SPECIAL ROUGHOMETER TESTS

1957

IOWA STATE HIGHWAY COMMISSION

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1957

Materials Department
Iowa State Highway Commission
February 1958

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ILLUSTRATIONS

GENERAL

During the 1957 season there was occasional opportunity to make special tests to determine the amount of influence of various construction factors and procedures. Without these objective measurements as a guide each engineer and contractor necessarily bases his viewpoint on the particular experiences he has had, and over a long period of time these men may arrive at good answers to a great many questions about roughness. However, the objective measuring process turns up an occasional surprise of great value, an unsuspected factor, and in any case there is a worth while saving of time, sometimes years, in getting the answers.

The tests and results reported here are valuable by themselves as useful information; but when the results can be combined with additional similar measurements or cases their utility will be further enhanced.

It has been found that engineers and contractors in the field are not only eager to make full use of all findings and conclusions arrived at, but actually are anxious to use the roughometer for special tests of their own to answer questions about which they are by nature curious. Their genuinely scientific attitude should be fostered and maintained by providing them all with the results given in this report, and by encouraging them to volunteer their own special problems for testing.

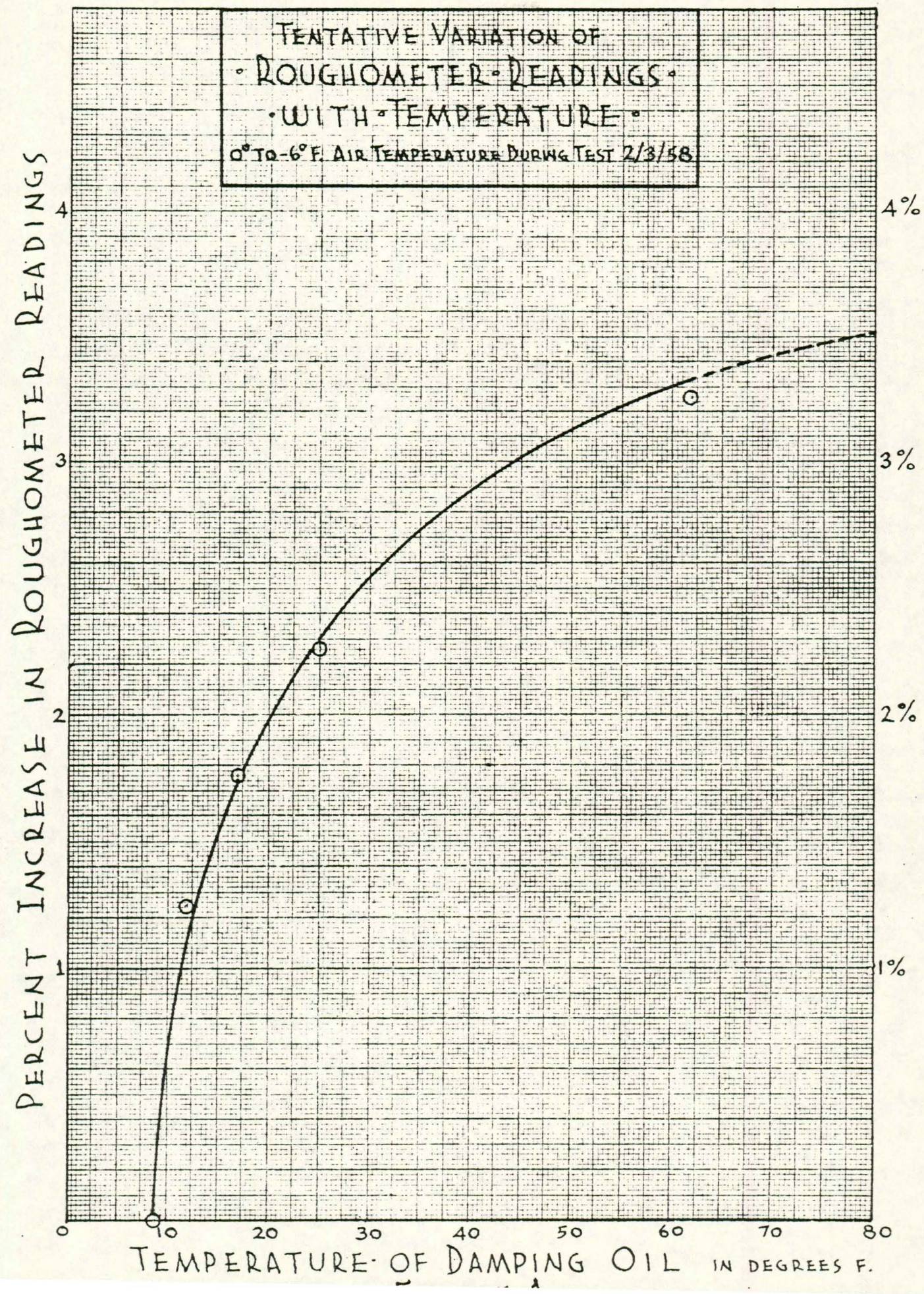
TENTATIVE TEMPERATURE CURVE FOR ROUGHOMETER

