1959 SUMMARIES OF PAVEMENT ROUGHNESS

Prepared for Road Construction Division

Report No. 324
Research Laboratory Division
Office of Testing and Research
Research Project 47 F-15

Michigan State Highway Department
John C. Mackie, Commissioner
Lansing, March 1961

1959 SUMMARIES OF PAVEMENT ROUGHNESS

In addition to the standard surveys of roughness on newly constructed concrete pavements, the 1959 measurements include two pavement widening projects and one special research project. All surveys were conducted in the usual manner, with the equipment and instrumentation used by the Research Laboratory Division in previous years plus an additional measuring instrument called an Acceleration Level Indicator which it is hoped will eventually supply more comprehensive roughness data. Approximately 675 lane miles of pavement were measured this year, about 75 miles more than in 1957 and 1958.

Concrete Pavement Construction

Individual concrete construction projects and their roughness values have been tabulated in Table 1, grouped by year of construction and ranked according to accumulated inches per mile roughness. In 1959, these values ranged from 95 to 188. During the nine years through 1959, measured roughness has varied from a low of 93 to a high of 282.

The roughness classifications "good" (0-130), "average" (131-174), and "poor" (175 or more) shown in Figure 1, while arbitrarily determined, have a reasonable relationship to riding comfort. Since the surveys were initiated in 1951, a total of 251 projects have been tested; 40, 49, and 11 percent of the projects examined have been in the good, average and poor categories, respectively.

Of the projects reported here, 51 percent were good, 42 percent were average, and 7 percent poor. Although these figures suggest poorer riding qualities than were reported in 1958, the values are better than those for 1957, and the 7 percent poor represents only 10 lane miles of approximately 675 lane miles tested.

Concrete Pavement Widening

The data resulting from roughness tests conducted on two widened concrete pavements is presented in tabular form in Table 2 and in graphic form in Figure 2. The testing and reporting procedures used on these

