SUMMARIES OF MICHIGAN PAVEMENT ROUGHNESS
1961 Test Program

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Synopsis

Results of field roughness measurements on newly constructed pavements are presented for the 1961 test year. Projects of rigid pavement (both two-lane and one-lane pours) and expressway-type flexible pavement are ranked according to pavement riding quality.

In addition, on the basis of new statistical analyses which are reported here, it is concluded that surface roughness of concrete pavement appears to be a function of project length. Longer projects have been consistently and notably smoother than shorter projects in surveys of more than 300 construction projects during the last 11 years. The analysis thus indicates the importance of close supervision and quality control for smoothness on shorter construction projects.

Approximately 678 lane miles of pavement were surveyed in the 1961 roughness measuring program of the Research Laboratory Division. This is the greatest annual volume of lane mileage surveyed in the entire 11-year test program. Comprising this lane mileage were 485 lane miles of standard rigid pavement (two-lane pours), 158 lane miles of flexible pavement, and 32 lane miles of rigid pavement widening (one-lane pours). All surveys were conducted in the usual manner, with the same equipment and instrumentation used the previous test year.

Rigid Pavement Construction (Two-Lane Pours)

Individual rigid pavement projects constructed as standard two-lane pours, and their roughness values as determined in the 1961 test program, are listed in Table 1, grouped by year of construction and ranked within these years according to accumulated inches per mile of roughness by

* Throughout this report, the terms "construction year" and "test year" are specifically used to distinguish between the period of construction operations, and the time when measurements were conducted by the Research Laboratory. Further, the term "project mileage" refers to length given by the Contract Division, "roadway mileage" refers to length of two-lane pavement, and "lane mile" to length in terms of individual vehicle lanes.

TABLE 1
ROUGHNESS DATA SUMMARY FOR RIGID PAVEMENT (TWO-LANE POURS)

Construction	Project	District	Length, mi	Type	Route and Project Location	Roughness: Integrator, In./Mile	Roughness: Level Indicator, g's/Mile	Paving Contractor
1959 CONSTRUCTION	F 82053, C2R*, C9R*	10	1.836	24 ft (Dual)	US 24 from Ford Rd (M 153), north to north of the Ann Arbor Trail	157	777	Cooke Contracting Co. (1)
1959 CONSTRUCTION	U 82052, C12U* U 82053, C1U* F 82053, C12R*	10	2.498	24 ft (Dual) & 24 ft	US 24 from Oxford Rd, north to Ford Rd (M 153)	176	993	Bairley & Lindley Inc.
1959 CONSTRUCTION	DU 82053, C6U* DU 82053, C14U* DU 82053, C15R*	10	2.840	24 ft	US 24 (southbound only) from Fenkell Rd (Five Mile Rd), north to Grand River Ave (US 16)	182	1012	R. J. Brighton
1959 CONSTRUCTION					Weighted Arithmetic Mean for 1959 Construction Tested in 1961	173	944	
1960 CONSTRUCTION	BI 81104, C7RN	8	5.430	24 ft	I 94 (eastbound only) from NYC RR, east to 1529 ft west of Fletcher Rd	129	663	Sargent Construction Co. (5)
1960 CONSTRUCTION	EBBF 37011, C2RN EBBF 37013, C4RN	5	6.700	24 ft (Dual)	US 27 BR Reloc (south connection) from 2100 ft south of Deerfield Rd, northwest to old US 27, and US 27 Reloc from north of Blanchard Rd, north and northwest to 875 ft north of Deerfield Rd	130	671	Hertel-Deyo Co. (8)
1960 CONSTRUCTION	BU 56023, C2U*, C3U	6	3.486	24 ft (Dual)	M 20 Reloc from Ellsworth St, Midland, east to Midland-Bay Co line	140	652	W. H. Knapp, Inc. (2)
1960 CONSTRUCTION	U 82053, C5R*	10	3.339	24 ft (Dual), 24 ft & 48 ft	US 24 from Belton Rd, north to Fenkell Rd (Five Mile Rd)	146	825	Cooke Contracting Co. (3)
1960 CONSTRUCTION	I 49025, C5UN, C6RN	2	4.055	24 ft (Dual)	US 2 from north approach of Mackinac Bridge, north to 2.839 mi north of north limit of St. Ignace	150	804	Loselle Construction Co. (4)
1960 CONSTRUCTION	BF 29011, C6RN	5	5.754	24 ft (Dual) & 24 ft	US 27 Reloc from north of Washington Rd (east of Ithaca), north to south of Lincoln Rd (east of Alma)	153	808	Sargent Construction Co. (5)
1960 CONSTRUCTION	BU 41131, C43UN*, C44UN*	5	1.000	24 ft (Dual)	US 131 Reloc from 28th St, Wyoming (M 11) north to Burton St, Grand Rapids	165	813	L. W. Edison Co.
1960 CONSTRUCTION	BF 52042, C5R BU 52042, C6U	1	1.920	24 ft (Dual), 22 ft (Dual), & 24 ft	US 41 - M 28 from 1.38 mi west of Marquette west city limit, east to east of the west limit	186	945	L. W. Brumm
1960 CONSTRUCTION					Weighted Arithmetic Mean for 1960 Construction Tested in 1961	144	747	
1961 CONSTRUCTION	BI 41025, C1RN, C9RN	5	4.782	24 ft (Dual)	I 196 - US 16 from Leonard St, Grand Rapids, north and west to west of US 131 BR (Plainfield Ave, Grand Rapids	103	468	Sargent Construction Co. & Pierson Contracting Co. (6)
1961 CONSTRUCTION	BF 37012, C3RN BF 37014, C5RN	5	8.036	24 ft (Dual)	US 27 BR (north connection) from old US 27 in Mt. Pleasant north and east to US 27 Reloc, and US 27 Reloc from M 20 north to north of Rosebush Rd	106	444	Denton Construction Co.
1961 CONSTRUCTION	EBI 41025, C5RN	5	2.923	24 ft (Dual)	I 96 - US 16 from 1321 ft north of Cascade Rd (US 16 BR), southeast to northwest of 28th St (M 11)	112	554	Sargent Construction Co. (5)
1961 CONSTRUCTION	BI 73171, C8RN	6	4.111	24 ft (Dual)	I 75 from 230 ft north of Townline Rd, north to south of Baker Rd	113	558	Sargent Construction Co. (7)
1961 CONSTRUCTION	BI 81104, C5RN	8	2.325	24 ft	I 94 (eastbound only) from the Jackson-Washtenaw Co line, east to NYC RR	114	601	Pierson Contracting Co.
1961 CONSTRUCTION	EBBF 76023, C3RN	6	5.290	24 ft (Dual)	M 78 Reloc from 2900 ft southwest of Grand River Rd, northeast to northeast of Ann Arbor RR	116	526	Denton Construction Co.
1961 CONSTRUCTION	BF 37014, C1RN	5	6.830	24 ft (Dual)	US 27 Reloc from north of Rosebush Rd, north to north of Herrick Rd	119	684	Denton Construction Co. (7)
1961 CONSTRUCTION	BF 29011, C8RN BF 29014, C1RN	5	3.900	24 ft (Dual)	US 27 Reloc from south of Lincoln Rd (old US 27 east of Alma), northwest to north of M 46	121	655	L. A. Davidson
1961 CONSTRUCTION	EBBF 37014, C7RN EBBF 18033, C1RN, C7UN	5 3	3.122	24 ft (Dual)	US 27 Reloc from north of Herrick Rd south of Clare, north to old US 27 north of Clare	122	705	Sargent Construction Co.
1961 CONSTRUCTION	BI 41024, C5RN	5	2.016	24 ft (Dual)	I 96 - US 16 from 930 ft northwest of Thornapple River Dr, east to 900 ft west of Whitneyville Rd	127	635	Pierson Contracting Co. (6)
1961 CONSTRUCTION	BI 41024, C7RN	5	2.003	24 ft (Dual)	I 96 - US 16 from north of 28th St (M 11), southeast to northwest of Thornapple River Dr	128	665	L. W. Edison Co.