Inasmuch as roughness measurements necessarily are made in different kinds of weather it has been desired to determine how much temperature correction would be required in a calibrating adjustment. The curve of Figure 1, which is tentative and is presented in the simplest form, shows the values obtained on February 3, 1958. Since the air temperature changed only from 6 degrees below zero to zero during the tests it is assumed that the road did not change in roughness during that time.

The conclusion is that the change with temperature is not very great, but it would be best to correct even for an amount as small as 1% to 3%. Above 60 degrees the curve is extrapolated (dotted line), and it would appear that in warm weather above 60 degrees the change is exceptionally small, while the relative change becomes much greater below 60 degrees. The upper end of the curve might be checked further in hot weather if it were possible to find a drive-in refrigerator in which to park the machine for cooling before making repeated tests during warm-up.

Accurate temperature correction is necessary for the comparison of the roughness of roads during hot and cold weather, or between mid-day and night, etc.

Form E-3


TENTATIVE VARIATION OF
ROUGHOMETER READINGS
WITH TEMPERATURE
0° TO -6° F. AIR TEMPERATURE DURING TEST 2/3/58
PERCENT INCREASE IN ROUGHOMETER READINGS
4
3
2
1
0
4%
3%
2%
1%
10
20
30
40
50
60
70
80
TEMPERATURE OF DAMPING OIL IN DEGREES F.

EXAMPLE OF AN OLD ROAD

In order to increase the range of roughness information available, a road about 38 years old in Palo Alto County was measured because of its age and the fact that it is in daily use the same as many newer roads. It is the portland cement road, Iowa 17, leading south from Emmetsburg to Mallard. It has many repaired cracks in it, but between cracks it appears to be surprisingly good.

The natives in the area say that it was paved by the Bauck and Brereton Company in 1919. The record is as follows:

	Section Miles	West Lane	East Lane
Start at Emmetsburg	1.00	153	166
	1.00	142	156
	1.00	162	166
	1.00	151	150
	1.00	140	153
	1.00	146	147
	1.00	144	146
	1.00	153	155
	1.00	139	141
	1.00	140	143
End at Mallard	1.00	141	147
Total	11.00	Av. 152	Av. 146

The average of two lanes for 11 miles is 149 in. per mile.

WET PAVEMENT

In one case on an asphaltic concrete road, Project S-849(2) at Cherokee, the measurement was made about 5:00 P.M. one evening with the sun shining in August and the tempera-

ture about 72 degrees. Because the road was not quite finished, another measurement was made the next morning under similar conditions except that there was a light rain and the pavement was wet. This second test showed a decrease of about 3 inches per mile for the three miles.

It is not known whether water on the road decreases the readings in any way, but in certain other cases where it was necessary to measure the road while wet it was thought that the readings were perhaps too low. To settle this question one way or the other it is planned to measure some roads both dry and wet by having a water truck precede the roughometer to make the road wet.

EFFECT OF DIRT ON PAVING

The slip-form paving in Palo Alto County, 7 miles long and constructed by the Hallett Company, was measured at a time when they were beginning the shouldering operations. A certain amount of dirt was tracked on the paving at various places. Because of this the Hallett Company requested that the road be measured again when it was clear of dirt. This recheck was made, accompanied by a representative of the Hallett Company, about two months after the original measurement. The first test showed an average of 95 inches per mile while the second showed 92.5, indicating that the dirt

Figure 2. Engineers from Fairfield and Ames in a typical field meeting near Donnellson.

on the road may have accounted for an average of about 2.5 inches per mile.