TABLE 1
SUMMARY OF ROUGHNESS DATA FOR CONCRETE PAVEMENT

	Project	District	Length, mi	Type	Route and Project Location	Accumulated Inches/Mile	Paving Contractor
1958 CONST.	DU 61022, C1U, C2R	5	0.851	44 ft	M 46 from Getty St, Muskegon, east to 251 ft east of east city limit	132	Hertel-Deyo Co.
	M 39081, C2R, C3U	7	2.106	44 ft	M 43 from 12th St east to Kalamazoo city limit	144	Eisenhour Construction Co.
					Weighted Arithmetic Mean for 1958 Construction	141	
1959 CONSTRUCTION	BI 11018, C1RN BI 80023, C1RN	7	4.977	Dual	I 94 from east of M 140 to west of Thomas Rd	95	Pierson Contracting Co. (1)
	BI 13082, C3RN	7	3.260	Dual	I 94 from Main St to west of the Kalamazoo River	102	L. A. Davidson
	BI 13081, C2RN	7	6.832	Dual	I 94 from 0.5 mi east of Climax Rd east to west of Main St, southwest of Battle Creek	103	L. A. Davidson
	BI 13082, C4RN	7	1.375	Dual	I 94 from west of the Kalamazoo River to west of Wheatfield Rd	103	L. A. Davidson
	BF 29011, C2RN	5	2.614	Dual	US 27 Reloc from Pierce Rd north, southeast of Ithaca	111	Sargent Construction Co. (2)
	BI 39024, C3RN BI 80024, C1RN	7	5.074	Dual	I 94 from Schussler Rd in Van Buren Co east to 6th St in Texas Twp, west of Kalamazoo	111	Sargent Construction Co. (2)
	BF 25042, C1RN	6	6.390	Dual	M 78 Reloc from M 13 northeast to Swartz Creek	112	Denton Construction Co.
	F 58034, C1RN, C2UN	10	9.003	Dual	US 23 Reloc from Morocco Rd north to M 50 in Dundee	114	Denton Construction Co.
	BI 38102, C1RN	8	4.518	Dual	I 94 from east of M 99 east to junction with old US 12	114	L. A. Davidson
	BI 11017, C1RN, C2RN	7	5.087	Dual	I 94 from Carmody Rd northeast to east of M 140	115	Pierson Contracting Co.
	BF 44011, C1R BF 63112, C5R	6	5.483	Dual	M 24 from Oxford north to Brauer Rd	115	Louis Garavaglia Contractors
	BI 34043, C3RN BI 41024, C1RN	5	3.309	Dual	I 96 from 1050 ft west of Kent-Ionia Co line east to Nash Hwy	116	Sargent Construction Co.
	BM 61072, C2RN, C3UN	5	4.502	Dual	US 31 from I 96 north to M 46	117	Hertel-Deyo Co. (4)
	M 58034, C8RN	10	7.966	Dual	US 23 Reloc from Mich-Ohio line north to Morocco Rd	118	Sargent Construction Co. (2)
	BI 73111, C1RN	6	1.865	Dual	I 75 from M 81 north to old US 23	121	Cooke Contracting Co. (3)
	BM 03112, C3RN	7	9.127	Dual	US 131 Reloc from M 118 north to Wayland	123	Carl Goodwin & Sons
	BI 34044, C3RN	5	2.599	Dual	I 96 from Portland Rd east to Grand River bridge	125	L. A. Davidson
	DF 73073, C1R DU 73073, C2U	6	3.844	Dual	US 10 - M 47 from Tittabawassee River east to Madison St, Saginaw	125	Denton Construction Co.
	DF 58042, C1R, C2U	10	7.662	24 ft, 44 ft & Dual	M 50 from US 23 - M 130 east to US 24 in Monroe	126	Denton Construction Co.
	BM 61074, C1RN, C2RN BM 61151, C2RN BM 61152, C4RN	5	1.090	Dual	US 31 Reloc from Hile Rd northeast to Airport Rd; Hile Rd crossing US 31 Reloc 2 miles south of Muskegon Hts; I 196 from Shettler Rd southeast	128	L. A. Davidson
	F 31051, C4R	1	2.354	24 ft	US 41 from Snake River northwest, south of Chassell	129	Thornton Construction Co.
	BI 34043, C2RN	5	8.572	Dual	I 96 from Nash Hwy to M 66	129	L. W. Edison Co.
	BI 82025, C27UN	10	1.235	36-ft Dual	Edsel Ford Exwy from Whittier Rd northeast to Detroit city limit	130	Charles J. Rogers, Cooke Contracting Co., and Jutton-Kelly Co.
	BI 13082, C1RN, C2RN	7	7.213	Dual	I 94 from old US 12 east to 17 1/2 Mile Rd	131	Julius Porath & Son and Sargent Construction Co. (2)
	BI 80024, C2RN	7	5.039	Dual	I 94 from west of M 119 east to Schussler Rd	131	Carl Goodwin & Sons
	DUSS 56051, C1U, C2U	6	2.610	44 ft	US 10 BR (Eastman Rd) from Ellsworth St, Midland, north to US 10 Byp	132	Hertel-Deyo Co. (4)

(1) Subcontract from S. D. Solomon & Sons
(2) Subcontract from Holloway Construction Co.
(3) Contract let to Cooke Contracting Co. and A. S. Leffler Gravel Co.
(4) Contract let to Hertel-Deyo Co. and C. E. Utterback
(5) Subcontract from Canonie Construction Co.
(6) Subcontract from Brown Brothers
(7) Subcontract from Louis Garavaglia Contractors
(8) Contract let to W. F. McNally Co. and A. J. Rehmus and Son

