R-278

MICHIGAN
STATE HIGHWAY DEPARTMENT
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MICHIGAN'S EXPERIMENT IN SNOW AND ICE REMOVAL BY RADIANT HEAT

Winter Season 1955-1956
Performance and Cost

Cooperative Research Project Between the
Michigan State Highway Department and the
Detroit Public Lighting Commission

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MICHIGAN'S EXPERIMENT IN SNOW AND ICE REMOVAL BY RADIANT HEAT

This is the ninth and final progress report on the Michigan experiment in snow and ice removal from highways by radiant heat. In 1947, 1000 feet of pavement was constructed in Wayne County on M-102 (Eight Mile Road) in co-operation with the Detroit Lighting Commission, using electrified steel wire-mesh grid, as an experimental heating agent. It is the purpose of this report to present performance and cost information for the winter season of 1955-56 and to summarize the more important results of the investigation. Previous information on this project may be found in Highway Research Reports Nos. 120, 130, 152, 165, 190, 192, 221, 246.

General Performance

In its last season, the heating system began operating on November 18, 1955, and was suspended the following February 11, because of breaks in the heating grids. The system was in use a total of 343.10 hours in 1955-56, as compared to 515.03 hours in the preceding season, and in reverse order for the other years, 582.78, 415.17, 731.18, 926.35, 548.70, and 506.59 respectively. Snowfall this season was greater than in the preceding one with a 1.3-inch increase; the average air temperature during the 1955-56 season was 3°F. higher than in the preceding winter.

For the fifth straight season, the hourly operating cost increased for the heating system. This year the cost was $2.59 per hour, compared to $2.47, $2.25, $1.97, $1.84, $2.02, $1.89, and $1.31 respectively for the previous seven seasons.

Related Tables

Complete data on operation and cost for the 1955-56 winter season, furnished by the Detroit Public Lighting Commission, is found in Table I. Information on operating time, energy consumption, and weather conditions is presented by months for all eight operating seasons in Table II, and Table III provides complete comparative operating information for the history of the project. A condensed tabular version of Table III, showing operating data and costs by years, is presented in Table IV.

