1930 Scivally, while regularly employed as county highway engineer or as a project engineer for the state highway department, served in a consulting capacity. In 1930 he went on a full-time basis with the district and continues in that capacity today.

APPENDIX

List of Equipment and Date Acquired

3——5 Cu. Yd. 2½-Ton Dump Trucks, (1947. 1948, 1950)
1——D7 Caterpillar Tractor with Dozer, (1946)
2——½-Ton Pick-up Trucks, (1937, 1948)
1——Fordson Tractor with mower attachment, (1947)
1——600-gallon road oil distributor mounted on 1½-Ton LWB Trunk, (1935)
1——Roller 4 Ton Fordson modified
1——Motor Patrol Caterpillar No. 11, (1938)
1——Motor Patrol Caterpillar No 112, (1950)
1——Front end loader (High Lift) mounted on rubber tires, capacity ¾ Cu. Yds., (1950)
1——Shovel, ½ Cu. Yd. capacity, (1940)
1——12,000-gallon Road Oil Storage Tank, (1948)
1——Scarifier, (1920)
1——Fresno Tumbling Type
1——Air Compressor and Rock Drill
1——Well Drill, (1943)
4——Power mowers for park Maintenance

PERFORMANCE STUDY OF CALCIUM-CHLORIDE-TREATED ROADS

E. M. Baylard, *Superintendent of Highways, Onondaga County, New York*

● The Secondary Roads Committee of the Highway Research Board was formed in 1947 in response to an expressed need for information on maintenance of secondary or county roads. One of the first activities of this committee was to conduct a survey of county maintenance units. In addition to collecting information on county highway organization, the survey attempted to determine from the counties the problems of maintenance on which they desire special studies. The four subjects given most response were: (1) stabilized aggregate surfaces, (2) drainage and erosion, (3) maintenance of low cost roads, and (4) dust alleviation.

It was agreed that a performance study of stabilized gravel roads in Onondaga County would be of interest. The program as conducted was the result of a series of conferences with representatives from the Bureau of Public Roads in Washington and Albany, the Bureau of Soils Mechanics of the New York State Department of Public Works, the Calcium Chloride Institute, and the Solvay Process Division of Allied Chemical and Dye Corporation.

HISTORY OF THE GRAVEL ROADS

Beginning in 1932 with a 50-mi. road program, the Onondaga County Highway Department had constructed 435 miles of calcium-chloride-treated gravel roads by the close of the 1938 season. The program was designed to provide: work relief with a maximum expenditure of money for labor and a minimum for materials; good all-weather farm-to-market roads; and adequate bases for higher-type surface when traffic conditions warranted.

At the present time, approximately 325 mi. of these roads have been covered with a bituminous surface mat or a gravel-tar mulch, leaving about 110 mi. still being maintained as calcium-chloride-treated gravel surfaces.

A detailed description of the materials and method of construction was reported by R. B. Traver and W. B. Hicks in the Proceedings of the Thirteenth Annual Meeting of the Highway Research Board, December 1933. For the purpose of this report it is necessary only to mention details which were factors in this gravel loss investigation.

Most important of these details is the fact that a standard road design was adopted, with a cross-section as illustrated in Figure 1. The actual construction consisted in clearing and grubbing work; the laying of permanent, ample culverts; and ditching and grading, using material from the ditches in building the subgrade. The grading was completed by blading and rolling to form a smooth, flat subgrade from ditch to ditch.

Bank-run gravel was spread on the subgrade, large stones removed by raking, and the surface shaped by blading, followed by rolling and honing. The quantity of gravel and shaping of the surface was guided by stakes to give a 9-in. depth at the center line, a six-in. depth 5 ft. either side of the center, and feathering out at 10 ft. This resulted in a partially compacted surface representing 1711 cu. yd. of gravel per mi., with an average depth for the 20-ft. width of 5.25 in. After final rolling, followed by traffic compaction, it was determined that the final average compacted depth was 4.75 in., representing approximately 1550 cu. yd. of surface material per mi.

After completion of the surface, flake calcium chloride was spread at the rate of 1½ lbs. per sq. yd. (8.8 tons per mi.) using an ordinary lime spreader.

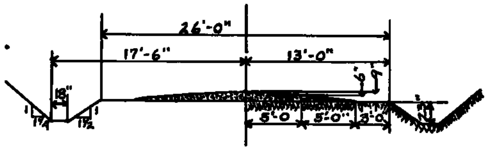

Figure 1. Typical section of gravel roads, partially compacted. Onondaga County, N. Y.

GRAVEL-LOSS STUDIES

The aggregate loss from untreated traffic bound surfaces under different traffic and climatic conditions has been variously estimated by highway engineers at 0.25 in. to 1 in. of material per year. However, no information based on actual measurements was available until a rather extensive investigation, sponsored by the Calcium Chloride Association, was made by the Department of Engineering Research of the University of Michigan between 1935–38. This study was reported in the 1938 PROCEEDINGS of the Highway Research Board, and included both untreated and calcium chloride treated gravel surfaces.

The test procedure consisted in taking wear measurements from permanent bench marks previously established by reading a level rod to an accuracy of 0.01 ft. on each ft. of cross-section of the maintained roadway. To guard against a general shift of foundation, level measurements also were taken from the bench marks to plates buried in the roadway below the frost line. A careful record was made of any new aggregate placed on the test projects during the period of investigation.

The test roads, after allowing for the above changes, showed an annual average loss on untreated roads of 284 cu. yd. of gravel per mi.; on stabilized calcium-chloride-treated roads of 91.5 cu. yd. per mi. With an average traffic count of 395 vehicles per day on these test roads, the average gravel loss per 100 vehicles per mi. per yr. was 72 cu. yd. on untreated roads, and 23 cu. yd. on calcium-chloride-treated roads.