TABLE 1 (Continued)
SUMMARY OF ROUGHNESS DATA FOR CONCRETE PAVEMENT

1959 CONSTRUCTION

Project		District	Length, mi	Type	Route and Project Location	Accumulated Inches/Mile	Paving Contractor
F	23041, C1R, C2U	8	2.340	24 ft	M 43 Reloc from Onieda Rd east to M 100, Grand Ledge	133	Eisenhour Construction Co.
BF	39024, C1RN, C2RN	7	6.174	Dual	I 94 from 6th St in Texas Twp east to US 131	133	Sargent Construction Co. (5)
BI	41024, C2RN	5	8.674	Dual	I 96 from Whitneyville Rd east to 1050 ft west of Kent-Ionia Co line	134	L. W. Edison Co.
BI	34044, C5RN, C6UN	5	1.693	Dual	I 96 from Grand River bridge east to old US 16 east of Portland	135	L. W. Edison Co. (6)
BF	38111, C3RN	8	1.406	Dual	US 127 Reloc from south branch of Grand River north to N.Y.C.R.R., southeast of Jackson	136	Sargent Construction Co.
M	52043, C2R	1	3.205	24 ft	US 41 southeast from northwest of the M 28 intersection	138	L. W. Brumm
BI	82025, C15UN	10	1.577	36-ft Dual	Edsel Ford Exwy from Conner Ave northeast to Outer Drive	140	Charles J. Rogers, Cooke Contracting Co.
BF	38111, C4RN	8	1.563	Dual	US 127 Reloc from McDevitt Rd north to south branch of Grand River	140	L. A. Davidson
DF	73062, C2R	6	4.049	48 ft & Dual	M 46 - M 47 from M 47 east to Tittabawassee River	141	Sargent Construction Co.
U	55011, C1U, C2R	1	0.771	44 ft	US 41 north from 39th St, Menominee	142	Bacco Construction Co.
BI	13083, C1RN, C2RN	7	5.031	Dual	I 94 from 17-1/2 Mile Rd to east of 22-1/2 Mile Rd	146	Julius Porath & Son (2)
I	82025, C33UN	10	1.506	36-ft Dual	Edsel Ford Exwy northeast from Kingsville Ave to Vernier Rd, Harper Woods	147	Western Construction Co. (7)
BI	38102, C2R	8	0.842	Dual	I 94 from Calhoun-Jackson Co line to Ludlow Rd	148	Eisenhour Construction Co. (1)
U	73062, C1U	6	0.966	Dual	M 46 Reloc from Gratiot St to Washington St, Saginaw	172	W. F. McNally Co. (8)
M	50021, C5U, C6R	9	0.665	Dual	M 59 Reloc from Mound Rd east to Clinton River bridge in Utica	180	Western Construction Co.
DUS DS	80041, C3U 80041, C4U, C5R	7	0.883	44 ft	M 43 from intersection of LaGrange St and Phillips St in South Haven southeast and south to US 31 Byp	180	Cross & White (5)
M	50998, C1R	9	0.990	Dual	M 59 (Mound Rd) from south of M 59 Reloc to Auburn Ave, Utica	188	Western Construction Co.
					Weighted Arithmetic Mean for 1959 Construction	124	
					WEIGHTED ARITHMETIC MEAN FOR 1958-59 CONSTRUCTION REPORTED ABOVE	124	

(1) Subcontract from S. D. Solomon & Sons
(2) Subcontract from Holloway Construction Co.
(3) Contract let to Cooke Contracting Co. and A. S. Leffler Gravel Co.
(4) Contract let to Hertel-Deyo Co. and C. E. Utterback
(5) Subcontract from Canonie Construction Co.
(6) Subcontract from Brown Brothers
(7) Subcontract from Louis Garavaglia Contractors
(8) Contract let to W. F. McNally Co. and A. J. Rehmus and Son

TABLE 2
SUMMARY OF ROUGHNESS DATA FOR 1959 CONCRETE PAVEMENT WIDENING

1959 CONST.

Project		District	Length, mi	Type	Route and Project Location	Accumulated Inches/Mile	Paving Contractor
BM	29011, C5RN	6	0.439	11 ft R & L	US 27A from Ithaca east city limit east to US 27 Reloc	160	Eisenhour Construction Co.
F U	78051, C1R 78051, C2U	7	2.653	11 ft R & L	M 78 from Mich-Ind. line north to US 112 in Sturgis	200	Sargent Construction Co.
					WEIGHTED ARITHMETIC MEAN FOR 1959 WIDENING	194	

