Experimental Foamed Plastic Base Course

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Procedures implemented to install foamed plastic on a clay subgrade near Winnipeg are described. The foam was a rigid polystyrene which was placed on the subgrade and covered with 12 in. of gravel base and a 4-in. bituminous surface. Information obtained by means of thermocouples indicated that thicknesses of foam of 2 in. reduced frost penetration to a few inches in the subgrade and 3¼ in. of foam essentially prevented frost penetration. The control section showed that the rigorous climate which generally experiences 3,500 degree-days of frost resulted in frost penetration of 7 ft when foamed plastic is not used.

•BECAUSE OF the development of the plastics industry and the many forms of plastics which were becoming available, a keen interest has been taken by the Manitoba Highways Branch in the uses of these materials. Interest in plastics as a base course replacement was caused by the possibility of shortages of gravel supplies in some areas and by road development in muskeg areas. The latter was a factor which led to discussions pertaining to the floating of roadbeds on lightweight foamed plastic bases over undisturbed muskeg. The economics of this application, however, were not attractive enough to create interest in an experiment.

Because gravel shortages could increase the cost of standard base construction and increased sales of foamed plastic could reduce their cost, attention was turned to replacement of gravel by foamed plastic in a standard highway section. Further discussions within the Materials and Research Section and with representatives of Dow Chemical of Canada Ltd. created much interest in the possible side benefit in controlling the spring thawing of the subgrade. The prevention of thawing from the top of the subgrade would allow the thaw to occur from the bottom of the frozen layer, thus allowing ice lens water to escape into the subgrade rather than to be trapped above the frozen layer creating a weak structure. The further possibility that frost penetration could be reduced or eliminated made a trial project extremely attractive.

Departmental approval was obtained for a trial, arrangements were made for the supply of foamed plastic by the Dow Chemical Co., and a location was chosen in the fall of 1962.

PROJECT LOCATION

The site selected for this trial is a 300-ft section of the Trans-Canada Highway approximately 11 mi east of Winnipeg. This portion of the northbound 2 lanes of the 4-lane divided highway is located immediately west of the end of concrete pavement and lies in a bituminous-surfaced section to be removed on construction of the Winnipeg Floodway. The site was nearly ideal in that the subgrade was well constructed, a nearby bituminous paving project could provide equipment and materials, and the highway carries relatively heavy traffic. In addition, it is located near Winnipeg for easy access by department personnel.

Winnipeg is approximately 60 mi north of the Manitoba-Minnesota border and experiences 3,500 degree-days of frost. Temperatures range from 100 to -40 F and

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depth of frost penetration under a pavement is generally from 5 to 7 ft. Precipitation is about 20 in. annually.

The Trans-Canada Highway in this location does not carry spring load restrictions and, therefore, the test section would be subject to fairly heavy loads throughout the year.

MATERIALS

The subgrade was constructed in a rural cross-section and consisted of a fat, A-7-5 (20) clay. This clay, commonly referred to as Red River Gumbo, exhibited a standard AASHO density of 97 pcf and an optimum moisture content of 25 percent. The classification tests yielded a liquid limit of 66 percent, and a plasticity index of 43. The soil consisted of 4 percent fine sand (passing a No. 40 sieve and retained on a No. 200), 16 percent silt (passing a No. 200 sieve but larger than 5μ) and 80 percent clay (smaller than 5μ). Results of density tests taken on the subgrade are given in Table 1.

Since the test area was only 300 ft in length subsectioned in three 100-ft lengths and each section had a different grade elevation requirement, it was difficult to provide a smooth surface on which to lay the foam plastic. To facilitate leveling, a thin layer of sand, approximately ½ in. in depth, was spread over the soil grade.

The foamed plastic, Styrofoam, was a continuously extruded, rigid polystyrene foam. The material was supplied in 4- by 8-ft sheets in thicknesses of 1½, 1¾ and 2 in. The sheets were held in place by wooden skewers. An asphalt emulsion was also supplied for painting joints between the sheets in an effort to seal them.

The gravel base course provided had the gradation given in Table 2. The gravel base was placed in a depth of 12 in. and compacted by a vibratory compactor to densities found to be 135.6 pcf at 3.0 percent moisture and 137.5 pcf at 2.7 percent moisture.