To the best of our knowledge no other systematic study of gravel loss has been made up to the present time.

PRESENT PERFORMANCE STUDY

A program for the proposed study of Onondaga County roads was first discussed at a meeting with R. B. Traver, county superintendent of highways, Syracuse, N. Y., in June 1951. Traver has since retired due to ill-health but has maintained an active interest in the investigation Two subsequent meetings were held in Syracuse in August and November 1951 to review the progress and to assist in planning this report. Technical representatives from the groups previously mentioned were present at these meetings.

During the first meeting an inspection trip was made over gravel roads in all sections of the county. Several test trenches were dug, and a distinct line of demarcation was found between the gravel surface and subgrade soil. With this assurance that the actual gravel depth could be measured with reasonable accuracy, and that a known quantity and depth of gravel was placed on each road during construction, it was agreed that a study of gravel loss would be the primary objective of the investigation.

Twelve test roads, representing conditions in the four quadrants of the county, were selected after being assured that no general gravel replacements had been made on any of these roads. In a few cases some gravel had been added to strengthen weak sections, but these were spotted by the section foremen so that they would not be included in any test area Most of the foremen and grader operators, as well as Traver and the writer, were with the highway department when these roads were constructed.

We are thoroughly familiar with the maintenance requirements and have good records of both construction and maintenance costs.

In addition to gravel loss, the plan of study included the sampling and analyses of surface gravel; in-place densities; traffic densities; subsoil data; weather data; maintenance methods, and costs.

Gravel Measurements

Two methods were used to determine the average depth of existing gravel on each test road·

Trench Method. A trench approximately 10 in. in width was dug from one edge to the center line, extending into the subgrade sufficiently to show the line of demarcation between surface and subgrade. Measurements of gravel depth to the nearest 0.1 in. were made at the center line and at 1 ft. intervals to the surface edge. For convenience, a string 10 ft. in length was held at the lower edge of the gravel at the center, and leveled to conform with the original subgrade surface. Where the surface width had been reduced, the line was always above the roadbed at the outer end, showing that some of the original subgrade had been removed by the grader.

The average gravel depth was then calculated from these measurements for a width of 20 ft., assuming that both halves of the surface were identical. The trenches were alternated at succeeding test stations on each road. Figure 2 shows measurements being taken at Station 13.

Crown Measurements. A wooden straight-edge 10 ft. in length was leveled, with one end at the center line, and held in place by an adjustable leg at the outer end. It was then assumed to be parallel with the original flat subgrade, and measurements were taken from the bottom of the straight edge to the surface at 1-ft. intervals over the entire width of 20 ft. Figure 3 shows these measurements being taken at Station 25.

Crown measurements were made as close as possible to the test trench at practically all test stations. The trench measurement of gravel depth at the centerline was substituted for the zero reading of the straight edge, and the gravel depths corresponding to the other readings were determined by difference.

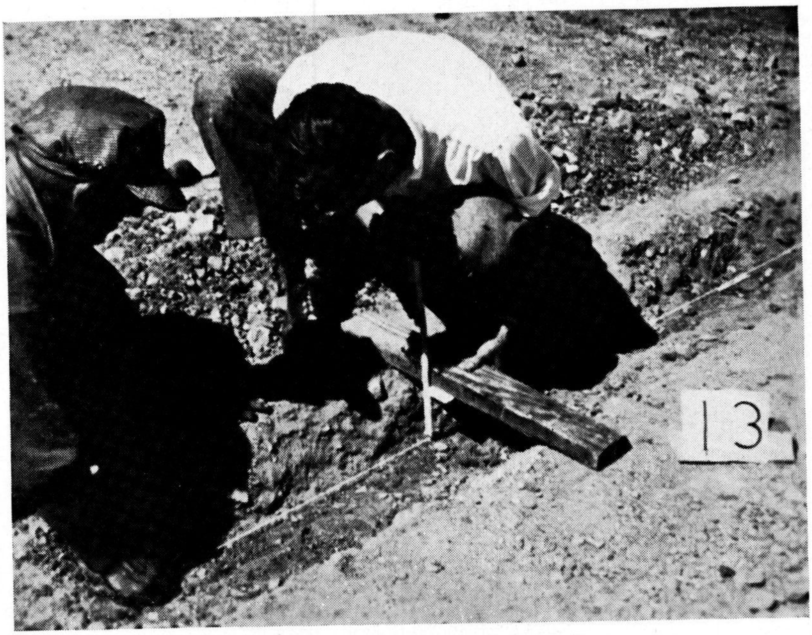

Figure 2. Trench measurements at Station 13.

In nearly all cases the average gravel depths obtained from the trench and crown measurements were practically identical for the same half of the surface. In some cases, however, the crown measurements showed less gravel on one side than on the other side of the established centerline. It was considered advisable, therefore, to calculate the gravel loss from the crown measurements.

Gravel measurements were made at 42 stations on the 12 test roads representing approximately 33 mi. The names of the roads with corresponding county-road numbers and other information are listed in Table 1.

The gravel loss at each test station, the average loss for each test road and the average loss for all roads are shown in Table 2. The loss was determined by difference between the original compacted depth of 4.75 in. and the slight increase in depth, with the other two stations showing slight decreases; the average was approximately the same as the original depth. It has been assumed, therefore, that the gravel loss on these three roads was zero.

Figure 3. Crown measurements at Station 25.