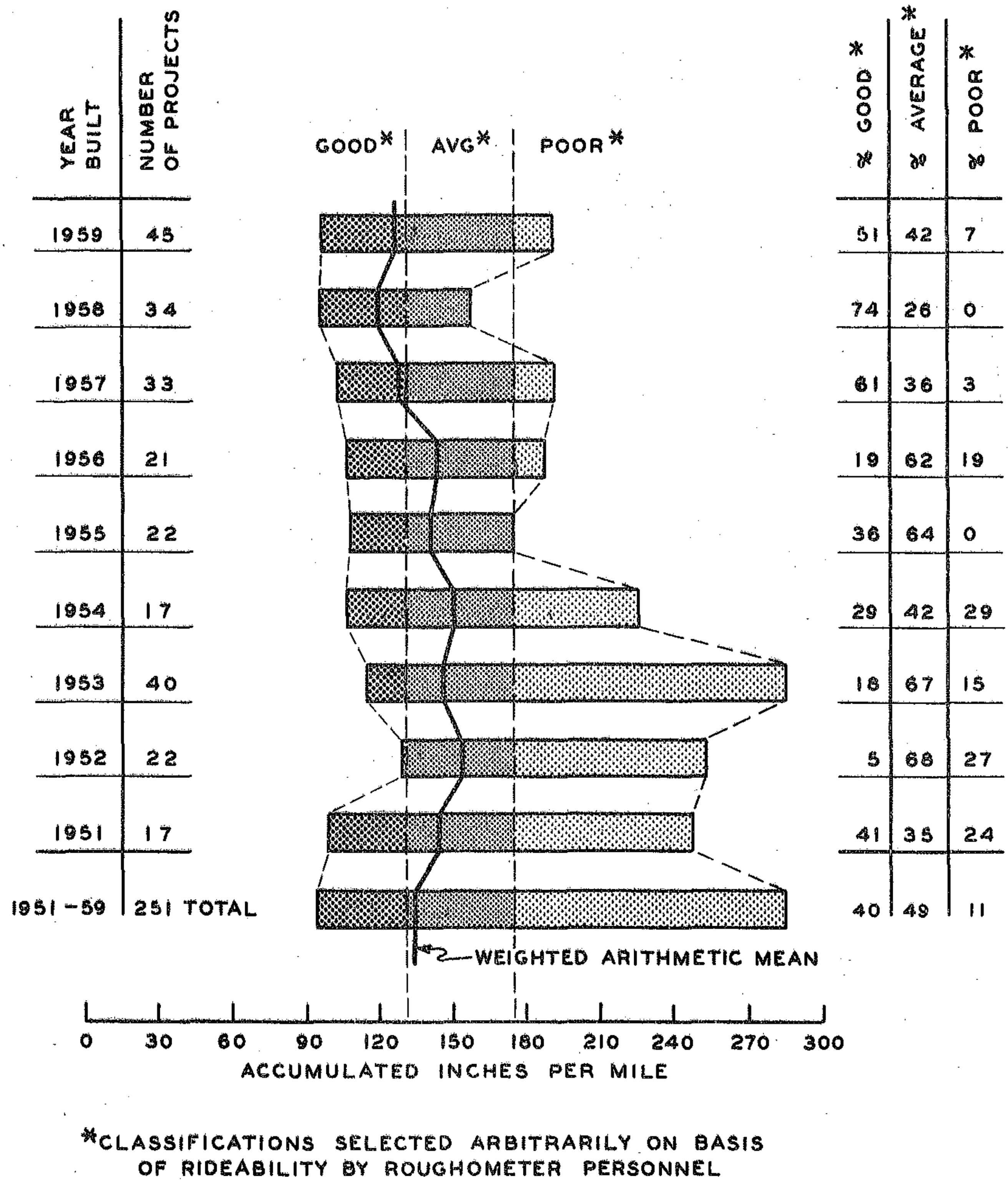

Figure 1. Annual roughness comparison for concrete pavement.

projects are identical to those employed on standard concrete pavements, However, due to the somewhat different construction procedures required for pavement widening, it is expected that the range of roughness values encountered will show some variation from that of standard concrete pavements. For this reason, concrete widening projects are reported and tabulated as a classification separate from standard concrete pavements.