The bituminous material was placed in two lifts of 2 in. each. The first lift, with an asphalt content of 4.0 percent, was placed on the gravel base which had been primed the previous day with an MC-0 at a rate of 0.25 gal/sq yd. The second lift had an asphalt content of 5.0 percent and was placed after the first lift had received a fog coat of 0.05 gal/sq yd. Both lifts were bound by 150/200 penetration asphalt cement and were laid with a Barber-Greene Model 879 paver. Rolling was accomplished by an 8-ton Huber-Worco steel roller for breakdown and finishing and a Rosco rubber tire roller with a gross weight of 27,000 lb and tire pressure of 85 psi for intermediate rolling.

The analysis of four samples taken from the road is given in Table 3.

INSTRUMENTATION

The test area was thoroughly instrumented with thermocouples at various depths and locations to measure pavement and soil temperatures throughout the year.

TABLE 1

RESULTS OF DENSITY TESTS ON SUBGRADE

Dry Density (pcf)	Moisture Content (%)
92.0	17.7
83.8	22.6
100.0	15.0
95.5	16.8
84.0	24.1

TABLE 2

Sieve Size	% Passing	
1 in.	100	100
¾ in.	97	90
½ in.	80	82
⅜ in.	73	75
No. 4	54	63
No. 10	41	51
No. 40	19	22
No. 80	12	14
No. 100	11	12
No. 200	9	10

TABLE 3
ANALYSES OF BITUMINOUS MIX

Analysis	Sample			
	1	2	3	4
Station	441	441	438	440
Lift	1st	1st	2nd	2nd
Type of material	Base	Base	Mat.	Mat.
Residual asphalt content (%)	3.9	4.6	5.0	5.0
Marshall stability at 140 F (lb)	836	1,274	1,321	1,335
Marshall flow (0.01 in.)	13	13	11	13
Marshall density (pcf)	143.7	147.9	147.7	148.1
Aggregate density (pcf)	138.3	141.4	140.7	141.0
Aggregate volume (%)	83.6	85.5	85.0	85.2
Asphalt volume (%)	8.7	10.4	11.2	11.4
Volume of voids (%):				
In mix	7.7	4.1	3.8	3.4
In aggregate	16.4	14.5	15.0	14.8
Voids filled with asphalt (%)	53.0	71.7	74.7	77.0
Percent passing sieve:				
3/4 in.	100	100	100	100
5/8 in.	98	97	95	99
3/8 in.	75	74	80	81
No. 4	60	61	66	63
No. 10	51	51	53	51
No. 40	16	16	17	17
No. 200	4.6	5.3	6.1	6.1

Thermocouple equipment was supplied by Thermo-Electric (Canada) Ltd. Thermocouples were made by soldering the ends of 24-gage copper-constantan wire and coating them with Glyptal. Sets of these were then taped to 1- by 2-in. sticks and placed in previously augered holes. All wires were carried to the edge of the subgrade through plastic tubing. The resulting cables were spliced into coaxial cable at junction boxes and then connected to jack panels in the instrument building.

Reading of the temperature at each thermocouple was accomplished by plugging the male jack, connected to a direct-reading Rubicon No. 273 potentiometer, into the appropriate female connector on the jack panels. This method produced quick readings with a minimum effort.

A recording hygro-thermograph was mounted on the roof of the building to record humidity and air temperature.

CONSTRUCTION

The subgrade was shaped and compacted so that each section would have the same final cross-section and elevation. This was the most difficult portion of the work as