TABLE 1
TEST ROADS: GENERAL INFORMATION

County Road Number	Name of Road	Year Constructed	Location in County	Length in Miles	Test Stations		
					No.	Reference Point	Distance from Reference Point
147	Whiting	1933	NE	0.60	3	N. Y. Rte. 31	0.05, 0.25, 0.45 mile N
254	Weaver	1938	NE	0.82	3	C. R. 123	0.2, 0.5, 0.75 mile N
253	Sneller	1938	NE	1.29	3	C. R. 16	0.2, 0.75, 1.0 mile W
216	O'Brien–Devoe	1935	NW	5.00	5	C. R. 106	0.5, 1.0, 1.7, 2.6, 3.9 mile S
226	Daboll	1935	NW	2.22	3	C. R. 272	0.6, 1.25, 1.8 mile W
202	NW Town Line	1934	SW	3.00	4	C. R. 41	0.7, 1.7, 2.2, 3.0 mile N
244	Shepard	1936	SW	1.20	1	C. R. 236	0.5 mile S
246	Otisco	1937	SW	5.30	6	U. S. Rte. 11A	0.7, 2.0, 3.0, 4.1, 5.7, 6.0 mile W
174	Graham	1933	SE	0.68	1	C. R. 112	0.5 mile S
173	Sentinel Heights	1933	SE	4.72	5	C. R. 174	0.3, 1.6, 2.6, 3.6, 4.5 mile S
171	No. 5 W. Barber Hill	1933	SE	4.00	5	C. R. 170	0.6, 1.6, 2.6, 3.5, 4.0 mile E
237	Swift Radway	1935	SE	1.55	3	C. R. 114	0.4, 0.9, 1.5, mile S

present average gravel depth calculated over a surface width of 20 ft.

Roads 147 and 237 showed some increase in gravel depth at each test station, indicating that the original compacted depth may have been slightly greater than the designed 4.75 in. One station on Road 254 also showed a

Slight increases in depth were found at a few other stations, but each of the remaining nine roads showed average gravel losses ranging from a minimum of 0.62 in. to a maximum of 3.45 in. The average loss for all 12 roads was 1.186 in. or 387 cu. yd. of compacted gravel per mi.

TABLE 2
GRAVEL LOSS DATA: 12 TEST ROADS

County Road No.	Test Station No.	Ave. Compacted Gravel[1] Depth in Inches over 20 ft. Width		Loss or Gain in Compacted Gravel				Age of Road	Traffic Count
		by Trench	by Crown	In	Cu. Yd. per Mi.	in. per yr.	Cu. Yd. per Mi. per Yr.		
								yr.	*vpd.*
147	1	5.1	5.6	+0.85	+277	+.047	+15	18	
	2	4.8	5.2	+0.45	+147	+.025	+8		
	3	5.7	4.9	+0.15	+49	+ 008	+3		59
	Ave.	5.2	5.23	+0.48	+157	+.027	+9		
254	4	4.8	4.6	−0.15	−49	−.012	−4	13	
	5	4 8	4 5	−0.25	−82	− 019	−6		
	6	5.2	5.2	+0.45	+147	+.035	+11		
	Ave.	4.93	4 77	+0.02	+7	+.002	+1		
253	7	3.5	3.5	−1.25	−408	− 096	−31	13	
	8	3.6	4.1	−0.65	−212	−.050	−16		
	9	4.6	4 8	+0.05	+16	+.004	+1		
	Ave.	3.9	4.13	−0.62	−202	−.084	−16		
216	10	5.2	5.2	+0 45	+147	+.028	+9	16	147
	11	2.0	1 9	−2.85	−930	− 178	−58		
	12	1.7	1 5	−3.25	−1060	−.203	−66		129
	13	3.7	3.7	−1 05	−342	−.066	−21		75
	14	2.9	—	−1.85[a]	−588[a]	− 116[a]	−37[a]		
	Ave.	3 1	3 08	−1.71	−558	− 107	−35		116
226	15	3.8	3.9	−0.85	−277	− 053	−17	16	109
	16	4 2	4.3	−0.15	−49	− 009	−3		75
	17	2 4	2 7	−2.05	−668	− 128	−42		
	Ave.	3.47	3.63	−1.02	−333	−.064	−21		92
202	18	3.9	3 2	−1.55	−505	−.091	−30	17	73
	19	2.4	2.7	−2.05	−668	−.121	−39		96
	20	3.3	2 6	−2.15	−701	−.127	−41		
	21	4 4	4.2	−0.55	−179	− 032	−11		
	Ave.	3 5	3 2	−1.58	−514	−.093	−30		85
244	22	3 7	3 4	−1 35	−440	−.090	−29	15	65
246	23	3.3	3 5	−1.25	−408	− 089	−29	14	76
	24	3.5	3.2	−1.55	−505	− 111	−36		
	25	3 4	3.2	−1 55	−505	− 111	−36		
	26	2 4	2 0	−2.75	−897	− 197	−65		190
	27	3 1	3.4	−1.35	−440	−.096	−31		182
	28	—	5.0	+0 25	+82	+.018	+6		
	Ave	3 14	3 38	−1.38	−450	− 099	−32		149
174	29	1 4	1.3	−3 45	−1125	−.192	−63	18	216
173	30	6 4	5 5	+0 75	+245	+.042	+14	18	162
	31	2 5	2 5	−2 25	−734	− 125	−41		
	32	5 0	5 1	+0.35	+114	+ 019	+6		
	33	2.0	2.1	−2.65	−864	−.147	−48		
	34	1.9	1.6	−3 15	−1027	−.175	−57		
	Ave	3 56	3.36	−1 39	−453	−.077	−25		162
171	35	3 1	2 2	−2.55	−831	− 142	−46	18	83
	36	2 8	2.9	−1 85	−588	− 103	−33		69
	37	5 6	5 1	+0 35	+114	+.019	+6		46
	38	3 2	3 0	−1 75	−571	−.097	−32		
	39	1.9	1.9	−2 85	−930	−.158	−52		
	Ave.	3 32	3 02	−1 73	−564	−.096	−31		66
237	40	5 9		+1.15[a]	+375[a]	+.072[a]	+23[a]	16	47
	41	5 0		+0 25[a]	+82[a]	+ 016[a]	+5[a]		
	42	5 3	5 7	+0 55[a]	+179[a]	+ 034[a]	+11[a]		
	Ave.	5.4	5 7	+0 65[a]	+212[a]	+ 041[a]	+13[a]		47
Ave all roads				−1 186	−387	− 074	−23 5	16	107