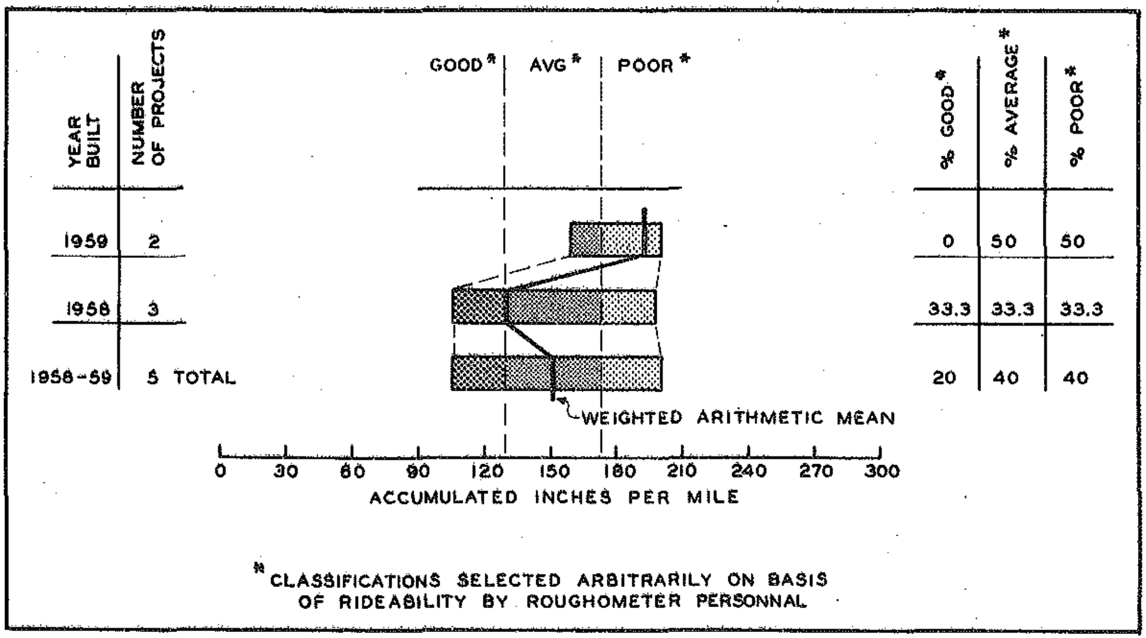

Figure 2. Annual roughness comparison for concrete pavement widening.

Continuously Reinforced Concrete Research Project

In the fall of 1958 an experimental continuously reinforced concrete pavement was installed on I 94 — US 16 near Portland. This installation, Construction Project BI 34044, C7RN, is located from just east of the intersection with M 66 to a point 5 miles east of this intersection.

This pavement consists basically of three types of pavement; continuously reinforced with no joints, standard pavement with contraction joints spaced at 99-ft intervals, and relief sections at the ends of the continuously reinforced of 1-in. expansion joints spaced alternately at 56 ft 3 in. and 42 ft 4 in.

The roughness testing procedures used on this project were identical to those employed on standard concrete pavements except that the new roughness measuring instrument, the Acceleration Level Indicator, was not used here. The following roughness levels were determined by these tests:

Pavement Type	Accumulated In. /Mi
Continuously reinforced (no joints)	122
Standard (99 ft joint spacing)	119
Relief sections (42 ft 4 in. and 56 ft 3 in. joint spacing)	151

Acceleration Level Indicator

As mentioned earlier in this report a new measuring system was incorporated into the roughness equipment for the first time this year.

Acceleration level data is obtained from a 0 to 2 g accelerometer mounted on the frame of the roughometer instrument. The signal from this transducer, which is proportional to the acceleration of the frame, is fed to an instrument which the Department is calling the Acceleration Level Indicator. This instrument incorporates five counters, each of which responds to a different level of acceleration. These levels may be adjusted to various sensitivities depending on the road surfaces encountered. The five levels which are recorded indicate the distribution and magnitude of roughness being measured.

At this time no roughness distribution information is being reported but will probably appear in future reports. For the present an "acceleration level rating factor" is being presented which incorporates the five recorded acceleration levels as follows:

$$\text{acceleration } (a) = 4\pi^2 f^2 d$$

$$\text{where } f = \text{frequency}$$

$$\text{and } d = \text{displacement.}$$

Thus, jerk (rate of change of acceleration)

$$= 8\pi^3 f^3 d$$

$$= 4\pi^2 f^2 d(2\pi f)$$

$$= 2\pi f a$$

and the Acceleration Level Rating Factor

$$= 2\pi (f_1 a_1 + f_2 a_2 + f_3 a_3 + f_4 a_4 + f_5 a_5).$$

This rating factor is based on the unit "jerk" (rate of change of acceleration) because this is considered to be the phenomenon most closely associated with riding comfort in the vibration frequency range ordinarily encountered. However, a substitution has been made in the formula; that is, occurrences per 180 seconds or per mile at the standard roughometer speed of 20 mph have been substituted for frequency. This variation in the jerk formula provides a rating factor with the units of g's per mile.

Figure 3 is included to show the agreement found to exist between the older integrator method and the acceleration level rating factor. The line drawn through the points on this graph is a best fit line based on the method of "least squares." The coefficient of correlation (r) was found to be 0.929, which is very good with 1 as perfect correlation and 0 as no correlation. The standard error of estimate (Sy) is ± 76.642, which means that 68 percent of the time the relation between integrator count and acceleration level rating factor will fall within the band shown in Figure 3. This indicates that the older instrumentation method, the integrator count, which has been used since 1949, is a reliable method of predicting riding comfort of pavements, since it correlates very well with the newer and more refined method of measuring acceleration of the frame. The latter method measures an effect which more directly influences riding comfort of the motorist and therefore perfect correlation is not expected. However this favorable evidence of correlation between the two methods demonstrates the value of retaining them both as complementary sources of roughness data.