* For widening or "third-lane" construction at these locations see Table 3.

(1) Contract awarded to Chas. J. Rogers Inc., Cooke Contracting Co., & Jutton-Kelly Co.
(2) Contract awarded to W. H. Knapp, Inc. and W. F. McNally Co.
(3) Contract awarded to Cooke Contracting Co. & Chas. J. Rogers Inc.
(4) Subcontract from Gilliland Construction Co.
(5) Subcontract from Holloway Construction Co.
(6) Subcontract from S. D. Solomon & Sons
(7) Subcontract from A. Lindberg & Sons Inc.
(8) Contract awarded to Hertel-Deyo Co. & C. E. Utterback

TABLE 1 (Cont.)
ROUGHNESS DATA SUMMARY FOR RIGID PAVEMENT (TWO-LANE POURS)

1961 CONSTRUCTION

Project	District	Length, mi	Type	Route and Project Location	Roughness: Integrator, In./Mile	Roughness: Level Indicator, g's/Mile	Paving Contractor
EBF 23061, C4RN, C6UN C8RN	8	5.281	24 ft	US 27 Reloc from old US 27 2660 ft north of Five Points Hwy, northeast and north to existing US 27 - M 78 northeast of Charlotte	130	511	L. W. Edison Co.
BF 37013, C8RN	5	3.370	24 ft (Dual)	US 27 Reloc from 875 ft north of Deerfield Rd, north to M 20	131	617	Hertel-Deyo Co. (8)
BI 41025, C3RN*	5	2.500	24 ft (Dual)	I 96 - US 16 from Leonard St, Grand Rapids, southeast to 1321 ft north of Cascade Rd (US 16 BR)	134	597	L. W. Edison Co.
EBBF 11081, C5R	7	2.244	24 ft (Dual), 48 ft, & 60 ft	I 94 BL from Fair St, Benton Harbor, east to I 94	134	611	Carl Goodwin & Sons, Inc. (9)
EBBF 76023, C2RN	6	6.590	24 ft (Dual)	M 78 Reloc from 850 ft east of M 47, northeast to 2000 ft southwest of Grand River Rd	135	505	C. F. Replogle Co.
EBBF 58033, C2RN	10	3.104	24 ft	US 23 Reloc (northbound only) from 141 ft north of Ann Arbor RR, north to Monroe-Washtenaw Co line east of Milan	137	732	S. J. Groves & Sons Co.
BU 41131, C55UN*	5	1.537	24 ft (Dual)	US 131 Reloc from Burton St, Grand Rapids, north to Franklin St (M 21 BR)	140	763	Hertel-Deyo Co.
BM 37015, C1RN	5	1.090	24 ft (Dual)	US 27 BR (south connection) from Herrick Rd, northwest to old US 27 south of Clare	141	764	Denton Construction Co. (7)
BI 70063, C10RN BI 41026, C3RN	5	6.254	24 ft (Dual)	I 196 - US 16 from east of 16th Ave (east of Marne), east to east of Bristol Rd (northwest of Grand Rapids)	142	790	Carl Goodwin & Sons, Inc.
EBBF 58033, C1RN	10	5.473	24 ft (Dual)	US 23 Reloc (northbound only) from 1050 ft north of M 50, north to 141 ft north of Ann Arbor RR	143	814	S. J. Groves & Sons Co.
BI 73111, C9RN	6	4.518	24 ft	I 75 (southbound only) from 3985 ft north of I 75 BL (southeast of Saginaw), north to 4289 ft north of M 46 interchange	147	643	Cooke Contracting Co.
BI 73171, C4UN, C6RN	6	5.093	24 ft (Dual)	I 75 from Birch Run Rd, north to 230 ft north of Townline Rd	147	812	Sargent Construction Co.
EF 82052, C14R*	10	0.564	24 ft	US 24 (southbound only) from Haskell St, north to 347 ft north of Hayes St.	149	832	Cooke Contracting Co.
BU 41131, C62UN*	5	0.624	24 ft (Dual)	US 131 Reloc from Franklin St, Grand Rapids (M 21 BR), north to Goodrich St	191	1073	L. W. Edison Co. (10)
EU 24011, C5U	4	0.587	24 ft (Dual) & 24 ft	US 31 Reloc from Bear Creek bridge, Petoskey, northeast to old US 31 (Bay View St)	244	1438	Hodgkiss & Douma, Inc.
				Weighted Arithmetic Mean for 1961 Construction Tested in 1961	128	633	
				WEIGHTED ARITHMETIC MEAN FOR 1961 ROUGHNESS TEST YEAR	134	677	