[1] Trench measurements
Test road averages indicating increase in gravel have been considered as showing no loss in computing overall averages

The ages of the test roads vary from 13 to 18 yr. with an average service of 16 yr. When the above gravel loss is calculated on a yearly basis it varies from 16 to 63 cu. yd. per mi. or an average loss of only 23.5 cu. yd. per mi. per yr. On the basis of loose gravel as loaded into a truck, this represents a loss of approximately 31 cu. yd. per mi. per yr.

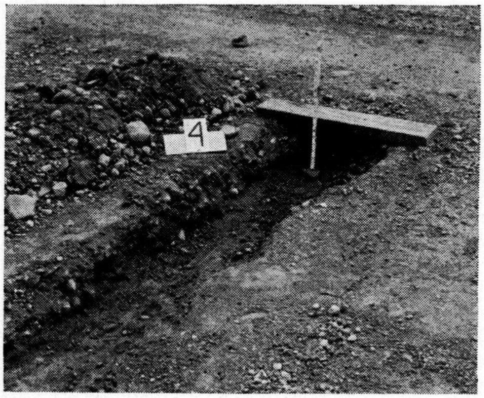

Figure 4. Typical trench: Station 4.

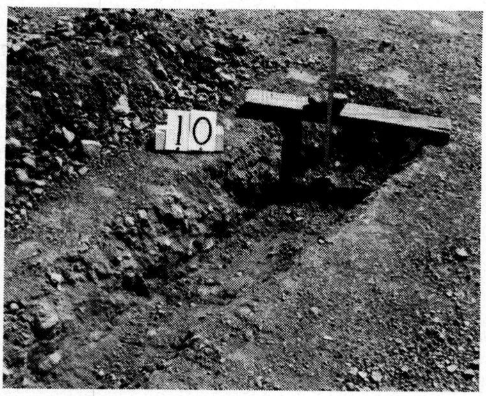

Figure 5. Typical trench: Station 10.

Figures 4, 5, and 6 show other typical trenches.

Figures 7, 8, and 9 are road views at Stations 18, 23, and 32. The latter shows a 17 percent grade, with the trench at Station 32 just below the crest of the hill.

Figure 10 represents the present typical road section as obtained from the average of all depths at each 1-ft. interval. The dotted line represents the original contour of the surface and shoulders. The gravel loss over the 16-yr. period is indicated by slight decreases in both gravel depth and surface width. It is evident also that in maintaining these roads the grader operators have bladed in shoulder material along with any loose gravel to provide for compaction.

It will be noted that the vertical scale of Figure 10 is twice that of the horizontal scale which exaggerates the change in contour considerably.

GRAVEL ANALYSES

Before replacing the gravel in the trenches, representative samples were taken at 10 test stations representing nine different roads, one or more in each quadrant of the county. After drying in the laboratory these samples were screened, and soil constants were determined on the material passing the No. 40 sieve.

The results of the tests are shown in Table 3. It is apparent that the run-of-bank gravel used on these roads contained a number of large stones, in some cases larger than 3 in. This makes the quantity of coarse aggregate (material retained on No. 10 sieve) appear to be rather high, ranging from approximately 64 percent to 77 percent, with an average of 71 percent for the 10 samples. Actually there is sufficient finer material in all cases to embed the coarse aggregate satisfactorily. This is due undoubtedly to the uniform gradation from coarse to fine material, as indicated by the typical gradation curves shown in Figure 11.

Plasticity indexes vary from 3.6 to 8.4, with an average of 5.6, which experience indicates is quite satisfactory for gravel surfaces maintained with calcium chloride.

IN-PLACE DENSITIES

Density tests using the sand-funnel method were made at eight stations on five different roads. A test hole is shown in Figure 12, and the test equipment in operation in Figure 13. The test results are shown in Table 4.

The dry densities varied from 139 to 155 lb. per cu. ft., with an average for the eight stations of 146 lb. per cu. ft. These results compare favorably with previous tests conducted about 1934 which showed an average of approximately 150 lb. per cu. ft. for similar calcium-chloride-treated gravel surfaces.

TRAFFIC DENSITIES

Traffic counts were taken on Saturday, September 29, 1951, from 6 A.M. to 6 P.M. at 14 locations on 10 of the test roads. The 24-hr. count was then calculated, using a factor derived from master station counts taken several years ago. These counts covered 24-hr. periods, both week days and week ends in various seasons of the year. A factor of 1.64 was obtained for converting a 12-hr. week end count in September to an average 24-hr. count.