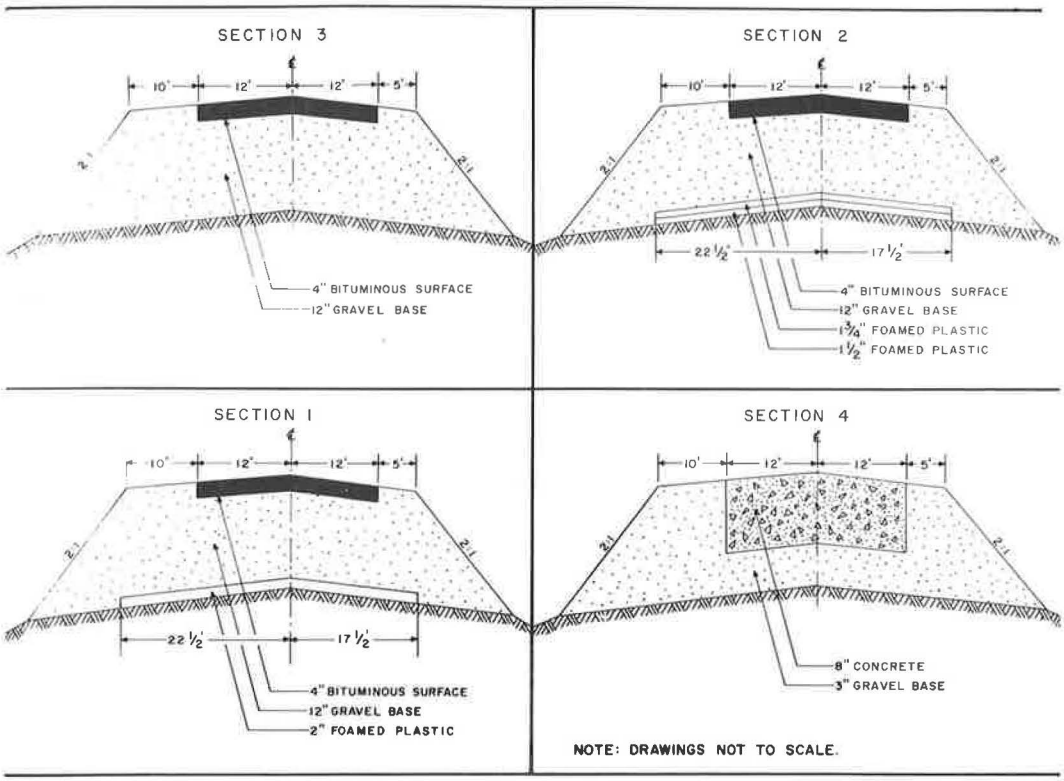

Figure 1. Cross-sections of test sections.

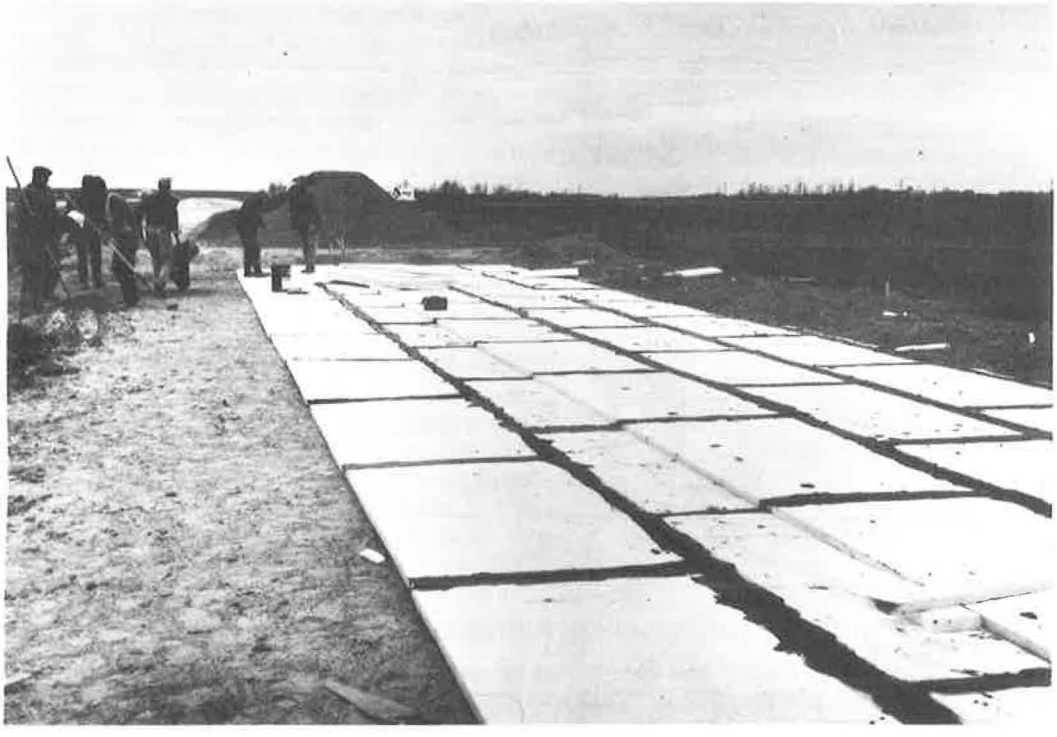

Figure 2. Partially completed section 2 showing two layers of foam plastic.