* For widening or "third-lane" construction at these locations see Table 3.

(7) Subcontract from A. Lindberg & Sons Inc.
(8) Contract awarded to Hertel-Deyo Co. & C. E. Utterback
(9) Contract awarded to Canonie Construction Co. & Carl Goodwin & Sons, Inc.
(10) Subcontract from L. W. Lamb Co.

Integrator measurements; where two or more projects have the same Integrator count, they are ranked by Level Indicator count. During the 11 years of the roughness surveys, these Integrator values have ranged from a low (smooth) of 93 to a high (rough) of 282. This year the range was from 103 to 244.

On the basis of riding quality, the Laboratory classifies projects in three Integrator-count categories: "good" (0 to 130 accumulated in. per mi roughness), "average" (131 to 174), and "poor" (175 or more). Table 2 shows that since 1961, with a total of 323 rigid pavement projects tested, 44, 45, and 11 percent of this total have been good, average, and poor, respectively. In the 1961 test year, 38, 49, and 13 percent of the 37 projects measured were good, average, and poor, respectively.

TABLE 2
ELEVEN-YEAR ROUGHNESS SUMMARY FOR RIGID PAVEMENT
(TWO-LANE POURS)

Test Year	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1951-1961
Total Projects	17	22	40	17	22	21	33	34	45	35	37	323
Percent <u>Good</u> 0-130 in./mi	41	5	18	29	36	19	61	74	53	83	38	44
Percent <u>Average</u> 131-174 in./mi	35	68	67	42	64	62	36	26	40	14	49	45
Percent <u>Poor</u> 175 or more in./mi	24	27	15	29	0	19	3	0	7	3	13	11
Weighted Arithmetic Mean	142	152	144	148	138	141	126	116	124	117	134	131
Project Mileage*	48.327	61.575	98.791	41.271	52.690	82.473	165.090	134.049	108.892	154.333	133.043	1140.529
Lane Mileage**	100.514	163.340	233.727	91.622	140.574	230.399	558.781	461.520	646.962	554.350	484.012	3664.801

* As given in Contract Division monthly "Report of Awards"
** Total mileage of 11- or 12-ft wide lanes

The weighted arithmetic mean for roughness of all projects tested this year increased 17 in. per mi over the mean for the preceding test year, as shown in Fig. 1. Two short projects with extremely high Integrator counts were significantly involved in this rise in the weighted arithmetic mean, both being less than 0.7 mi in length. The roughest pavement this year was 0.6 mi long, and had an Integrator count of 244 in. per mi; this is the roughest project encountered among newly constructed pavements since 1953, and the third roughest project measured in the whole 11-year test program. The extreme degree to which this project alone departed from the norm helped raise the mean for this test year.

Partly because of these short, rough projects, the "general trend toward improvement in overall pavement smoothness," cited in the 1960 roughness summaries (Research Report No. 366), did not continue in the