In another case, in Pottawattamie and Shelby Counties, an asphaltic concrete road had considerable dirt on one side for a distance of a mile. Measurement with the dirt on the road showed 75 inches for the mile, and after removal of the dirt with a patrol blade it showed 57 inches.

EFFECT OF SAWED AND SEALED JOINTS

Part of the portland cement concrete of Projects F-217(3) and F-87(5), Muscatine and Scott Counties, was measured before and after the sealing of the sawed joints to see if the joints affected the roughness. The 4.50 miles measured before and after showed a decrease of about two inches per mile at the later measurement, which probably indicates that the dirt which was washed off the road by the intervening rains had a much greater effect than the sealed joints.

A similar measurement was made on 2.75 miles of Project F-1049(2) in Black Hawk County. The results after sealing showed an increase of 1.7 inches per mile on the north lane and 1.4 inches per mile on the south lane, or an average increase of about 1.5 inches per mile.

All of the above results would not apply to rougher joints or to the older joints, of course. It is likely that on neat joints the tire flexes gently as it passes over a joint. It appears that the Portland Cement Association has a point, when, in their advertisements they say that the "thump" is gone.

WIDENING VERSUS OID PAVING

The portland cement widening of Project F-41(12), constructed by Booth and Olson for a length of 5.68 miles, was measured at the same time that the center of each lane of the old paving was measured. The results are as follows:

	Average Roughness	
	Widening	Old Paving
North Lane	109	113
South Lane	108	112

It appears from the above figures that the widening may tend to be similar in roughness to the old paving it adjoins. This may be due to the fact that an effort is made to join the edge of the widening to whatever level the old paving happens to be at every point. The same principle may apply to the laying of asphaltic concrete, where the lane that is put down second has to join the first lane at the center. The disadvantage of having to join the first lane may tend to make the second lane rougher; but this is yet to be checked.

Figure 3. Typical construction scene encountered enroute to a job.

FORWARD AND ADVERSE PAVER DIRECTION

Several people have asked if the portland cement paving measures the same in the forward as in the adverse direction of travel of the paver. Others have believed that there could be no difference and that the question should not even be considered. In any case, the quickest way to find out is to take some measurements.

A part of Project F-1049(2) in Black Hawk County was measured on both sides of the road before it was opened to traffic. A distance of 4.75 miles showed an average of 100.8 and 101.0 on the south lane and 96.6 and 95.2 on the north lane. Since these differences are small this would lead to the conclusion that there is no significant difference on conventional paving.

Another job was measured in the same way but was of the slip-form construction. This is Project F-982(3) in Warren County. For a distance of 2.75 miles measured there proved to be a difference as follows:

	North Lane	South Lane
Forward Direction	98.6	96.1
Adverse Direction	93.9	93.3
	4.7	2.8

Thus, the road measured an average of 3.75 inches per mile smoother in a direction adverse to the direction of the paver. Since the difference is rather large but the distance measured

is small any tentative conclusion will have to be held in abeyance pending further tests, although this test leaves open the possibility that there may be a difference.

PROPORTION OF COARSE AGGREGATE VERSUS ROUGHNESS

Several different mixes were used in the portland cement concrete of Projects F-217(3) and F-87(5) in Muscatine and Scott Counties. The #1 mix, with a higher proportion of coarse aggregate, was used for 839 feet and the #4 mix was used for 1196 feet, making these sections too short for any useful roughness comparisons.

The #2 mix was used for 3.25 miles and the #3 for 6.50 miles, and the comparison in roughness of the finished concrete is confined to these two. The coarser #2 mix showed an average of 85.85 inches per mile, while the #3 mix showed 82.50. This is a difference of 3.35 inches per mile, and is statistically significant enough for the amounts measured. But in a single case of this kind there is no certainty that the difference is alone due to the nature of the aggregate. Therefore, in order to draw any conclusions it will be necessary to collect the data from many projects where the only constant factor in all of them is the proportion of the mix. Meanwhile, the present test shows that it is possible that there is a difference in roughness due to the aggregate used.

Figure 4. Engineers from Mason City at a meeting in Worth County.