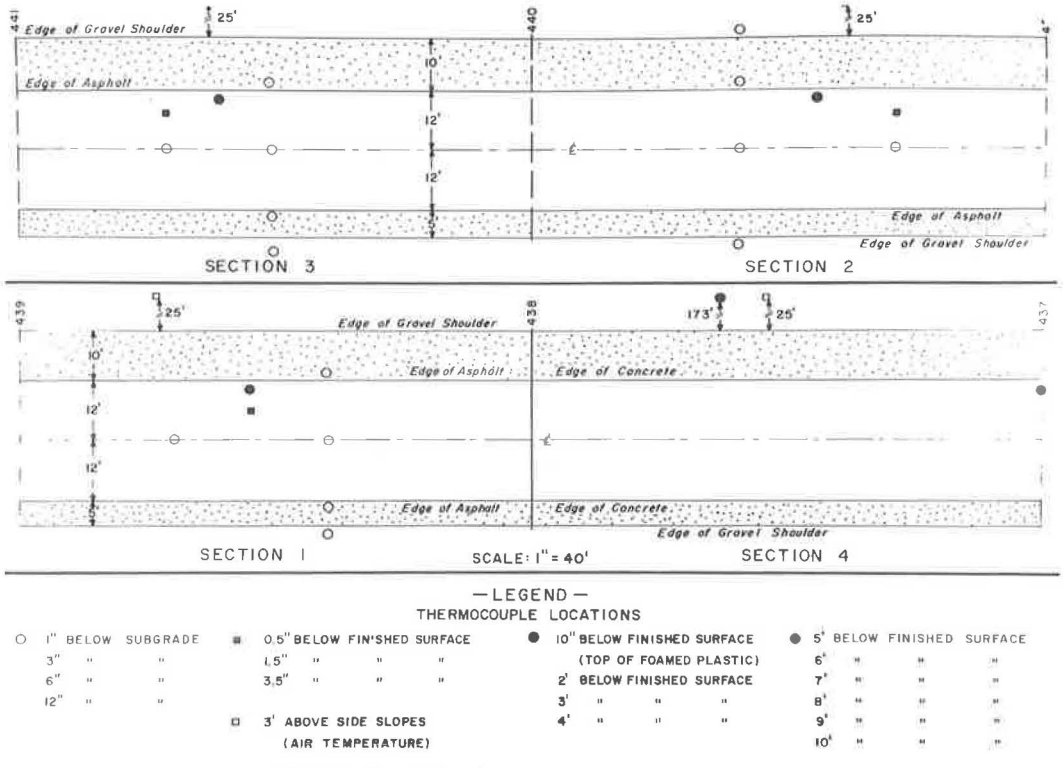

Figure 3. Plan of thermocouple locations.

Figure 4. Wedges of foam plastic being placed in gaps between sheets; machine placing base course on foam plastic.

the sections were only 100 ft long, which hardly allowed the motor grader and packers sufficient room to maneuver.

TABLE 4

BENKELMAN BEAM DEFLECTIONS ON FOAMED PLASTIC TEST SECTION

Date	Pavement Temperature (°F)	Deflections		
		Sect. 1	Sect. 2	Sect. 3
10/22/62	48	52	60	54
10/30/62	49	40	50	42
3/27/63	52	42	44	20
4/ 6/63	66	50	62	44
4/15/63	80	90	90	74
4/24/63	60	68	68	50
4/26/63	68	100	92	86
5/ 1/63	74	114	96	86
5/ 6/63	75	84	78	70
5/10/63	74	76	80	70
5/15/63	84	102	108	100
5/23/63	80	84	78	84
5/28/63	60	76	70	68
6/14/63	70	88	70	70
6/25/63	72	72	70	76
8/17/63	81	54	54	44
4/ 1/64	54	10	12	4
4/16/64	78	32	54	42
4/20/64	38	32	56	34
4/29/64	54	40	44	32
5/ 1/64	62	60	58	56
5/ 8/64	68	64	54	50
5/16/64	54	60	52	50
5/21/64	84	80	68	60
5/25/64	84	78	66	70
5/26/64	74	80	66	70
5/29/64	62	66	58	64
6/ 1/64	52	58	48	48
6/ 5/64	92	80	56	54
6/12/64	68	68	72	68
6/22/64	77	76	74	64