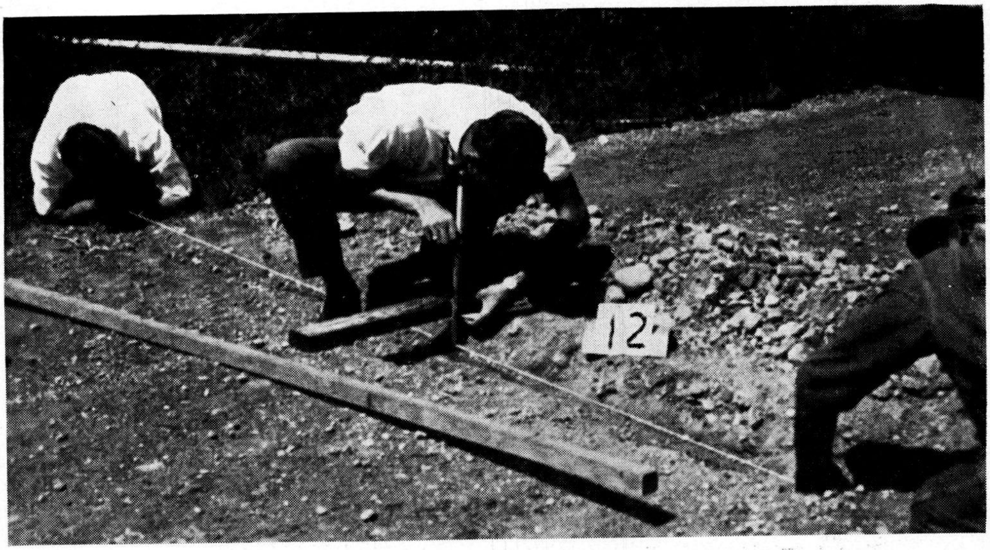

Figure 6. Trench measurements at Station 12.

Figure 7. Station 18 on N. W. Town Line Road.

The traffic-count summary is shown in Table 5, and listed also in Table 1 opposite the sta-

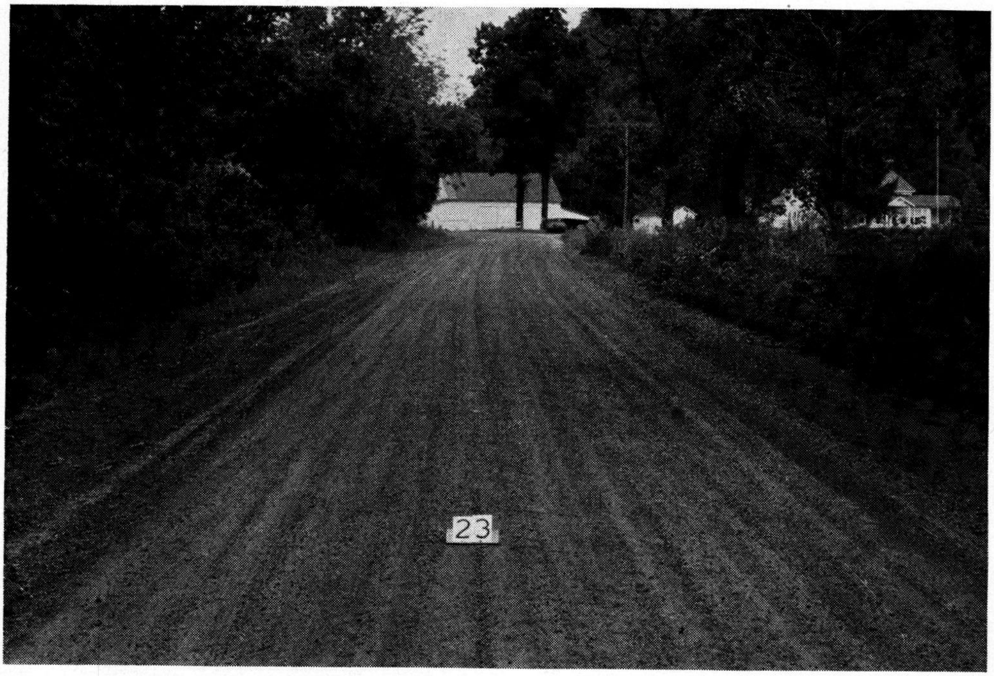

Figure 8. Otisco Road from Station 23.

Figure 9. Sentinel Heights Road: 17 percent grade.

tions where the counts were taken. The results do not show any direct relationship between gravel loss and traffic density, although the greatest loss was shown by the road with highest traffic count. Most of the roads apparently carry less than 100 vehicles per day, with an average count of 107, as indicated by the tests.

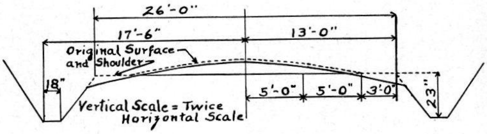

Figure 10. Average section of 12 calcium-chloride-treated gravel roads after 16 years' service.

TABLE 3
GRADATION AND SOIL CONSTANTS

County Road No.	Test Station No.	Percent Passing 3-in.	2-in.	1-in.	¾-in.	No. 4	No. 10	No. 40	No. 200	L.L.	P.I.
147	3	100.0	97.4	77.7	65.1	35.5	26.5	17.9	8.8	16.3	5.7
254	5	100.0	89.8	77.9	69.5	35.4	25.4	18.8	8.8	15.9	6.0
253	7	100.0	90.9	68.7	60.5	37.4	28.5	22.3	14.7	19.7	5.8
216	10	95.7	82.8	55.2	47.9	27.7	22.6	18.1	12.5	17.3	4.3
216	13	100.0	92.8	66.6	57.2	29.9	22.6	17.0	12.1	17.0	4.3
226	16	100.0	93.2	73.0	64.5	42.4	35.6	28.4	15.5	16.5	5.6
202	18	94.1	84.8	71.9	69.1	47.4	30.6	18.1	13.8	24.2	8.8
246	23	91.4	76.8	61.2	54.7	38.1	29.9	15.8	7.5	14.8	3.6
173	32	89.8	87.1	64.0	57.7	39.1	33.7	23.8	7.6	13.0	3.8
171	37	100.0	90.6	79.6	71.2	49.3	35.5	17.1	11.7	20.4	8.4
Ave.		97.1	88.6	69.6	61.7	38.2	29.1	19.7	11.3	17.5	5.6

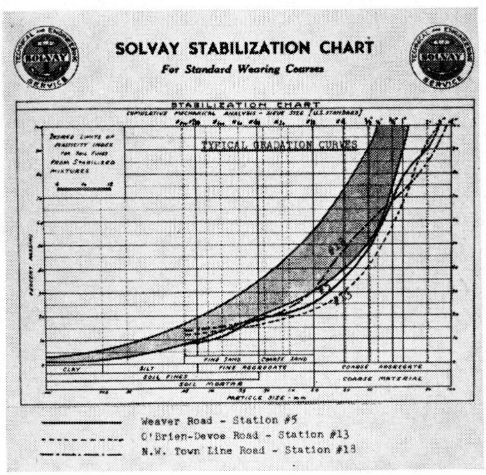

Figure 11. Typical gradation curves.