TABLE I

SUMMARY OF OPERATING DATA AND COSTS FOR SEASON 1955-56

DATA FURNISHED BY DETROIT PUBLIC LIGHTING COMMISSION

SYSTEM IN OPERATION		Time"ON"	CONCRETE SECTION		BITUMINOUS SECTION		PRECIPITATION		Average Mean at Site-°F (Air)	Average Temperature of Pavement at Control Point	
From	To	Hr. Min.	Energy Consumed KWH	Cost P. L. C. Rate	Energy Consumed KWH	Cost P. L. C. Rate	Snowfall Sleet Inches	Water Equivelant Inches		Concrete °F	Bituminous °F
NOVEMBER											
11:35 p.m. 11-18-55	9:30 p.m. 11-19-55	21 : 55	800		800		3.7	0.18	32	40	38
3:00 a.m. 11-26-55	9:40 a.m. 11-26-55	6 : 40	340		400		0.3	0.01	33	40	38
9:00 a.m. 11-27-55	4:55 p.m. 11-28-55	19 : 55	1160		1200		T	T	17	30	32
	November Totals	48 : 30	2300	$ 54.00	2400	$ 56.25	4.0	0.19	27	37	36
DECEMBER											
9:25 p.m. 12- 1-55	3:00 p.m. 12- 2-55	17 : 35	580		960		3.1	0.26	29	40	36
9:40 a.m. 12- 5-55	6:00 p.m. 12- 5-55	8 : 20	460		520		0.5	0.04	29	40	38
8:42 p.m. 12- 8-55	7:55 p.m. 12- 9-55	23 : 13	1480		1960		0.3	0.02	23	40	38
5:33 p.m. 12-14-55	7:45 a.m. 12-15-55	14 : 12	700		920		0.1	0.01	18	38	34
10:12 a.m. 12-15-55	1:40 p.m. 12-15-55	3 : 28	340		400		T	T	18	38	37
4:15 a.m. 12-18-55	12:15 p.m. 12-18-55	8 : 00	240		280		0.2	0.02	22	40	37
5:40 a.m. 12-21-55	9:30 p.m. 12-21-55	15 : 50	1600		1840		0.5	0.03	18	39	36
10:08 a.m. 12-30-55	10:20 p.m. 12-30-55	12 : 12	820		960		0.1	T	23	38	36
	December Totals	102 : 50	6220	$135.40	7840	$161.93	4.8	0.38	23	39	37
JANUARY											
9:56 a.m. 1- 2-56	7:30 a.m. 1- 3-56	21 : 34	1040		1200		2.0	0.28	31	40	38
5:15 p.m. 1-11-56	7:50 a.m. 1-12-56	14 : 35	1500		1360		1.0	0.08	29	40	20
4:30 a.m. 1-19-56	7:45 a.m. 1-20-56	27 : 15	1880		1760		2.9	0.22	24	37	36
9:35 a.m. 1-20-56	7:35 p.m. 1-20-56	10 : 00	340		280		0.8	0.06	19	39	36
5:10 p.m. 1-28-56	1:50 p.m. 1-29-56	20 : 40	700		800		0.1	0.07	29	39	36
4:35 a.m. 1-30-56	7:00 p.m. 1-31-56	38 : 25	1840		1900		4.1	0.30	23	36	36
	January Totals	132 : 29	7300	$152.68	7300	$152.68	10.9	1.01	26	39	34
FEBRUARY											
12:40 a.m. 2- 2-56	11:30 p.m. 2- 2-56	22 : 50	1380		1560		2.9	0.24	26	38	36
5:59 a.m. 2- 9-56	6:30 p.m. 2-10-56	12 : 31	1040		1200		2.0	0.21	32	38	38
9:50 a.m. 2-11-56	9:50 a.m. 2-12-56	24 : 00	1160		1200		1.4	0.19	32	40	38
	February Totals	59 : 21	3580	$ 82.80	3960	$ 91.35	6.3	0.64	30	39	37
	Season Totals	343 : 10	19,400	$424.88	21,500	$462.21	26.0	2.22	27[a]	38[a]	36[a]

[a]Average

TABLE II

SUMMARY OF OPERATING TIME, ENERGY CONSUMPTION, AND WEATHER CONDITIONS
Winter Seasons 1948-49 through 1955-56

Month	Time "ON" - Hours							
	1948-49	1949-50	1950-51	1951-52	1952-53	1953-54	1954-55	1955-56
November	----	66.70	101.50	---	25.12	---	---	48.30
December	79.65	83.55	254.50	241.71	86.24	79.82	113.47	102.50
January	190.93	116.50	177.23	185.67	219.60	214.32	148.58	132.29
February	142.01	140.01	337.92	174.70	49.45	138.36	190.44	59.21
March	94.00	122.69	55.20	129.10	34.76	150.28	61.34	------
April	----	19.25	----	----	----	----	----	------
Total	506.59	548.70	926.35	731.18	415.17	582.78	515.03	343.10

Month	KWH Consumption															
	1948-49		1949-50		1950-51		1951-52[a]		1952-53[a]		1953-54[a]		1954-55		1955-56	
	Concrete	Asphalt	Concrete	Asphalt	Concrete	Asphalt	Concrete	Asphalt	Concrete	Asphalt	Concrete	Asphalt	Concrete	Asphalt	Concrete	Asphalt
November	----	----	1980	2280	5660	7120	----	----	460	----	----	----	----	----	2300	2400
December	2590	2180	2080	2780	12840	15150	15940	14680	4500	4280	5440	5160	9120	9840	6220	7840
January	5010	5600	4400	5200	7740	9130	8120	6600	10360	9820	11700	10760	8060	8920	7300	7300
February	3540	3770	8560	7960	17220	16360	6360	5480	2780	2520	8080	7620	9900	10820	3580	3960
March	2670	3470	4840	4860	1570	1860	4160	3640	1840	1440	7200	6940	2760	2920	----	----
April	----	----	920	680	----	----	----	----	----	----	----	----	----	----	----	----
Total	13810	15020	22780	23760	45030	49620	34580	30400	19940	18060	32420	30480	29840	32500	19400	21500

[a]KWH consumption in asphalt section was lower than that of concrete section for three seasons. This was not normal. It was discovered that temperature control bulb in asphalt section had come in contact with heating grid.