Following the fine-grading with ½ in. of sand, work commenced on the placement of the foam plastic. The cross-sections for the project are shown in Figure 1. Section 1 received one layer of 2-in. by 4-ft by 8-ft foamed plastic sheets placed so as to reduce the continuity of the joints. The sheets were pegged into place by wooden skewers and the joints were painted with an asphalt emulsion. The difference in shoulder width is due to the divided highway median design in this area. Section 2 received one layer of 1½-in. and one of 1¾-in. thick foam. Again the joints were staggered on each layer as well as from one layer to the next (Fig. 2). Section 3, the control section, received the same base, pavement, and instrumentation as sections 1 and 2, but was not insulated with foamed plastic.

The standard concrete pavement at the east end, adjacent to test section 1 is also shown in Figure 1.

The plan of thermocouple location is illustrated in Figure 3. The coded location points indicate similar installations. There are thermocouples in the adjacent field, the air at the shoulder, the subgrade, the base course and the bituminous pavement.

The base course was placed as soon as possible to help hold the plastic in place. A crawler tractor with a front end bucket was used to place the base gravel (Fig. 4). The base was dumped ahead of the machine to provide a ramp. When the initial ramp, about 8 to 12 in. thick and 10 to 20 ft wide, had been built along the length of the project, trucks were able to carry the gravel over the foamed plastic without damaging it.

The loader then loaded the trucks from the stockpile, the trucks deposited it, and a motor grader did the spreading. A depth of 12 in. of gravel base was used.

A vibratory compactor was used to attain density and the completed base was primed. The following day the two lifts of bituminous material were placed and compacted.

TEST RESULTS

Benkelman beam rebound measurements are taken throughout the spring, summer and fall. The results of these tests are given in Table 4.

Temperature measurements are taken periodically, more frequently during times of extreme temperature change such as spring and fall. Of the hundred of readings taken, only the more important ones are plotted in Figures 5 to 9.