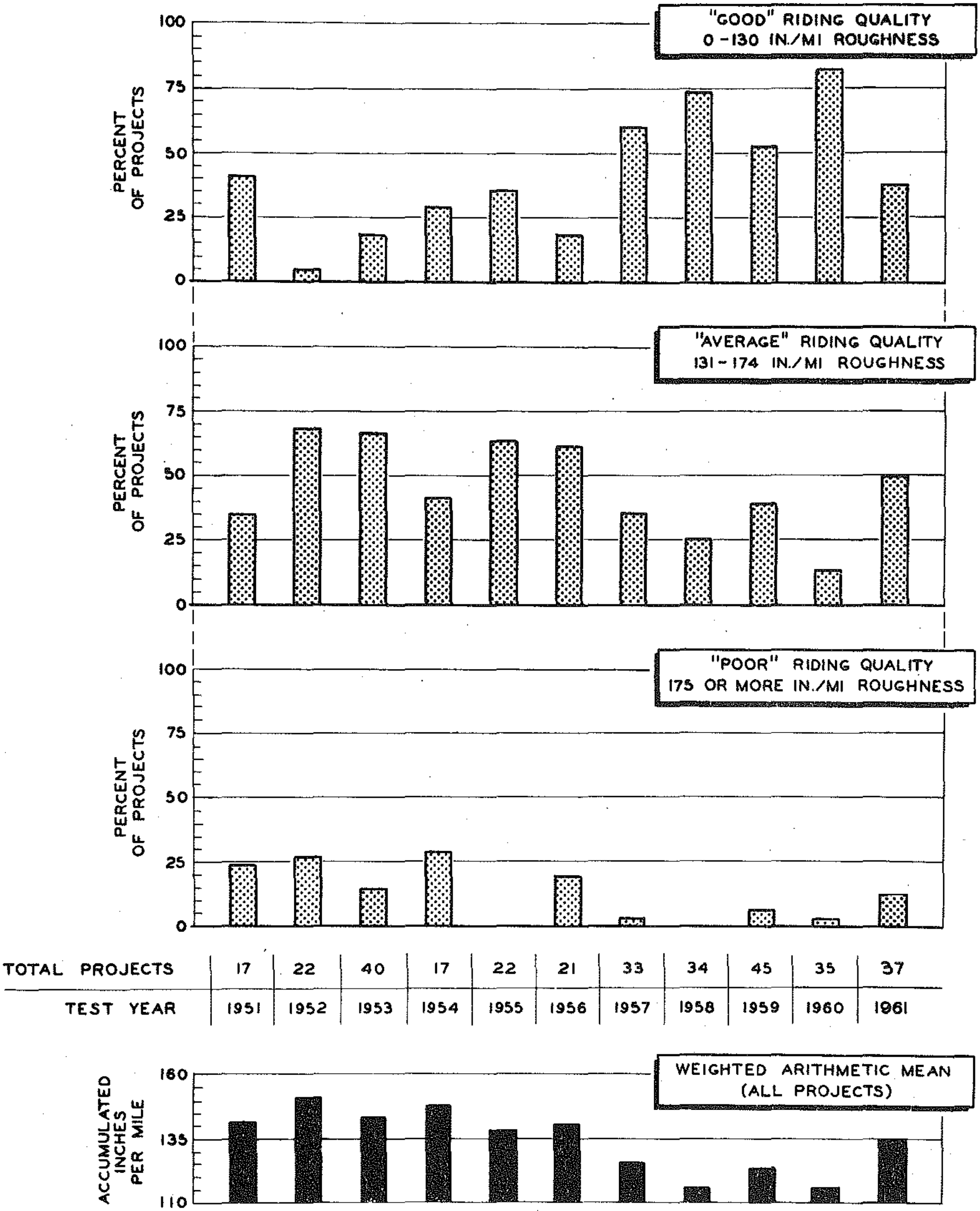

Figure 1. Annual roughness comparison for rigid pavement projects.

1961 test year. The percentages of all projects tested in the "poor" and "average" categories increased, while the percentage of "good" projects decreased.

Correlation of Roughness Measuring Instruments

The Laboratory's roughness measuring instruments are the Integrator (used since 1951) and the Acceleration Level Indicator (added in 1959 for supplementary and more extensive measurements, and intended for eventual

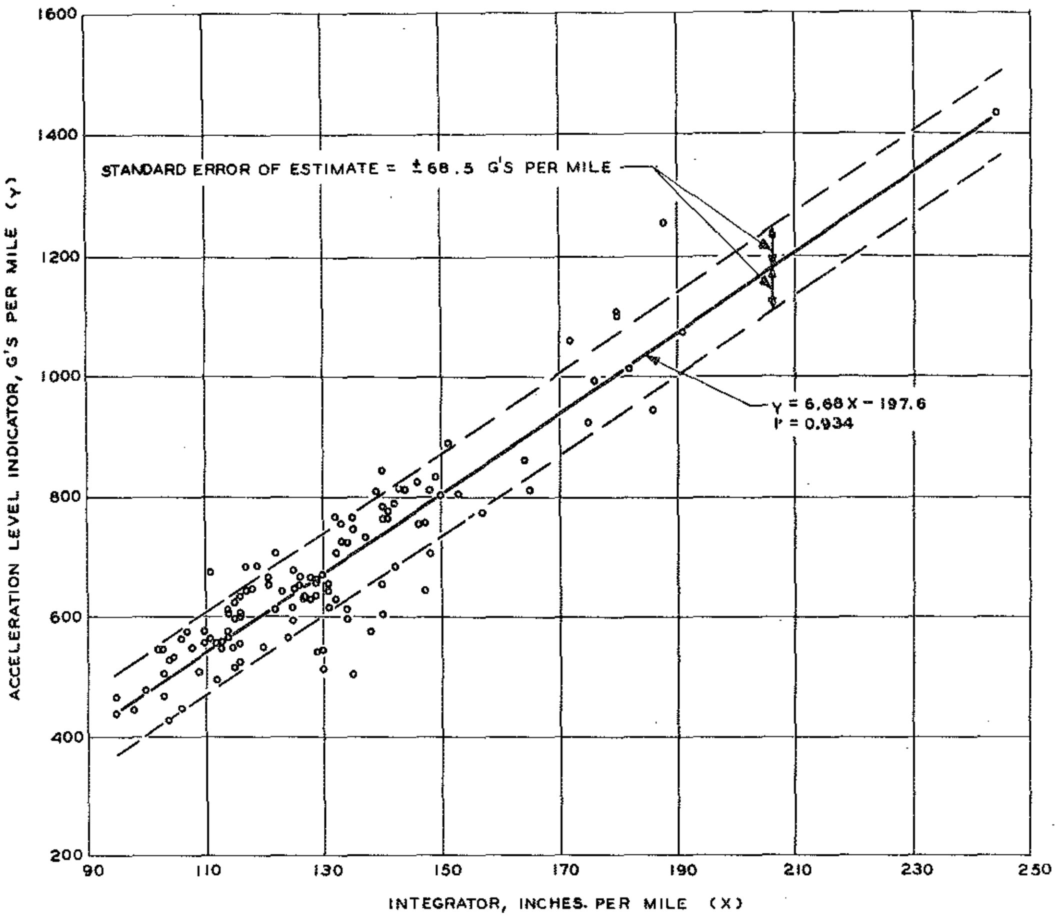

Figure 2. Comparison of rigid pavement roughness measurements by Acceleration Level Indicator and Integrator methods.

replacement of the Integrator as the primary rougnness measuring instrument). Correlation between the two instruments in their three years of combined use, as shown in Fig. 2, gives a standard error of estimate of

$\pm$ 68.5 g's per mile (Acceleration Level Indicator value) and a correlation coefficient of 0.934, indicating that the two instrumental systems are producing consistent and reliable results. This agreement between the instruments has resulted in immediate discovery and correction of occasional minor errors or irregularities in field measurements.