(Note the scattered [illegible])

THE TWO LANES OF SLIP-FORM PAVING

While measuring Project F-210(1) for roughness in Plymouth County a difference in the readings for the two sides of the slip-form paving was noticed. In trying to explain this, it occurred to Eldon Schoeneman, Resident Engineer, that the reason might be due to the fact that the foreman and inspectors circulate on the operator's side and tend to watch the subgrade more closely on that side. This might then tend to make the right-hand lane smoother. Upon checking the direction of travel of the paver, including a point two miles from the north end where the paver had been turned about during construction, the figures were found to correlate perfectly.

Following this further, the details of the paver directions were then obtained from the resident and county engineers involved for all the jobs of any size which were measured during the present season. In all, more than 58 miles of slip-form paving were tested for smoothness of the right-hand lane.

The results proved to be quite striking, and were the same for any company in the field, whether Hallett, Duesenberg, or Carlson. Wherever the paver was turned about the smooth side changed to the other side of the road to remain in the right-hand lane. Out of 17 sections or paver directions there were only two exceptions, and in these two the roughness was

practically equal in the two lanes. The list of the 17 sections is as follows:

Project	County	Miles	Average Roughness		
			Right Lane	Left Lane	Difference
F-1007(2)	Howard-Winneshiek	11.33	88	93	5
PC-GL	Boone	2.00	83	84	1
S-902(6)	Palo Alto	3.00	93	95	2
		3.92	89	96	7
Kempton Road	Polk	1.50	103	108	5
		2.00	86	92	6
S-854(6)	Greene	1.98	70	75	5
	"	1.89	72	75	6
	"	2.00	69	73	4
County Rd.	Hamilton	.50	86	90	4
		1.46	85	96	11
S-506(5)	Iowa	4.75	85	89	4
F-982(3)	Warren	3.25	94	93	-1
FN-1103	"	.96	102	104	2
F-210(1)	Plymouth	2.00	73	83	10
		5.50	77	86	9
F-886(9)	Plymouth Woodbury	10.50	94	93	-1
Av. for 17 sections and		58.54 mi.	86	90	4

The difference of 4 inches between the average of 86 for the right-hand lane and 90 for the left-hand lane is quite large.

It is possible that there is a tendency to watch the right-hand track of the paver more than the left-hand, but the resident engineer on the Howard-Winneshiek project re-

ported that the difference on this job was more likely due to a difficulty that was encountered in adjusting the left-hand end of the screed on the new machine operated by the Carlson Company.

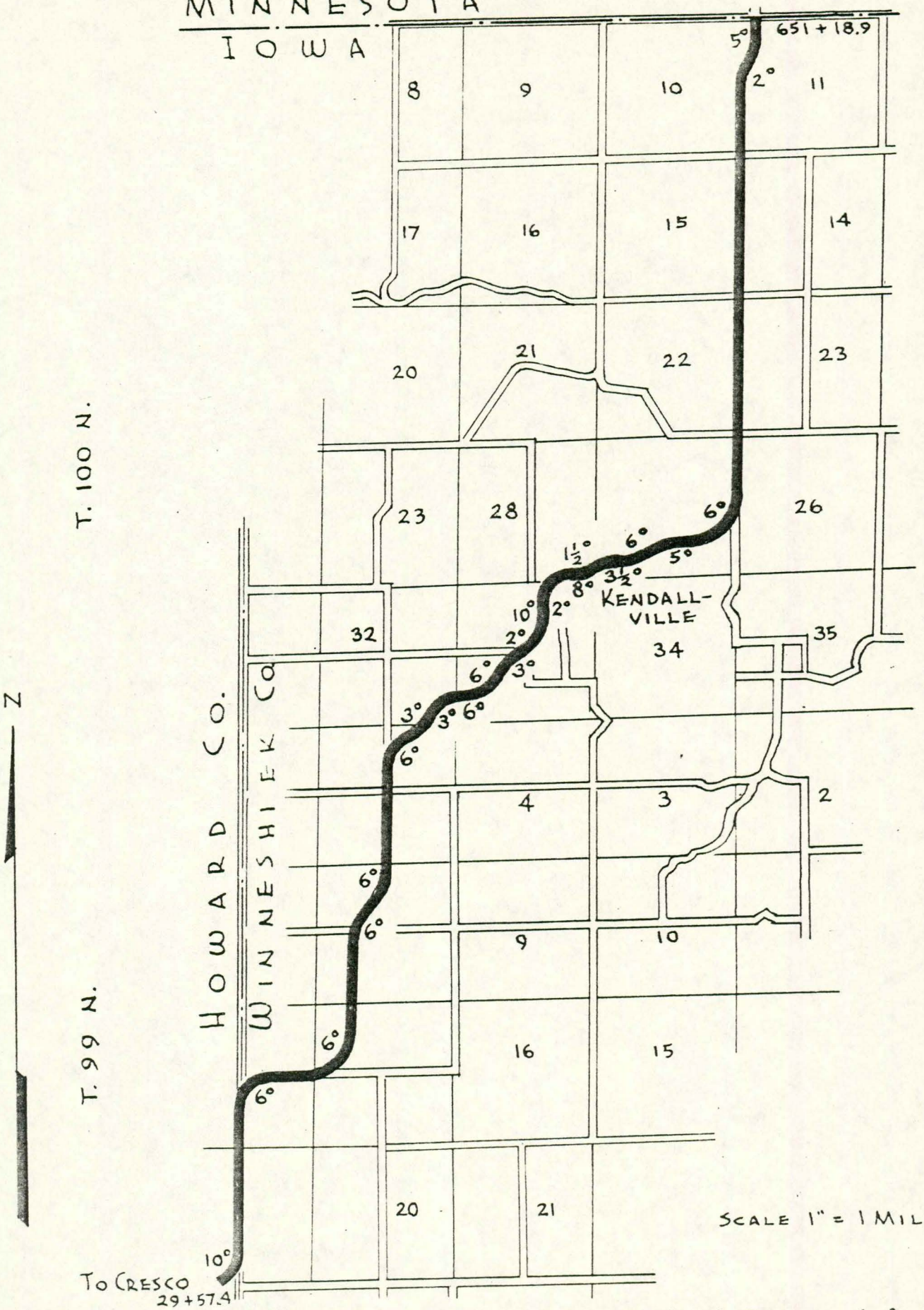
In Hamilton County much of the excess roughness seemed to be due to many poor joints at the end of each day's work.