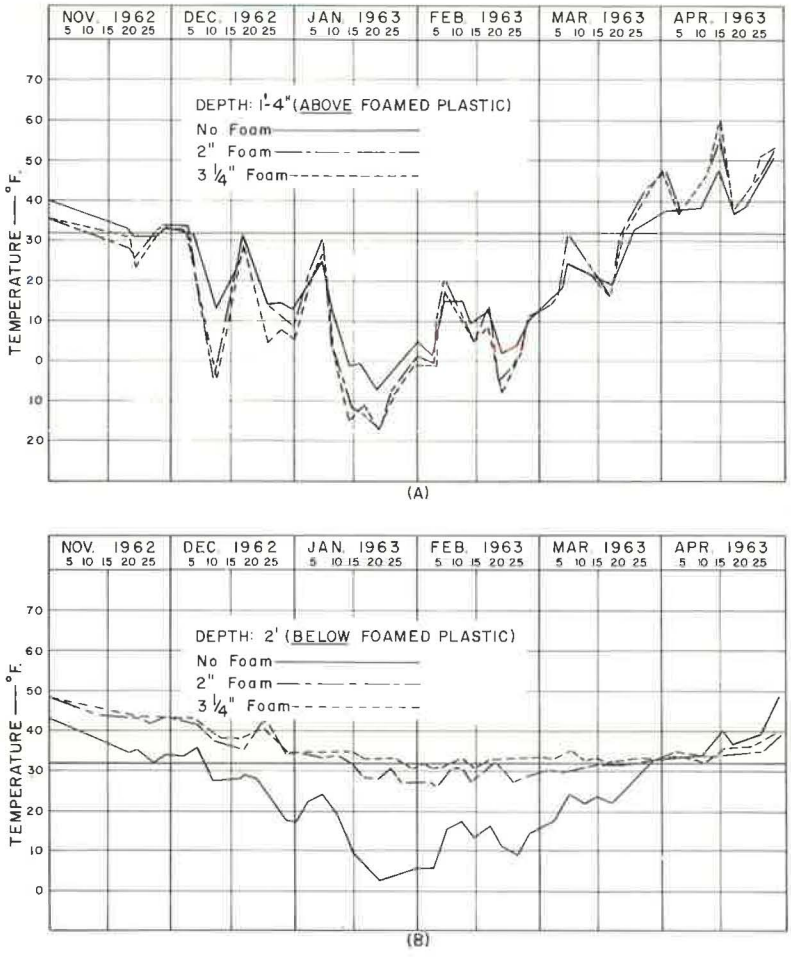

Figure 5. Variation in temperature above and below foamed plastic with time of year.

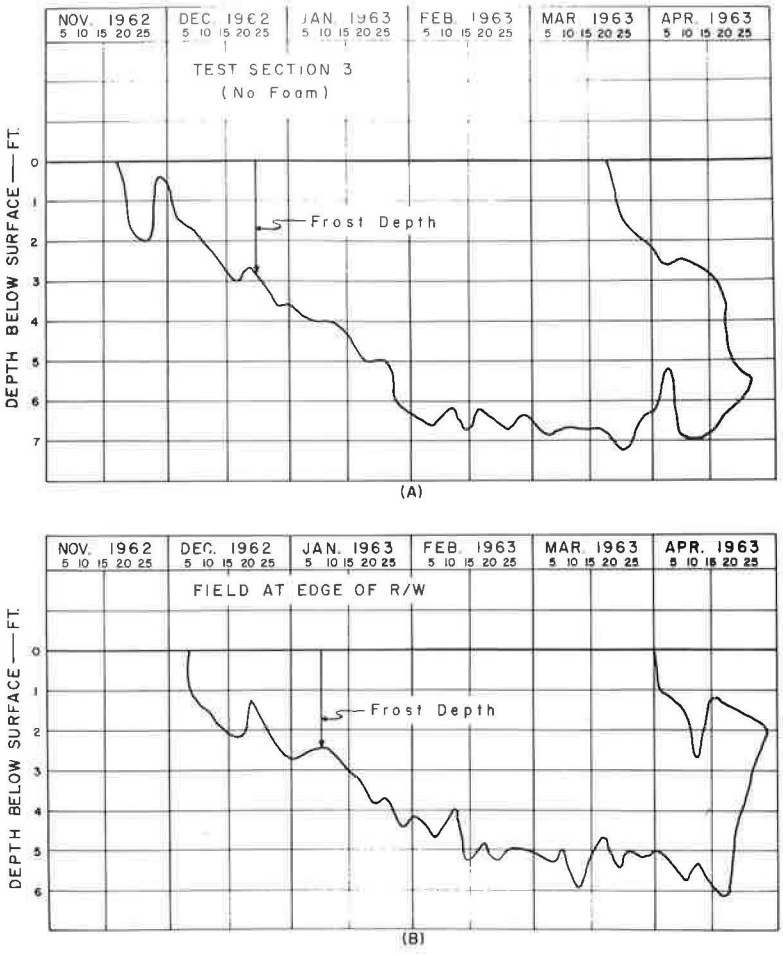

Figure 6. Variation in frost depth with time of year.

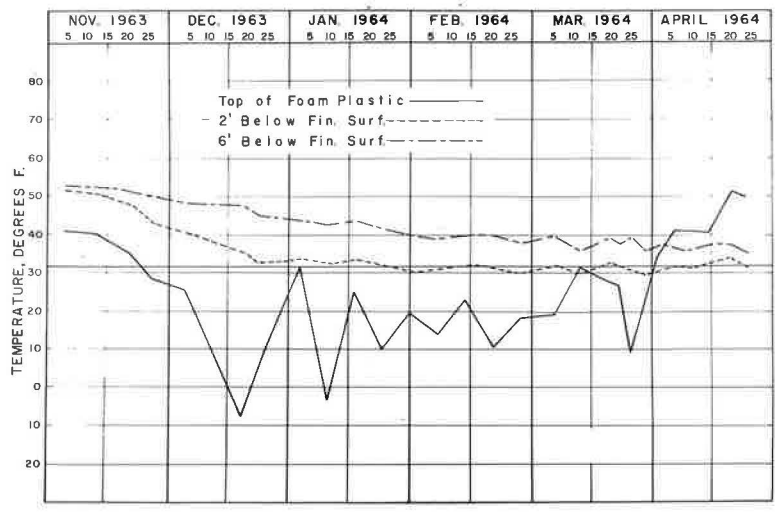

Figure 7. Comparison of temperature with time of year at three depths in section 1.