Relationship of Smoothness and Project Length

On the basis of logic and their own experience, most highway engineers would probably agree with the proposition that the shorter a rigid pavement project is, the greater is its likelihood of having a rough surface. It is undoubtedly true that as construction progresses at a given site, the men and machines generally tend to improve in efficiency in proportion to the extent of their activities. Thus, other things being equal, later pavement is often likely to be better pavement.

To the authors' knowledge, no statistical analysis has even been attempted specifically to demonstrate this relationship between length and smoothness. In view of the marked influence that a few short, rough projects exerted this year on Michigan's long-range figures for pavement roughness, such an analysis was made, including data from 320 projects* measured since 1951, totalling 1892 roadway miles, and varying in length from 22.9 to only 0.1 roadway miles.

This statistical analysis took the following forms and did show an association between smoothness and length for these projects, as follows:

1. Scatter Plot. Roughness in accumulated inches per mile (Integrator count) was plotted against project length in roadway miles as shown in Fig. 3, in which the good, average, and poor categories of riding quality are delineated. Using 6 roadway miles as an arbitrary demarcation between "longer" and "shorter" projects, all longer pavements are average or good in riding quality, while shorter pavements appear only in the poor and average categories of riding quality.

2. "t" Test. Mean lengths for projects in the good and poor categories of riding quality were found to be 7.620 and 1.867 roadway miles,

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* Three other projects were excluded from the total 323 surveyed, because of unusual design or construction characteristics, such as short or irregular slab length, etc.

respectively. To test the difference between these means, all data from the two categories were subjected to a t-test, a statistical technique used to assess the reliability of differences in such sample statistics as the mean, variance, standard deviation, etc. A definite difference between these data is evident in the t of 3.373 obtained for 120 degrees of freedom. The pertinent distributions are illustrated in Fig. 4. Further, Fig. 5 illustrates that a similar difference also can be obtained between the roughness distributions of shorter and longer projects, again using 6 roadway miles as an arbitrary demarcation between length types.

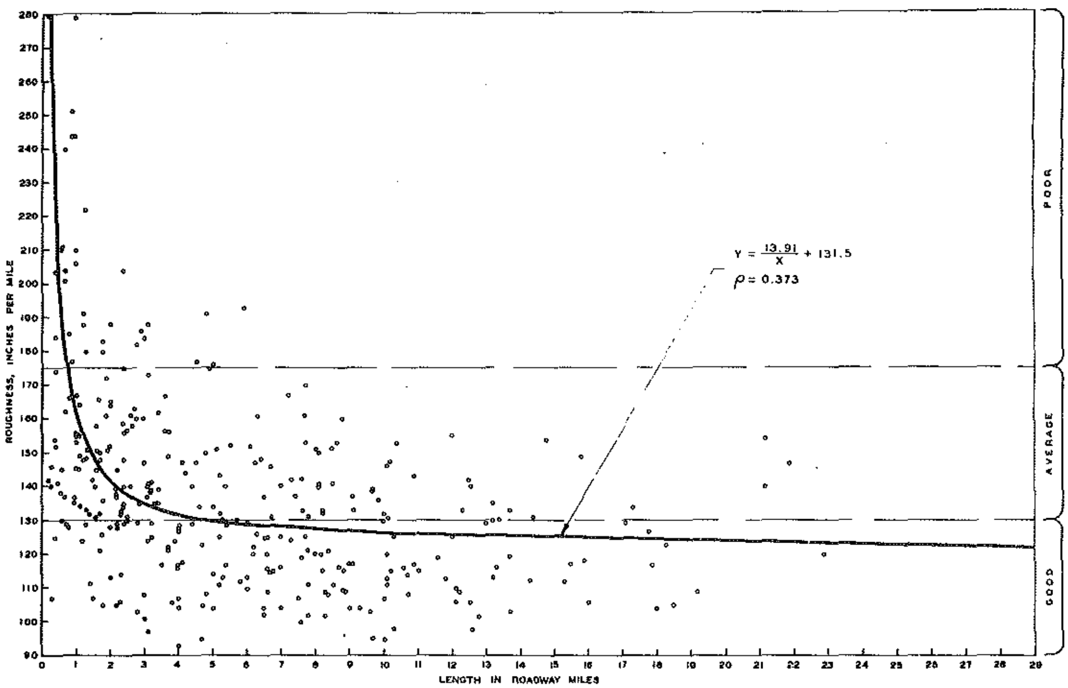

Figure 3. Scatter plot of pavement roughness versus roadway length for 320 Michigan projects, with correlation curve.

3. Correlation. Carrying the investigation further, a correlation analysis was performed, producing a correlation index of 0.373 (significant at a confidence level better than 0.01) using the hyperbolic curve

$$y = \frac{13.91}{x} + 131.5 \qquad (1)$$

The curve superimposed on the scatter plot in Fig. 3 was taken from the 320 projects; curvilinear correlation was used because, as may be observed, the relationship between roughness and length obviously is non-linear.

4. Means vs. Length. In an attempt to reduce the data given in Fig. 3, the roughness means of successive 1-mile increments of roadway mileage were plotted as shown in Fig. 6. These means follow the same general trend toward geometrical decrease in roughness as project roadway mileage increases.