The new instrumentation, which also determines the magnitude distribution of vertical acceleration, will also be of use to the Department in determining the cause of roughness at certain specific points and in comparing differences in construction methods over short lengths of pavement. Another use is in a research study of the effect of pavement roughness on dynamic axle load variation, or impact, which is now being conducted.

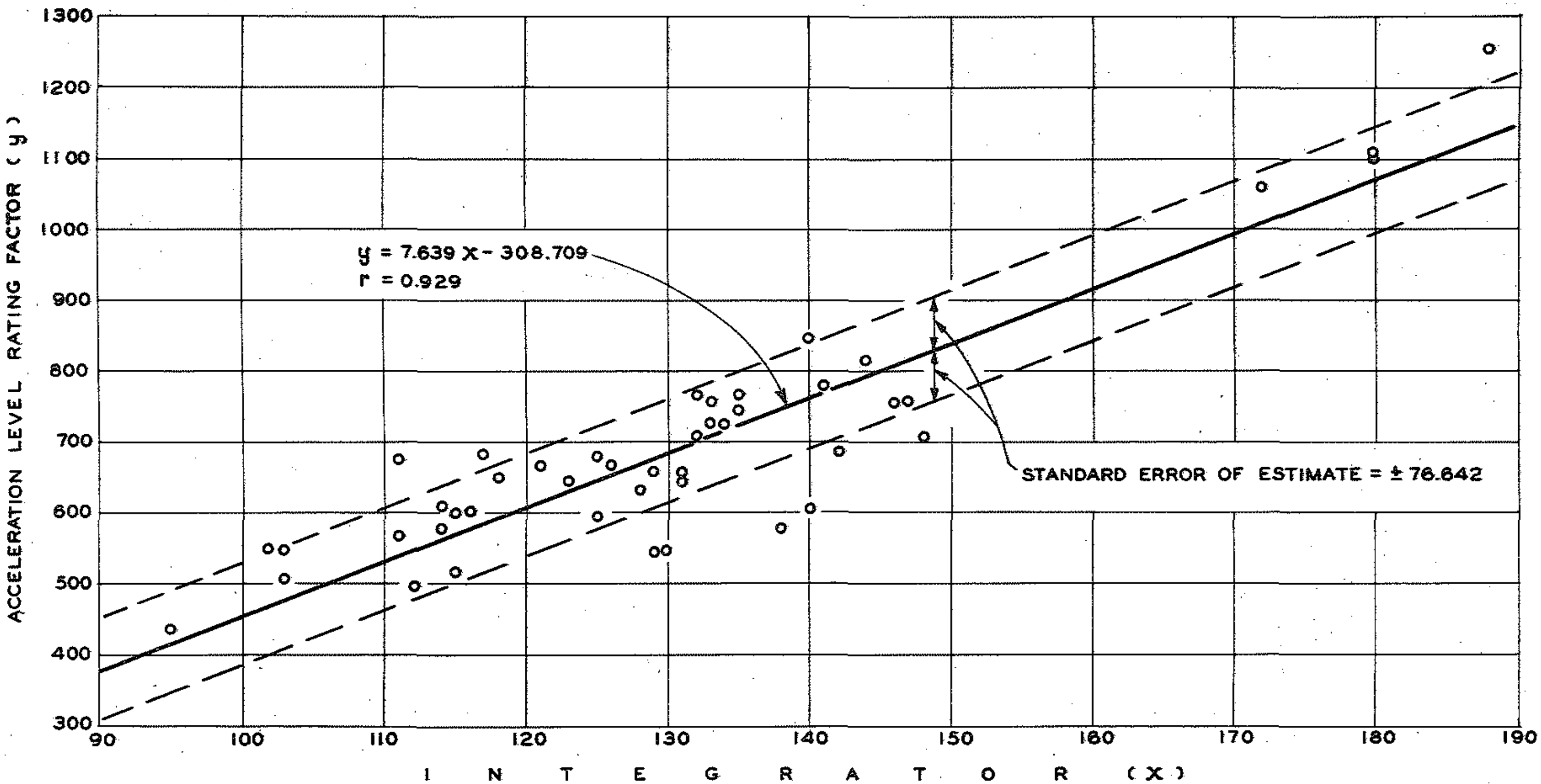

Figure 3. Comparison of pavement roughness measurements by Acceleration Level Indicator and Integrator methods.