SUBSOIL CHARACTERISTICS

Onondaga County is located in the north-central part of New York, midway between Albany and Buffalo. It is composed of a deeply dissected rolling plateau ranging from 700 to 2000 ft. above sea level, and a mildly dissected lake plain with a general level of about 400 ft. above the sea. The total area is approximately 781 sq. mi. The lake plain

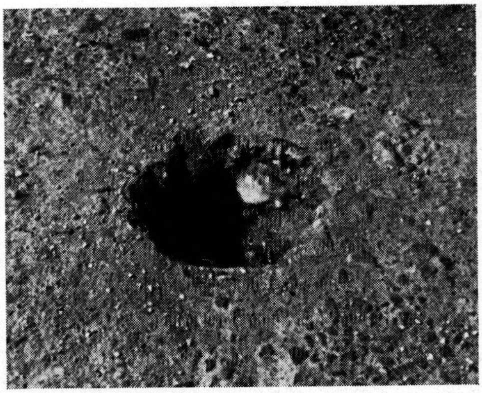

Figure 12. Test hole for density: Station 8.

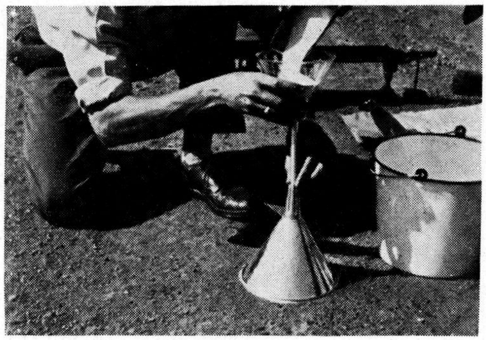

Figure 13. Sand-funnel method for density.

TABLE 4
WEARING COURSE DENSITY TESTS
(In-place density by sand-funnel method)

County Road No.	Name of Road	Test Station No.	Density (Dry)	Moisture
			lb per cu ft	*percent*
254	Weaver	6	139.3	3.52
253	Sneller	7	144.5	3.68
	Sneller	9	139.1	2.97
	Sneller	9[a]	140.8	3.19
216	O'Brien-Devoe	10	154.9	3.41
	O'Brien-Devoe	10[a]	152.0	3.12
226	Daboll	14	146.1	2.84
	Daboll	16	152.0	3.51
173	Sentinel Heights	30	151.6	2.22
	Sentinel Heights	32	142.7	3.18
Ave.			146.4	3.16

[a] Check on previous test at this station.

occupies the northern one third of the county and the plateau region the remaining two thirds to the south.

The soil throughout the county is primarily a silty loam varying from a fine, sandy silt-loam in the northern lake plain to a gravelly silt-loam in the southern plateau region. Analyses of subgrade soils in various sections of the county were made over a period of years from about 1934 to 1938. A classification of these subgrade soils by the method used by the Public Roads Administration indicates a variation between A-1 and A-7, with a maximum group index of 8, as determined by Method M145-49 of the American Association of State Highway Officials.

The soils in the northeastern and northwestern sections of the county are primarily in the A-4 group, those in the northwest having a slightly lower average group index than those in the northeast section. In the southwestern section the soils vary from A-2 to A-6, with a maximum group index of 3. To the southeast the soils again are predominately of the A-4 classification but with one series of tests falling in the A-1 group. The average group index in this section was about 3.

TABLE 5
TRAFFIC COUNT SUMMARY FOR 24-HOUR PERIOD
(12 hour.24 hour traffic count factor = 1.62)

Name of Road	Location of Traffic Counter	Direction from Counter	Test Station No Represented	Passenger and Truck	School Bus	Total
1) Whiting Road	South Bay Road	N	—	285	2	287
		S	3	57	2	59
2) Devoe-Peck	Vanburen Road	N	—	105	2	107
		S	10	143	4	147
3) Devoe-Peck	Warners Road	N	12	125	4	129
		S	13	68	4	72
4) Daboll	Kingdom Road	E	15	107	2	109
		W	16	73	2	75
5) North West Town Line	Shepard Road	S	21	39	2	41
6) North West Town Line	Old Seneca Turnpike	N	19	92	4	96
		S	18	73	—	73
7) Shepard	North West Town Line	E	—	76	—	76
		W	22	63	2	65
8) Otisco	Tully Farm Road	E	—	49	4	53
		W	23	76	—	76
9) Otisco	State Route #80	E	26	186	4	190
		W	27	178	4	182
10) Graham	Sentinel Heights Road	N	29	214	2	216
11) Sentinel Heights	Graham Road	E	30	160	2	162
12) No. 5 W. Barber Hill	Cemetery Road	E	35	79	4	83
13) No. 5 W. Barber Hill	Pompey Center Road	E	37	42	4	46
		W	36	65	4	69
14) Swift Radway	Berwyn Road	S	40	45	2	47

WEATHER DATA

Weather data for Onondaga County are shown in Table 6, as obtained from reports by the U. S. Department of Commerce, Weather Bureau, at Syracuse, N. Y. The climate of the county is influenced by the Great Lakes and the proximity of the Appalachian Mountains which place this section in the great cloud area of the United States. It is located also in the path of most storms moving out of the St. Lawrence Valley.