Fred M. Short, Palo Alto County Engineer also has volunteered to report, "In my opinion, one factor to consider regarding roughness is the width of track made by the form line grader. It seems to me that a wide excavation would be more desirable to prevent the subgrade machine from getting up on one edge or the other as they vary from their string-line. This, in my opinion, is the major cause of the roller coaster effect."

Whatever the cause or causes of this apparent excess of roughness in the left hand lane, it would seem advisable to inform all slip-form construction people at once of these findings. With attention focused on the problem the cause might be located and corrected; and the result of this could be an appreciable improvement in construction.

GRADES AND CURVES OF SLIP-FORM PAVING

In order to determine the relative roughness of slip-form paving built upon different kinds of terrain a project



• LAYOUT • OF • PROJECT • F-1007 (2) •

PORTLAND CEMENT CONCRETE, SLIP-FORM, 1957

MATERIALS DEPARTMENT, IOWA STATE HIGHWAY COMMISSION, JANUARY 1957

Figure 6. Resident Engineer at north end of slip-form project. Wheel of roughometer is located on Minnesota line.

in Howard and Winneshiek counties was investigated in November 1957. The cooperation of James O. Loy, Resident Engineer, and his staff made it possible to stake out the different parts of the road according to the plans for direct measurement of the sections with the roughometer to save time.

The project is F-1007(2), 11.42 miles long, 7" thick and 22 feet wide, and runs from two miles east of Cresco north to the Minnesota line. The road was constructed by the Fred Carlson Company; and although it was this company's first job with a slip-form paver the construction process and results appeared to be very much like those of any other company.

The terrain provided an unusual opportunity for measuring construction on grades and curves, because there were 22 curves in the 11.42 miles ranging from 1½ degrees to 10 degrees, and there were something like 35 different upgrades and 35 different downgrades.

Thus, it was possible to measure the inside land and outside lane of each curve separately, while the grades were divided into two groups: those of less than 3% and those 3% or greater. Where the grades were gentle, short, and variable from plus to minus a separate classification was made. The level and straight paving was separated into still another group. In addition, the measurements were taken both in the center of each lane and at a point approximately 18 inches from the outside edge of each lane. It was thought that this

latter measurement would be of particular interest because of the possibility of edge-slumping due to the lack of forms, although this represents only a first effort at measurement of slip-form paving outside the regular driving lane.