WEATHER CONDITIONS DURING OPERATIONS

Month	1948-1949			1949-1950			1950-1951			1951-1952		
	Snow-fall, in.	Water Equivelant	Mean Air Temp. °F	Snow-fall, in.	Water Equivelant	Mean Air Temp. °F	Snow-fall, in.	Water Equivelant	Mean Air Temp. °F	Snow-fall, in.	Water Equivelant	Mean Air Temp. °F
November	----	----	----	4.5	0.76	32	8.4	1.25	18	----	----	----
December	0.50	0.49	38	4.7	0.48	33	6.5	1.91	24	18.0	2.25	23
January	4.60	0.26	35	9.2	0.71	30	12.4	0.79	34	10.7	1.83	27
February	3.10	0.39	25	12.6	2.29	25	7.4	1.38	20	7.3	0.77	27
March	2.10	0.11	25	9.6	0.81	24	5.7	1.41	30	6.7	1.00	31
April	----	----	----	0.4	0.40	26	----	----	----	----	----	----
Total	10.30	1.25		41.0	5.45		40.4	6.74		42.7	5.85	
	Average temperature 31			Average temperature 28			Average temperature 25			Average temperature 28		

Month	1952-1953			1953-1954			1954-1955			1955-1956		
	Snow-fall, in.	Water Equivelant	Mean Air Temp. °F	Snow-fall, in.	Water Equivelant	Mean Air Temp. °F	Snow-fall, in.	Water Equivelant	Mean Air Temp. °F	Snow-fall, in.	Water Equivalent	Mean Air Temp. °F
November	----	----	35	----	----	----	----	----	----	4.00	0.19	27
December	4.02	0.44	30	6.2	0.66	25	5.8	0.75	29	4.80	0.38	23
January	9.56	1.17	28	6.1	1.77	24	2.7	0.22	23	10.90	1.01	26
February	0.60	0.11	28	13.9	1.52	30	10.9	0.88	23	6.30	0.64	30
March	0.60	0.15	26	11.9	1.09	21	5.3	0.28	21	-----	----	--
April	----	----	----	----	----	----	----	----	----	-----	----	--
Total	14.78	1.87		38.1	5.04		24.7	2.13		26.00	2.22	
	Average temperature 29			Average temperature 25			Average temperature 24			Average temperature 27		