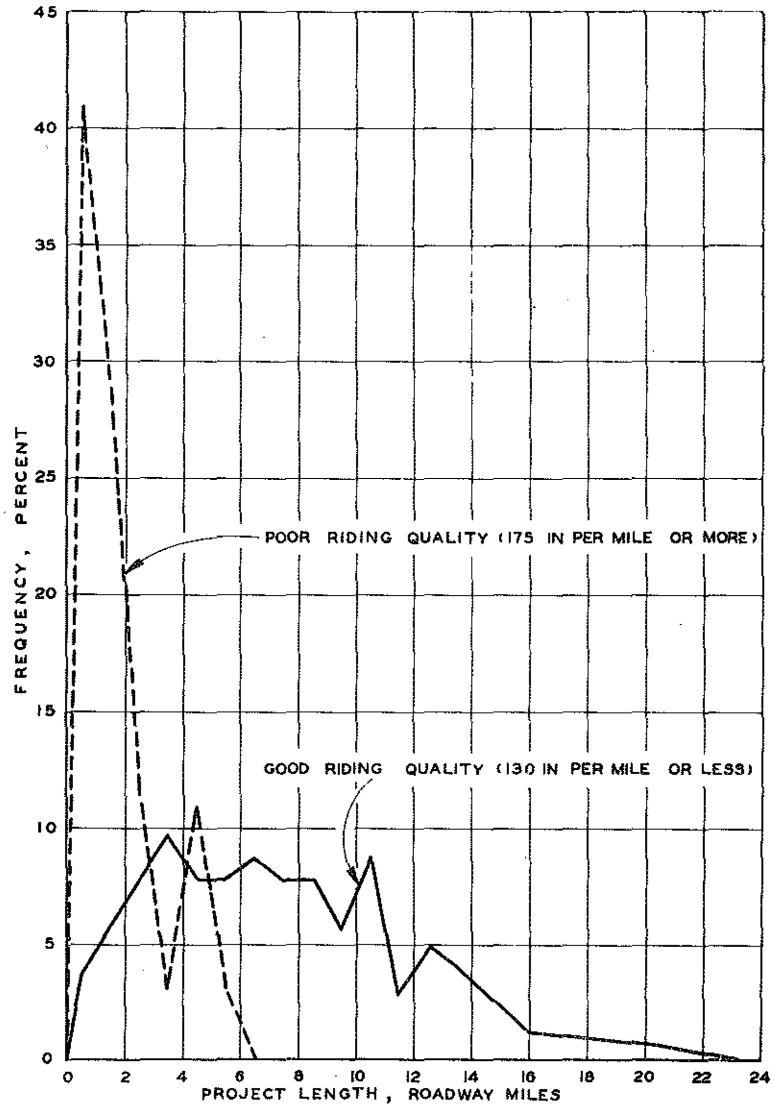

Figure 4. Frequency distributions of project lengths for "good" and "poor" categories of riding quality.

5. Standard Deviations vs. Length. Finally, perhaps the most significant of the various statistical determinations made, in its indication of the role and importance of quality control in construction operations, is

the plot of the relationship between standard deviation of roughness and roadway mileage. This is also illustrated in Fig. 6, where the standard deviations of successive 1-mile increments are plotted. A definite decrease in roughness standard deviation appears as roadway mileage increases, indicating that these longer projects are characterized by less variation in roughness. Roughness data clearly are statistically more predictable, more reliable, and more consistent as project mileage increases. The geometric relationship between roughness standard deviations and roadway mileage, like that between roughness means and roadway mileage, is one of decreasing roughness as roadway mileage increases, or more precisely, it is a decay function as indicated in Equation 1.

Figure 5. Frequency distributions of pavement roughness for "long" and "short" projects.

To eliminate the possibility that some combination of changing construction methods, gradual modification of test methods, and the long-term increase that has occurred in average project length, might have produced the trend in question, roughness and roadway length since 1951 were re-analyzed by successive two-year periods. Approximately the same relationship was obtained in each of these five successive two-year periods, so that construction methods, survey methods, and increasing average length do not account for the trend.

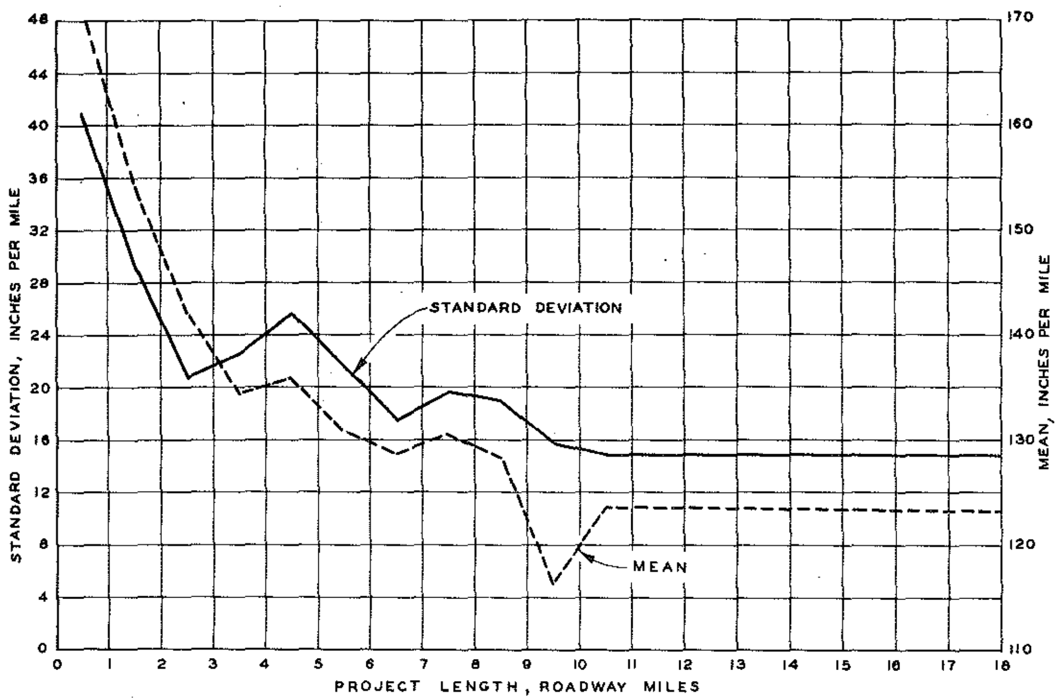

Figure 6. Roughness standard deviations and roughness means versus project length in roadway miles as computed for successive 1-mi increments.