Many measurements were involved in all this, even though an effort was made to simplify the whole procedure as much as possible. The yield of information was well worth while, although it is somewhat proportional to the time spent in getting it; and if time had permitted, it would have been even better to have divided each curve into parts according to the amount of the grade at the curve or to have analyzed the record from this standpoint.

As it is, the roughness due to the grade at the curves is confounded with the absolute values of roughness due to the curves; but this does not affect the relative comparison of the inside lane with the outside lane of any curve since the same grade can be assumed to prevail on both sides of the road. Also, the comparisons are dependable because the measurements were made under conditions that did not change during the short period of the tests.

The slip-form paving was found to be quite variable, as would perhaps be expected, and this precluded a further break-down of the relatively small amount of data obtained in the measurement of one project in a small amount of time. General conclusions are evidently dependent upon trends which can be determined, and if the data from more projects were to

be combined with the present data there would be more differences discernable.

For example, the differences between the inside lanes and outside lanes of the curves here did not fit any pattern with respect to the degrees of curvature, but when the 22 curves were combined the difference between lanes for the average was very pronounced. With more cases provided by more projects a separate difference could possibly be established for each of the different degrees of curvature and the confounding effects of the grades extracted; more cases, of course, raise the statistical confidence level for any particular difference found. Also, more cases of each size of grade would permit the determination of roughness according to size rather than according to the two groups of above and below 3% grade used here.

But since a graphic record was made for both the center-of-lane and the edge measurements the data can be further broken down or combined with other data at any future time. The size and location of grades and curves according to the project plans and the graphic record will permit detailed analysis in any way desired. For instance, where the grade changes on a curve the roughness for each part of the curve can be read on the roughness record separately and in very short sections.

The present separation of the measurements shows that there are differences which warrant making several conclusions.

The size of these differences and the number of miles measured would surely place the statistical confidence level above 1%, although time was not taken to make this test. Also, it should be borne in mind that the following findings and conclusions pertain tentatively to this project and its roughness measurements:

1. Level slip-form paving is outstandingly smooth, but the paving on a downgrade of less than 3% is virtually as good.

2. Paving a downgrade of more than 3% is not as difficult as paving an upgrade of less than 3%.

3. The most difficult of all is paving an upgrade of more than 3%.

4. The inside lane of a curve is definitely rougher than the outside lane in the average case.

5. The difference between the inside and outside lanes of a curve varies from an average of 3 inches per mile at the center of the lane to 18 inches per mile measured 18 inches from the edge.

6. For the entire road the average measurement at 18 inches from the edge was 23% more than the measurement at the center of the lanes. Since there is quite a difference between the measurement at the center of the lane and near the outside edge it would be well to take measurements at some future time in other longitudinal lines to determine a "roughness profile" to aid in evaluating slip-form paving.

7. The various numerical comparisons and results are shown on Figure 9 and 10.

8. In using a slip-form paver the greatest care should be exercised in paving upgrades of any size, in paving downgrades of more than 3%, and in paving curves, with special attention to the inside lane. Attention at these points would probably result in improved construction.