TABLE III

SUMMARY OF COMPARATIVE OPERATING DATA FOR EIGHT SEASONS

	1948-1949	1949-1950	1950-1951	1951-1952	1952-1953	1953-1954	1954-1955	1955-1956
Total Time "ON"	506.59 hrs.	548.70 hrs.	926.35 hrs.	719.77 hrs.	415.17 hrs.	582.78 hrs.	515.03 hrs.	343.10 hrs.
Total Energy Consumption - KWH								
Concrete Section	13,810	22,780	45,030	34,580	19,940	32,420	29,840	19,400
Asphalt Section	15,020	23,860	49,620	30,400	18,060	30,480	32,500	21,500
Total KWH Consumption	28,830	46,640	94,650	64,980	38,000	62,900	62,340	40,900
Energy Consumption per 500-ft. Section per Hour of Operation - KWH								
Concrete Section	27.3	41.5	48.6	48.06	48.02	55.6	58.3	56.53
Asphalt Section	29.7	43.5	53.6	42.24	43.50	52.3	63.4	62.65
Total Consumption per 500-ft. Section per Hour	57.0	85.0	102.2	90.30	91.52	107.9	121.7	119.18
Percentage difference (Asphalt to Concrete)	+8.8%	+4.8%	+10.3%	-12.1%	-9.4%	-6.36%	+8.18%	+9.77%
Energy Consumed per 500-ft. Section per Hr. per Sq. Ft. of Heating Surface in Watts								
Concrete Section	18.4	27.9	32.7	32.0	31.9	37.0	38.8	37.69
Asphalt Section	20.0	29.3	36.1	28.0	28.8	34.8	42.2	41.77
Total Cost - (Detroit Public Lighting Commission Rate)								
Concrete Section	$319.66	$ 507.24	$ 893.93	$ 701.15	$429.41	$ 669.25	$ 613.12	$424.88
Asphalt Section	343.76	533.78	973.10	627.49	388.49	636.39	659.03	462.21
Total Cost	$663.42	$1,041.02	$1,867.03	$1,238.64	$817.90	$1,305.64	$1,272.15	$887.09
Cost per 500-ft. Section per Hour of Operation								
Concrete Section	$0.63	$0.92	$0.97	$0.97	$1.03	$1.16	$1.19	$1.24
Asphalt Section	0.68	0.97	1.05	0.87	0.94	1.09	1.28	1.35
Total Cost	$1.31	$1.89	$2.02	$1.84	$1.97	$2.25	$2.47	$2.59
Total Snowfall								
Total in Inches	10.3	41.0	40.4	42.1	14.78	38.1	24.7	26.0

TABLE IV

SUMMARY OF OPERATING DATA AND COSTS
for years 1948 to 1956

Winter	Snowfall Inches	Water Equiv.	Avg. Temp. of	Hrs. "ON"	Total KWH	Avg. Hourly KWH	Total Season Cost
48 - 49	10.3	1.25	31	506.59	28,830	56.91	$ 663.42
49 - 50	41.0	5.45	28	548.70	46,000	83.83	1,041.02
50 - 51	40.4	6.74	25	926.35	94,000	101.47	1,867.03
51 - 52	42.1	5.81	28	719.77	64,980	90.28	1,328.62
52 - 53	14.8	1.87	29	415.17	38,000	91.53	817.90
53 - 54	38.1	5.04	25	582.78	62,900	107.93	1,305.64
54 - 55	24.7	2.13	24	515.03	62,340	121.04	1,272.15
55 - 56	25.9	2.22	27	343.10	40,900	119.21	887.09

Breaks in Heating Elements

There were numerous breaks in the heating elements this year, many occurring at the same locations as in former years. The Detroit Public Lighting Commission concluded that these were caused by moisture seeping into cracks in the pavement, corroding the grid wires. Extensive pavement repairs and wire breakage caused cessation of the project on February 11, 1956. Figure 1 shows the locations of all breaks that had occurred during six seasons preceding termination of the project.

Effect of Demand Factor on Design and Operating Cost

In designing a similar electrical heating installation, particular attention should be given to the demand factor in localities where rates are based on a demand charge.

In this experiment, design called for 55 watts per square foot for quick melting, and a thermostat was included to shut off the power when not needed. Since a demand factor charge was not included in computing energy costs, the figures presented by the Public Lighting Commission reflect the true cost only where there is no demand charge.

When there is a large demand charge, a more economical installation might be provided by designing for continuing operation with a lower wattage, such as 25 watts per square foot, with heating elements operating throughout the snow removal period. Under certain conditions this method might leave slush on the road during the actual snowing period, but there would be adequate traction since ice would not form on the road surface, and all snow would melt off when the snowfall ceased.

CONCLUSIONS

The investigation produced these observations:

1. The experiment demonstrated that it is possible to remove snow and ice from concrete or bituminous highway surfaces by radiant heat, produced from electrical energy passing through steel wire-mesh heating grids embedded at a depth of 1.5 to 2 inches beneath the surface.
2. Although this method would be relatively expensive in comparison with normal methods employing de-icing salts and snowplows, undoubtedly road areas exist or will be built where this method might be justified to deal with certain hazardous winter traffic situations, particularly at ramps, critical turning areas, or traffic interchanges.