The average precipitation of 35.5 in. is well distributed over the year, with no marked periods of dry or wet weather. The months of May to November inclusive average about 12 days each with 0.01 in. or more of rain.

The average temperature during this same period is 60 F., with an average monthly high of 71 F. in July, and an average low of 40 F. in November. Relative humidities for this period are quite consistent, with an average of 71 percent, an average monthly high of 75 percent in September and November, and an average monthly low of 67 percent in May. In general, weather conditions are favorable for the maintenance of gravel roads with calcium chloride.

MAINTENANCE METHODS

The maintenance of calcium-chloride-treated roads in Onondaga County includes the following operations: (1) Cleaning culverts and drainage ditches; (2) maintaining a smooth modified A-shaped crown of at least 0.5 in. per ft. to permit rapid drainage of surface water to the ditches; (3) maintaining a consolidated surface free from floating material; and (4) treating with calcium chloride as required to maintain a compacted moist surface.

Spring maintenance on these roads starts shortly after the spring rains while they are still in a moist condition. This is ordinarily accomplished in May and early June. Ditches and culverts are cleaned, and the surface is reshaped using a power grader. Sometimes a road is in good condition and requires only a light honing for smoothing the surface.

Where reshaping is necessary, or there is bad pot-holing, the grader operator cuts the surface, starting at the center, and carries part of this material to each side. He cuts just enough to eliminate pot-holes and provide sufficient float for reshaping. This material is then bladed back toward the center, with a little shoulder material if there appears to be an excess of coarse aggregate. Several passes are usually made to insure proper crown and to provide a smooth riding surface. Any large stones which are brought up during the blading, and not again embedded, are bladed to the shoulders.

As soon as the spring maintenance on a road is finished a surface application of flake calcium chloride is made at the rate of 0.75 lb. per sq. yd. or approximately 4.4 tons per mi. It is important to apply this treatment as soon as possible after blading to prevent drying out of the gravel and loss of fines.

During the summer and fall months the maintenance on these roads consists of only two or three light honings, using power graders or under-body truck blades. Any loose gravel from the sides is bladed to the center of the road with a little shoulder material, then carried back toward either side and feathered out at the edge of the mat.

The number of annual honings depends somewhat upon traffic density, climatic conditions, and stability of the wearing surface. Honing between spring and summer applications of calcium chloride is usually unnecessary on Onondaga County roads. Late in the fall the surface is given a final honing in preparation for the winter season. In no case is the consolidated surface disturbed during the summer or fall, since any shallow pot-holes are readily filled and smoothed over by routine honing.

The second application of flake calcium

TABLE 6

METEOROLOGICAL SUMMARY FOR PERIOD 1902–1950 INCLUSIVE

Month	Mean Daily Temperatures			Precipitation				Relative Humidity				Mean Number of Days with 0.01 inch or more precipitation
	Max	Min	Monthly	Mean Total	Max Monthly	Min Monthly	Max in 24 Hours	1.30 AM E.S.T.	7.30 AM E.S.T.	1.30 PM E.S.T.	7.30 PM E.S.T.	
Jan.	32.4	17.0	24.7	2.81	5.87	1.00	3.67	77	76	70	77	18
Feb.	31.5	15.9	23.7	2.49	5.22	0.76	2.35	78	76	70	75	17
March	41.4	25.6	33.5	3.15	5.97	0.63	1.97	78	75	63	72	17
April	53.6	36.1	44.9	2.95	7.61	0.79	2.91	77	71	57	65	15
May	66.5	47.3	56.9	2.89	5.54	0.19	2.24	81	69	54	65	13
June	75.6	56.6	66.1	3.62	15.92	0.55	4.79	82	71	55	66	12
July	80.7	61.8	71.2	3.30	7.37	0.30	3.22	83	74	54	66	11
Aug	78.4	59.9	69.1	3.08	7.26	0.66	3.26	84	77	56	69	10
Sept.	71.6	53.1	62.3	2.86	6.76	0.51	2.83	85	79	59	75	11
Oct.	60.1	42.8	51.5	2.97	6.83	0.39	2.92	82	78	59	75	13
Nov.	46.7	33.2	40.0	2.61	7.78	0.32	2.07	79	78	67	74	15
Dec.	34.7	21.3	28.0	2.77	6.55	0.85	2.44	78	78	71	76	17

chloride is usually made in August or early September immediately after honing and at the same rate as the spring treatment. When honing is necessary between calcium-chloride treatments, it is done after a rain while the surface is moist so that loose material will consolidate again without re-treating.

No attempt is being made to set up a standard maintenance practice, since it is realized that this will vary in different localities. It is our firm belief, however, that this type of surface performs best in any locality if kept moist with calcium chloride and maintenance blading is kept at a minimum.

The maintenance costs on the 12 test roads for 1951 are itemized in Table 7. The costs apply only to surface maintenance, and do not include cleaning ditches and culverts, mowing, or brush cutting. The costs do include the addition of crushed gravel in some cases, and possibly some other miscellaneous items, which show in the blading costs Use of equipment on any job is charged as rental at a daily rate of $53.60 for all trucks; $33.60 for power graders; and $60.40 for truck equipped with highway spreader.