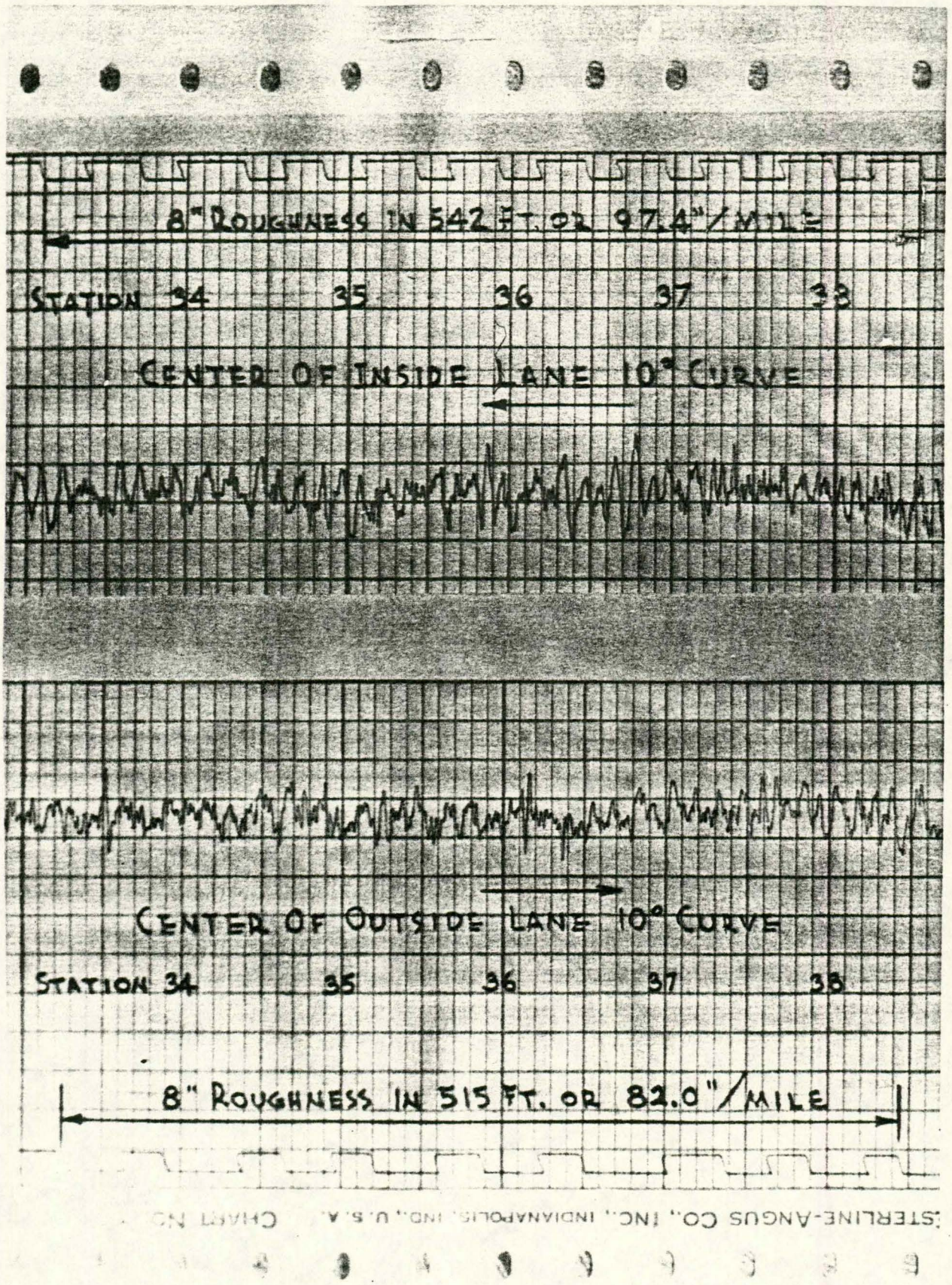


Figure 7. Comparison of record for inside and outside lanes at a curve.