3. During eight years of service, grids in the concrete section developed 10 breaks, and in the bituminous section 56 breaks. In all cases, the breaks occurred at cracks in the pavement surface. The sequence of grid breaks is shown in Table V.

TABLE V

GRID BREAKAGE DATA

Season	Concrete	Bituminous
1948-1949	0	0
1949-1950	0	0
1950-1951	0	5
1951-1952	3	7
1952-1953	0	6
1953-1954	1	4
1954-1955	4	21
1955-1956	2	13
Total	10	56

Such conditions could not be tolerated in a normal installation. This grid breakage clearly indicates that the type of concrete reinforcing mesh used in this experiment is not suitable for heating grids. It is recommended that commercially available electric heating cable be considered for future installations of this nature.

4. As shown below in Table VI, the power consumed per square foot of heated area varied between 50 and 75 percent of the normal operating wattage, which was 52 watts for the bituminous section and 62 watts for the concrete section. This indicates that the heating elements were "OFF" during a considerable portion of the operating time. It should be noted that in order to produce the desired melting condition during the experiment, it was necessary to adjust the system to the previously noted operating wattage from the original design figure of 55 watts.

TABLE VI

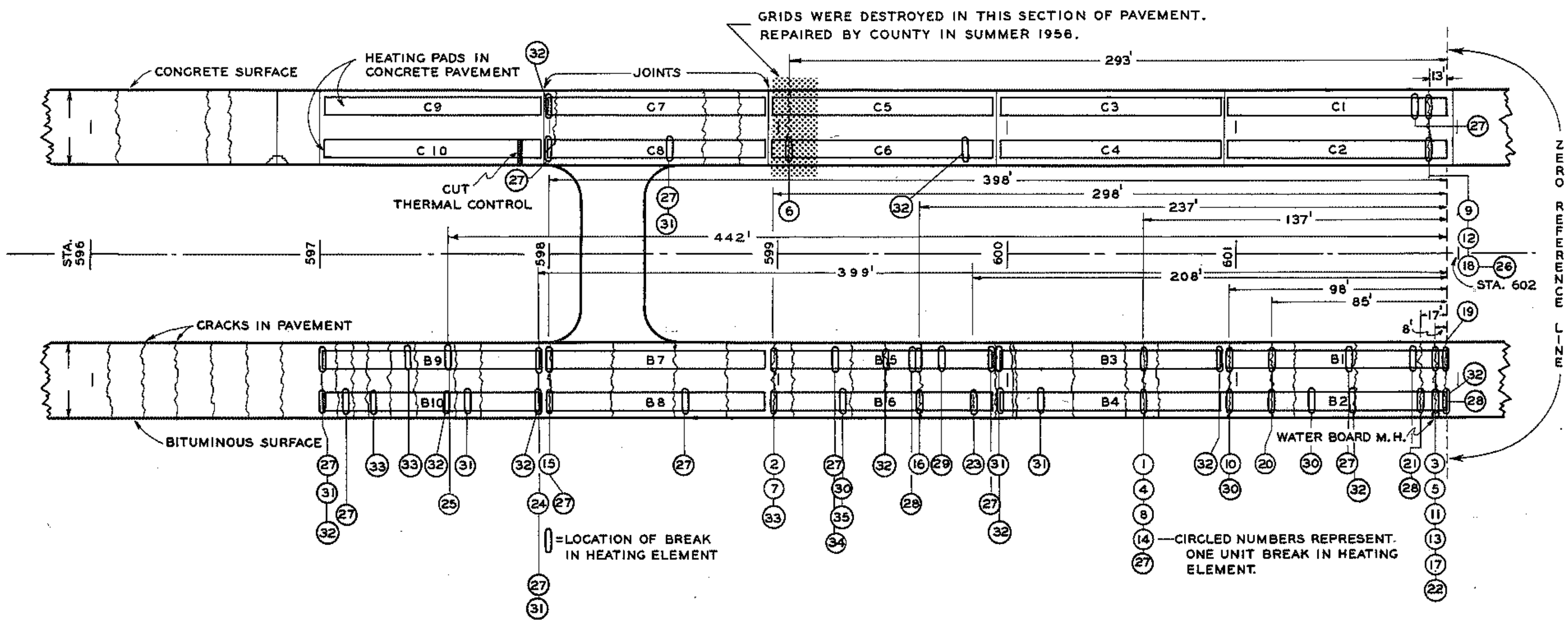
SUMMARY OF HEATING ENERGY CONSUMPTION IN RELATION TO CLIMATOLOGICAL FACTORS

Year	Watts Per Hour Per Sq. Foot of Heated Area		Percent Difference	Snowfall	Avg.
	Concrete	Asphalt	Asphalt to Concrete	In.	Temp. °F.
1948-1949	18.4	20.0	+ 8.8	10.3	31
1949-1950	27.9	29.3	+ 4.8	41.0	28
1950-1951	32.7	36.1	+10.3	40.4	25
1951-1952	32.0	28.0	-12.1	42.1	28
1952-1953	31.9	28.8	- 9.4	14.8	29
1953-1954	37.0	34.8	- 6.7	38.1	25
1954-1955	38.8	42.2	+ 8.2	24.7	24
1955-1956	37.7	41.8	+ 9.8	25.9	27