Thus it was concluded that by various statistical methods, the relationships between project length and pavement roughness were clear enough, for these projects, to indicate a trend toward increasing smoothness with increasing length. Because the t-test results will not occur by chance factors alone as often as one time in a thousand, a conclusion that roughness is a function of project length definitely is warranted.

Given this quantity of data and this trend, it is apparent that close supervision and quality control are particularly important for smoothness on shorter construction projects.

Rigid Pavement Construction (One-Lane Pours)

In addition to the usual surveys of roughness on newly constructed standard rigid pavements (two-lane pours), the 1961 measurements included 10 rigid pavement widening projects (one-lane pours), with the results shown in Table 3 and Fig. 7.

The testing and reporting procedures used for these projects are the same as those for standard rigid pavements. However, due to somewhat different construction procedures required in pours of one lane-width, the range of roughness values varies somewhat from that for standard rigid pavements. For this reason widening projects are reported and tabulated separately from standard rigid construction. Table 4 summarizes test data obtained during the four years in which this type of construction has been under study.

Flexible Pavement Construction

Seven projects built to Interstate expressway standards were surveyed in 1961. The accumulated inches per mile figures presented in Table 5 are the result of measuring runs in separate wheel tracks in the traffic and passing lanes.

As in the case of rigid pavement widening, this type of roughness measurement represents a supplement and extension of the Department's roughness program, and will be included in all future annual reports as construction warrants. Normally, only flexible pavements of expressway quality will be included in future surveys, although other bituminous projects may be measured when special roughness conditions make this desirable.

TABLE 3
ROUGHNESS DATA SUMMARY FOR RIGID PAVEMENT WIDENING
(ONE-LANE POURS)

	Project	District	Length, mi	Type	Route and Project Location	Roughness: Integrator, in./Mile	Roughness: Level Indicator, g's/Mile	Paving Contractor
1959 CONSTRUCTION	DU 82053, C6U, C14U, C15R	10	2.849	12 ft	US 24 (median side, southbound only) from Fenkell Rd (Five Mile Rd), north to Grand River Ave (US 16)	146	794	H. J. Brighton
	F 82053, C2R, C9R	10	1.836	12 ft	US 24 (median sides, both roadways) from Ford Rd (M 153), north to the Ann Arbor Trail, and US 24 (median side, northbound only) north of the Ann Arbor Trail	160	784	Cooke Contracting Co. (1)
	U 82052, C12U U 82053, C1U F 82053, C12R	10	2.498	12 ft	US 24 (outer sides, both roadways) from Oxford Rd, north to Ford Rd (M 153)	176	993	Bairley & Lindley Inc.
					Weighted Arithmetic Mean for 1959 Construction	160	861	
1960 CONSTRUCTION	U 82053, C5R	10	3.339	12 ft	US 24 (median sides, both roadways) from Belton Rd, north to Fenkell Rd (Five Mile Rd)	148	814	Cooke Contracting Co. (2)
	BU 56023, C2U	6	0.957	12 ft	M 20 Reloc (outer sides, both roadways) from Ellsworth St, Midland, east to Washington St	153	776	W. H. Knapp, Inc. (3)
	BU 41131, C43UN, C44UN	5	1.000	12 ft	US 131 Reloc (median sides, both roadways) from 28th St, Wyoming (M 11), north to Burton St, Grand Rapids	178	1119	L. W. Edison Co.
					Weighted Arithmetic Mean for 1960 Construction	155	865	
1961 CONSTRUCTION	BI 41025, C3RN	5	2.500	12 ft	I 96 - US 16 (median sides, both roadways) from Leonard St, Grand Rapids, southeast to 1321 ft north of Cascade Rd (US 16 BR)	162	828	L. W. Edison Co.
	BU 41131, C55UN	5	1.537	12 ft	US 131 Reloc (median sides, both roadways) from Burton St, Grand Rapids, north to Franklin St (M 21 BR)	163	884	Hertel-Deyo Co.
	EF 82052, C14R	10	0.564	12 ft	US 24 (median side, southbound only) from Haskell St, north to 347 ft north of Hayes St	173	832	Cooke Contracting Co.
	BU 41131, C62UN	5	0.624	12 ft	US 131 Reloc (median sides, both roadways) from Franklin St, Grand Rapids (M 21 BR), north to Goodrich St	199	1160	L. W. Edison Co. (4)
					Weighted Arithmetic Mean for 1961 Construction	168	885	
					WEIGHTED ARITHMETIC MEAN FOR 1959-61 CONSTRUCTION	161	869	

(1) Contract awarded to Chas. J. Rogers Inc., Cooke Contracting Co., & Jutton-Kelley Co.
(2) Contract awarded to Cooke Contracting Co. & Chas. J. Rogers Inc.
(3) Contract awarded to W. H. Knapp & W. F. McNally
(4) Subcontract from L. W. Lamb Co.

*All construction is "third-lane" widening to projects reported in Table 1.