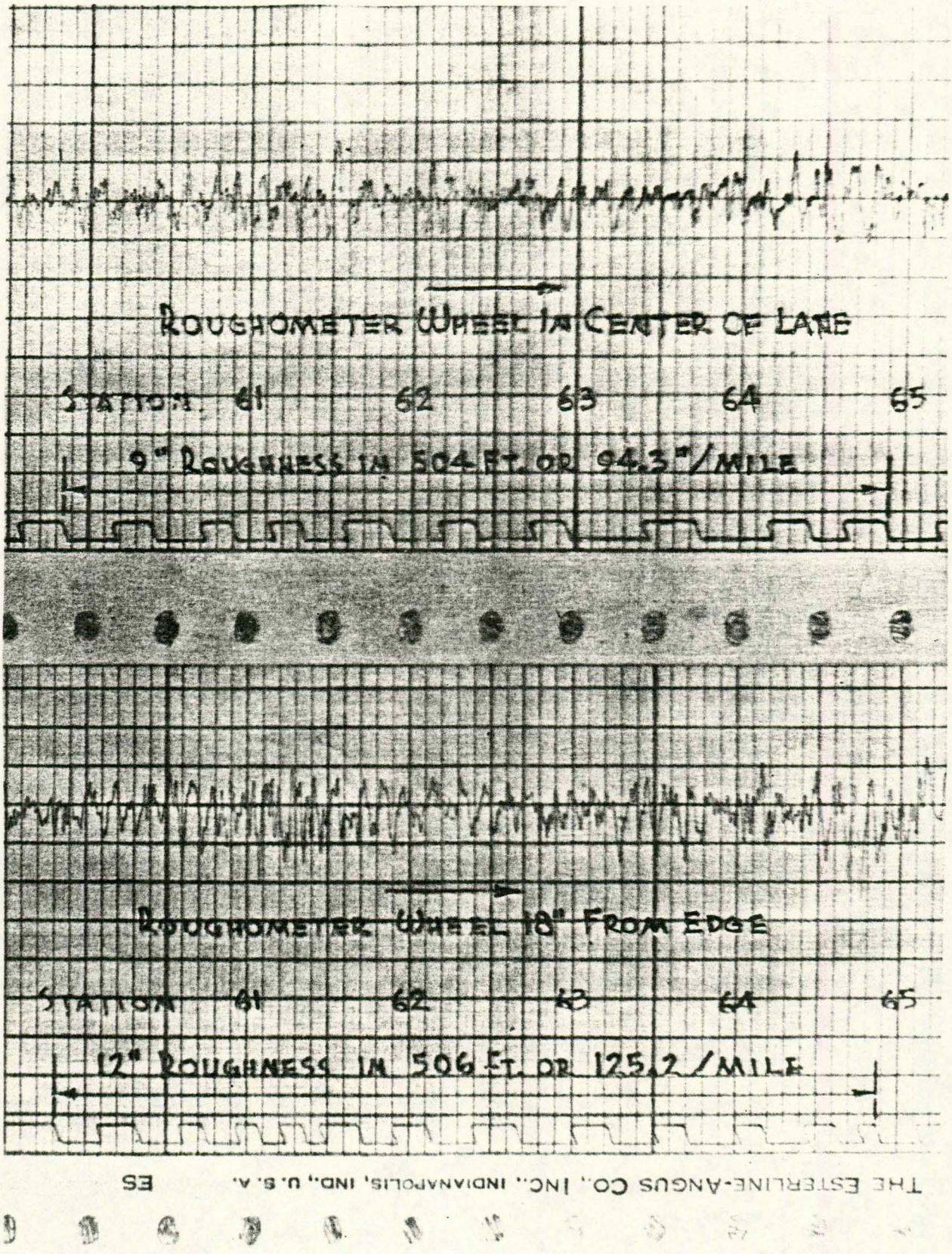


Figure 8. Comparison of the record at center of lane with the record made near the edge.

KIND OF TERRAIN	MILES	CENTER	EDGE
LEVEL PAVING	3.45	80	104
ROLLING SLOPES	5.29	90	109
GRADES, ACCORDING TO PAVER TRAVEL			
UPGRADES			
3% TO 6%	1.77	112	124
0% TO 3%	0.35	102	110
DOWNGRADES			
3% TO 6%	1.93	101	116
0% TO 3%	1.16	81	104
CURVES, TWENTY-TWO 1½° TO 10°			
INSIDE	4.24	95	125
OUTSIDE	4.30	92	107
TOTAL ROAD	22.84	91	112

* ROUGHNESS RATE IN INCHES PER MILE.
EDGE MEASUREMENT IS 18" FROM OUTSIDE.

• ROUGHNESS • SUMMARY •
• WITH • TWO • LANES • COMBINED •

PROJ. F-1007(2) HOWARD-WINNESHIEK CO.

MATERIALS DEPARTMENT • IOWA STATE HIGHWAY COMMISSION • JANUARY 1957

	West Lane			East Lane		
Kind of Terrain	Miles	Edge	Center	Center	Edge	Miles
Level Paving	1.65	102	76	83	105	1.80
Rolling Slopes	2.65	101	87	93	117	2.64
Grades, according to paver travel						
Upgrades						
3% to 6%	0.89	130	112	113	117	0.89
0% to 3%	0.18	113	102	102	108	0.18
Downgrades						
3% to 6%	0.96	108	94	108	125	0.96
0% to 3%	0.58	96	76	86	112	0.58
Curves, twenty-two 1½° to 10°						
Inside	2.34	120	96	95	130	1.90
Outside	1.90	105	92	92	108	2.41
Total Road	11.42	108.	88	93	115	11.42

* Roughness Rate In Inches Per Mile.
Edge Measurement Is 18" From Outside.

• Roughness • Summary • By Lanes •

Project F-1007 (2) Howard-Winn. Co.

Materials Department • Iowa State Highway Commission • January 1957