5. With reference to Table VI there was a noticeable increase in yearly energy consumption irrespective of operating and climatic conditions. It is believed that this increased energy consumption over the years indicates loss in grid efficiency probably caused by the gradual overall physical deterioration of the heating grids, and by increasing electrical losses throughout the system.

6. With the exception of seasons 1951-1952, 1952-1953, and 1953-1954 when the bituminous section was not operating properly, the bituminous section required from 5 to 10 percent more energy than the concrete section. This consistent difference in power consumption between the two sections is believed due primarily to the relative thermal conductivity of the bituminous and concrete pavements, the ratio as determined by laboratory tests being 8.0 and 6.1 respectively. (See Table VI.)

7. No attempt has been made to correlate heating costs with snow depth and temperature conditions at the time of operation because the site chosen for the experiment was not typical of that which would be encountered under normal installations. The experimental test area was comparatively flat with no special drainage facilities for the melt water. The melt water formed an insulating layer over the heated area, preventing efficient transfer of heat to the freshly fallen snow. This would impose an added burden on the heating system. Slush and water were removed by normal traffic action.



DATE	BREAK NO.	
11 - 24	1	'50 TO '51
12 - 28	2	
1 - 14	3	
1 - 21	4	
1 - 27	5	

DATE	BREAK NO.	
12 - 4	6	'51 TO '52
12 - 4	7	
12 - 4	8	
12 - 5	9	
12 - 10	10	
12 - 13	11	
12 - 18	12	
1 - 16	13	
1 - 16	14	
1 - 30	15	

DATE	BREAK NO.	
11 - 6	16	'52 TO '53
11 - 6	17	
11 - 10	18	
11 - 10	19	
1 - 30	20	
1 - 30	21	

DATE	BREAK NO.	
11 - 30	22	'53 TO '54
11 - 30	23	
12 - 1	24	
12 - 1	25	
12 - 2	26	

DATE	BREAK NO.	
10 1 - 31	27	'54 TO '55
12 - 10	28	
10 - 22	29	
2 - 10	30	
2 - 24	31	

DATE	BREAK NO.	
11 - 18	32	'55 TO '56
1 - 17	33	
2 - 7	34	
2 - 15	35	

FIGURE 1

LOCATION OF CRACKS AND BREAKS IN HEATING ELEMENTS

EIGHT MILE ROAD EXPERIMENTAL PAVEMENT HEATING FOR SNOW AND ICE REMOVAL