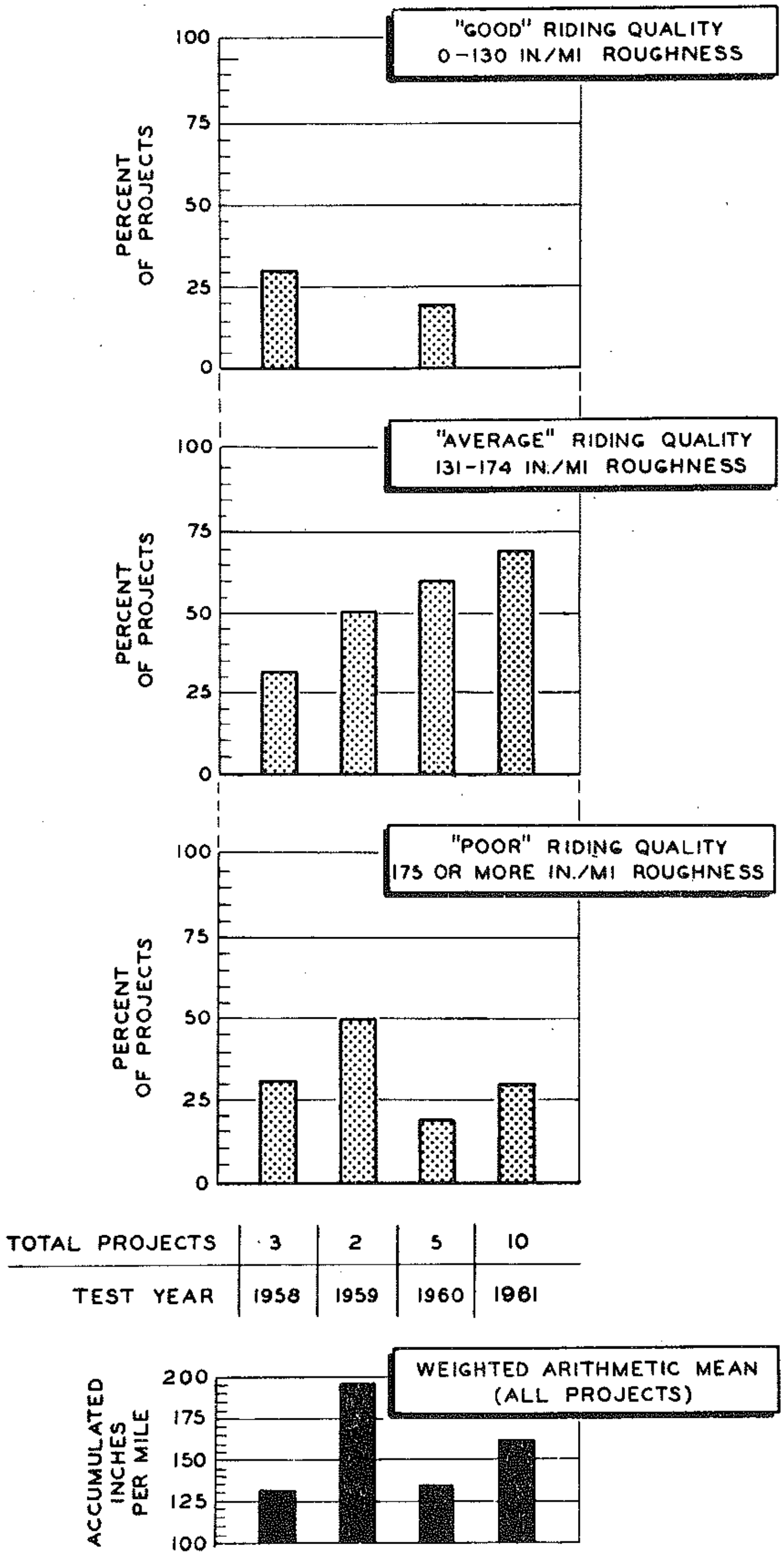

Figure 7. Annual roughness comparison for rigid pavement widening projects.

TABLE 4
FOUR-YEAR ROUGHNESS SUMMARY FOR RIGID PAVEMENT WIDENING
(ONE-LANE POURS)

Test Year	1958	1959	1960	1961	1958-1961
Total Projects	3	2	5	10	20
Percent <u>Good</u> 0-130 in./mi	33.3	0	20	0	10
Percent <u>Average</u> 131-174 in./mi	33.3	50	60	70	60
Percent <u>Poor</u> 175 or more in./mi	33.3	50	20	30	30
Weighted Arithmetic Mean	130	194	140	161	151
Project Mileage*	6.403	3.092	13.925	17.704	41.124
Lane Mileage**	10.533	3.872	24.152	31.679	70.236

* As given in Contract Division monthly "Report of Awards"
** Total mileage of 11- or 12-ft wide lanes

TABLE 5
ROUGHNESS DATA SUMMARY FOR FLEXIBLE PAVEMENT

Project	District	Length, mi	Type	Route and Project Location	Roughness		Paving Contractor
					Integrator, In./Mile	Level Indicator, g's/Mile	
BI 61152, C5RN	5	5.297	24 ft (Dual)	I 196 - US 16 from 300 ft southeast of US 31, southeast to the Muskegon-Ottawa Co line	91	395	Reith-Riley Construction Co.
EBF 72013, C1RN	4	9.643	24 ft (Dual)	US 27 Reloc from 9.181 mi south of M 55, north to 0.462 mi north of M 55	96	260	Ann Arbor Construction Co. & Lake & Howell Co.
EBI 11015, C10RN, C14UN	7	7.873	24 ft (Dual)	I 94 from Snow Rd, north to Ridge Rd	101	467	Reith-Riley Construction Co. & Globe Construction Co. (1)
BI 11015, C8RN	7	6.759	24 ft (Dual)	I 94 from 2947 ft southwest of Easy Rd, north to Snow Rd	106	466	Globe Construction Co. (2)
EBI 70063, C6RN EBI 70064, C1RN	5	3.020	24 ft (Dual)	I 196 - US 16 from 2750 ft northwest of State Rd, southeast and east to Fitzgerald St	117	484	Paul C. Miller (3)
EBI 70063, C8RN	5	4.880	24 ft (Dual)	I 196 - US 16 from Fitzgerald St, east to 72nd Ave	119	591	Michigan Colprovia Co. (4)
BI 70064, C3RN	5	2.053	24 ft (Dual)	I 196 - US 16 from Muskegon-Ottawa Co line, southeast to 2750 ft northwest of State Rd	124	502	Paul C. Miller
				Weighted Arithmetic Mean for 1961 Construction	104	425	

(1) Subcontract from Holloway Construction Co.
(2) Subcontract from Canonie Construction Co.
(3) Subcontract from Maclean Construction Co.
(4) Subcontract from S. J. Groves & Sons Co.