TABLE 7
SURFACE MAINTENANCE COSTS FOR 1951

Name	Length Miles	Blading, etc		Calcium Chloride Treatment			Total
		Rentals	Labor	Rentals	Labor	Chloride	
Weaver	0 82	66 72	23 37	67 00	14.56	132 50	304 15
Sneller	1 29	95 92	76 12	67 00	12 30	210 00	461 34
O'Brien–Devoe	6.33	200 20	86 87	147 40	36 62	1,128 70	1,599.79
Daboll	2 22	839 02[a]	474 09[a]	107 20	14 19	463 47	1,897 97[a]
NW Town Line	3 00	160 74	88 51	127 40	20 08	577.27	974 00
Shepard	1 20	92 00	41 07	60 40	13 40	247 87	454 74
Otisco	6 64	298 62	96 41	160 80	28 44	1,169 94	1,754 21
Graham	0 68	240 91[a]	212 36[a]	109 80	19 49	183 49	766 05[a]
Sentinel Heights	4 72	203 06	145 17	147 40	22 36	648 76	1,166 75
#5 W Barber Hill	5 31	487 80[a]	183 55[a]	241 20	58 03	712 86	1,683 44[a]
Swift Radway	5 71	1,706 41[a]	669 30[a]	262 00	48 60	1,047 50	3,733 81[a]
Totals	37 92	4,391 40[a]	2,096 82[a]	1,497 60	288 07	6 522 36	14,796 25[a]
Ave /mile year		115 80[a]	55 30[a]	39 50	7 60	172 00	390 20[a]

[a] Includes costs of crushed gravel to strengthen weak spots.

Whiting Road not included. Improving 0.75 mile with addition of crushed gravel in preparation for bituminous-surface treatment.

SPREADING FLAKE CALCIUM CHLORIDE

Prior to 1950 the conventional agricultural lime spreader towed behind a truck was used for spreading flake calcium chloride. The method is familiar to nearly everyone. Labor was required for loading the bagged material into the truck, opening the bags, dumping the calcium chloride into the spreader, operating the spreader controls, and disposing of empty bags. Also required were trucks for hauling the calcium chloride, a service truck to transport the men to and from the job, and a foreman. The spreading operation consisted in a trip down one side and back on the other side with 8-ft. spreads, then down through the center with an overlapping spread 8 ft. in width where traffic is heaviest. By this method approximately 1 mi. of 20-ft. roadway could be treated per hour with one spreader and crew at an estimated average cost of about $42 per mi.

Since 1950, the flake calcium chloride has been spread with Highway Model E spreader, manufactured by the Highway Equipment Company The calcium chloride, in bulk form, is dumped directly into the spreader, then driven to the job and spread over the 20-ft. surface with a single pass down the center of the road. The truck driver handles the entire operation alone.

Side boards are placed on the spreaders so that they hold 6 tons of bulk flake calcium chloride. Each load will treat approximately 1.4 mi. of 20-ft. roadway. The actual spreading time requires only about 12 minutes per load, but considerable time is consumed in travel to and from the job to get the calcium chloride. It is possible therefore to make only about four trips per day with one unit, spreading 24 tons of calcium chloride over approximately 5.6 mi. of gravel surface.

With the rental on the truck and spreader at $60.40, and a driver at $12 per day of 8 hr., this means an average spreading cost of only $13.25 per mi. of road treated. This cost varies, of course, with the length of haul to and from the road, but it is calculated that this spreading method saves at least $25 per mi. of treated road as compared with the old method. In addition, it frees trucks and men for other maintenance work.

SUMMARY AND CONCLUSIONS

This sixteen-year performance study of calcium-chloride-treated gravel roads in Onondaga County shows a gravel loss of only 23.5 cu. yd. per mi. per yr. for roads carrying from 41 to 216 vehicles per day. Comparing this loss with those reported by the University of Michigan and others for untreated gravel roads, it appears logical to assume a saving of at least 50 cu. yd. of gravel per mi. per yr. by maintenance with calcium chloride.

Of much greater importance from the standpoint of economy is the fact that there also is a decided saving in annual blading costs. H. A. Radzikowski, chairman, Highway Research Board Project on Maintenance, discussed blading costs on soil aggregate roads in Bulletin 29 (1950), following an analysis of maintenance in six areas in six states. He reported that some roads were bladed as many as 160 times, and that the cost per operation ran as high as $7.25 per mi.

It is estimated that our blading costs average about $9 per mi. using a Diesel-powered grader at a rental charge of $33.60 per day and an operator at $12 per day of 8 hr.

Assuming that it would be necessary to blade our roads about once a week between May and November if they were not treated with calcium chloride, this would mean 25 to 30 bladings as compared with our present maintenance of three to four bladings. On the basis of an annual saving of 25 bladings at $9 each, and a saving of 50 cu. yd. of gravel at $1 per cu. yd. on the road, there is a saving of $275 per mi. per yr. in favor of calcium chloride treated gravel as compared with untreated gravel roads. This saving more than offsets our present treating costs of approximately $210 per mi. per yr.

In addition to the economical factor, our calcium chloride treated roads are stable in all kinds of weather, and at similar driving speeds provide a degree of security and safety equal to that provided by other type surfaces. The motorists using these roads, as well as the residents, are satisfied with this type of surface. When conditions warrant improvement, these roads serve as excellent bases for bituminous or concrete wearing surfaces, as has been the case with some 300 mi. of similar roads in Onondaga County which have been surface treated during the past 10 or 12 years.

In concluding, I would like to express my appreciation to T. E. Coultry, division materials engineer, Public Roads Administration, Albany, N. Y.; Earl Fuller, Bureau of Soils Mechanics, New York State Department of Public Works, Albany, N. Y.; W. E. Dickinson, Calcium Chloride Institute, Washington, D. C.; and E. N. McGee, L. M. Pellow, and R. H. Billings of Technical Service, Solvay Process Division of Allied Chemical & Dye Corporation, for their coöperation and assistance in planning this study and correlating the data for this report.