/>
		Inertial_40mph_02 T1	<input checked="" type="checkbox"/> LElev.	Full	<input checked="" type="checkbox"/>
		Inertial_40mph_03 T1	<input checked="" type="checkbox"/> LElev.	Full	<input checked="" type="checkbox"/>
		Inertial_40mph_STOP_20mph_01 T1	<input checked="" type="checkbox"/> LElev.	Full	<input checked="" type="checkbox"/>
		Inertial_40mph_STOP_20mph_02 T1	<input checked="" type="checkbox"/> LElev.	Full	<input checked="" type="checkbox"/>
		Inertial_40mph_STOP_20mph_03 T1	<input checked="" type="checkbox"/> LElev.	Full	<input checked="" type="checkbox"/>

File	Profile	IRI (in/mi)
0speed_10mph_01 T1	LElev.	89.35
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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
Inertial_40mph_STOP_20mph_01 T1	LElev.	101.62
Inertial_40mph_STOP_20mph_02 T1	LElev.	128.21
Inertial_40mph_STOP_20mph_03 T1	LElev.	176.05

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

Repeatability & Accuracy Comparison. Figures 5 and 6 below shows a ProVal comparison of same surface data from the zero-speed device with the 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. Future and further validation of the zero-speed profiler will include participation in equipment certifications under DOT and AASHTO standards.

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 (%)
Ospeed_30mph_01 T1	Ospeed_30mph_02 T1	98.32	0.988	99.51	0.0	88.89	89.34	0.51
Ospeed_30mph_01 T1	Ospeed_30mph_03 T1	99.17	1.000	99.18	0.1	88.89	89.45	0.63
Ospeed_30mph_01 T1	Ospeed_30mph_05 T1	98.16	0.988	99.39	0.1	88.89	89.75	0.97
Ospeed_30mph_02 T1	Ospeed_30mph_03 T1	97.87	0.988	99.06	0.0	89.34	89.45	0.12
Ospeed_30mph_02 T1	Ospeed_30mph_05 T1	99.43	1.000	99.46	0.0	89.34	89.75	0.46
Ospeed_30mph_03 T1	Ospeed_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.

1-5ft

Repeatability - Left								
Basis	Comparison	Correlation (%)	Shape Coefficient	Roughness Coefficient	Offset (ft)	Basis IRI (in/mi)	Comparison IRI (in/mi)	IRI Difference (%)
Ospeed_30mph_01 T1 - BWBP	Ospeed_30mph_02 T1 - BWBP	98.34	0.992	99.16	0.0	24.53	24.75	0.90
Ospeed_30mph_01 T1 - BWBP	Ospeed_30mph_03 T1 - BWBP	97.30	0.985	98.82	0.0	24.53	24.56	0.13
Ospeed_30mph_01 T1 - BWBP	Ospeed_30mph_05 T1 - BWBP	98.83	0.996	99.25	0.0	24.53	24.70	0.69
Ospeed_30mph_02 T1 - BWBP	Ospeed_30mph_03 T1 - BWBP	95.91	0.977	98.21	0.0	24.75	24.56	-0.76
Ospeed_30mph_02 T1 - BWBP	Ospeed_30mph_05 T1 - BWBP	98.46	0.996	98.88	0.0	24.75	24.70	-0.21
Ospeed_30mph_03 T1 - BWBP	Ospeed_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 (%)
Ospeed_30mph_01 T1 - BWBP (1)	Ospeed_30mph_02 T1 - BWBP (1)	97.60	0.980	99.58	0.0	73.44	74.50	1.44
Ospeed_30mph_01 T1 - BWBP (1)	Ospeed_30mph_03 T1 - BWBP (1)	98.76	0.995	99.24	0.1	73.44	73.83	0.53
Ospeed_30mph_01 T1 - BWBP (1)	Ospeed_30mph_05 T1 - BWBP (1)	97.39	0.979	99.46	0.1	73.44	74.60	1.57
Ospeed_30mph_02 T1 - BWBP (1)	Ospeed_30mph_03 T1 - BWBP (1)	97.59	0.985	99.10	0.0	74.50	73.83	-0.90
Ospeed_30mph_02 T1 - BWBP (1)	Ospeed_30mph_05 T1 - BWBP (1)	99.41	0.999	99.51	0.0	74.50	74.60	0.13
Ospeed_30mph_03 T1 - BWBP (1)	Ospeed_30mph_05 T1 - BWBP (1)	97.81	0.984	99.42	0.0	73.83	74.60	1.04

Profiler Certification: Detailed Results

25-125ft

Repeatability - Left								
Basis	Comparison	Correlation (%)	Shape Coefficient	Roughness Coefficient	Offset (ft)	Basis IRI (in/mi)	Comparison IRI (in/mi)	IRI Difference (%)
Ospeed_30mph_01 T1 - BWBP (2)	Ospeed_30mph_02 T1 - BWBP (2)	96.53	0.971	99.43	0.0	36.21	35.13	-2.98
Ospeed_30mph_01 T1 - BWBP (2)	Ospeed_30mph_03 T1 - BWBP (2)	97.18	0.980	99.17	0.1	36.21	35.17	-2.89
Ospeed_30mph_01 T1 - BWBP (2)	Ospeed_30mph_05 T1 - BWBP (2)	96.13	0.968	99.28	0.1	36.21	34.88	-3.68
Ospeed_30mph_02 T1 - BWBP (2)	Ospeed_30mph_03 T1 - BWBP (2)	98.42	0.991	99.35	0.1	35.13	35.17	0.09
Ospeed_30mph_02 T1 - BWBP (2)	Ospeed_30mph_05 T1 - BWBP (2)	99.26	0.998	99.52	0.0	35.13	34.88	-0.73
Ospeed_30mph_03 T1 - BWBP (2)	Ospeed_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 ▲