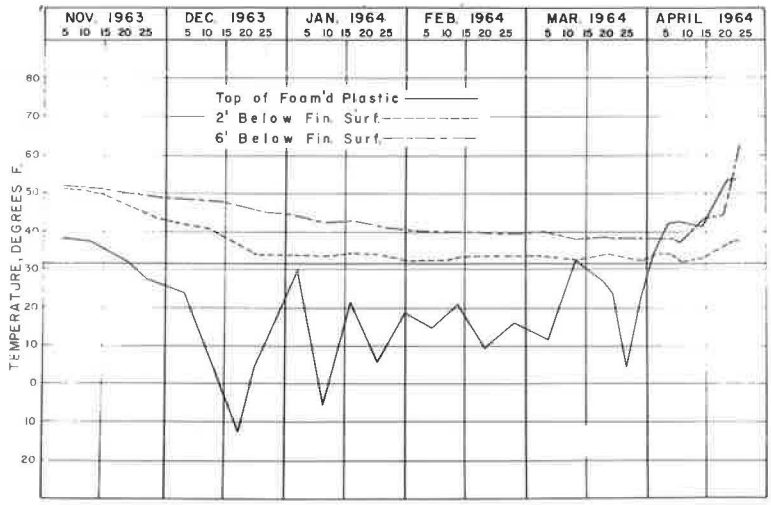

Figure 8. Comparison of temperature with time of year at three depths in section 2.

Figure 5a shows the temperature variations at a depth of 16 in. from pavement surface, immediately above the foamed plastic. The extremes in temperature are greater in the section containing foam than in the one which did not. Figure 5b shows temperature variations at a depth of 2 ft 0 in. which would be below the foamed plastic layer in sections 1 and 2. These measurements indicate that there is only slight frost penetration of the soil below the 2-in. foam and practically none below the $3\frac{1}{4}$-in. layer. The temperature below the $3\frac{1}{4}$-in. layer was never lower than 30 F and only reached 26 F under the 2-in. layer. In the control section, the temperature at this depth dropped to 2 F.

Figure 6 shows temperature variation in the control section and for a point in the prairie. The frost penetrated to a depth in excess of 7 ft in the road where there was no insulation and to a depth of about 6 ft in the prairie where there had been some snow cover.

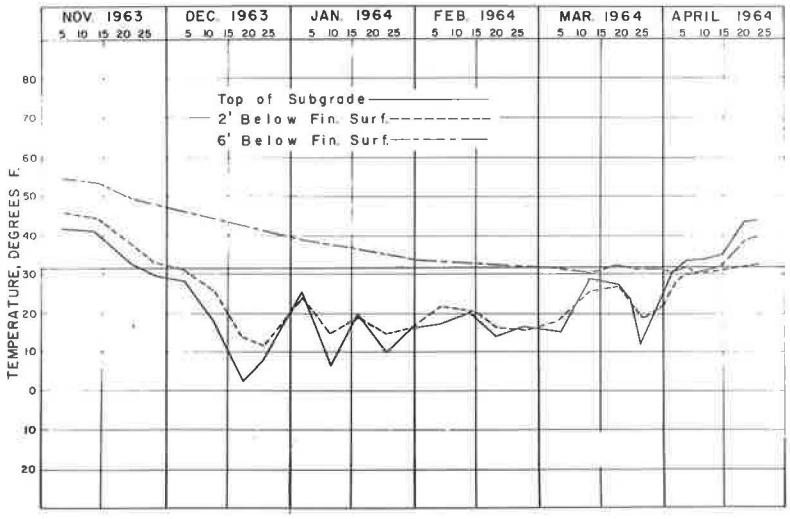

Figure 9. Comparison of temperature with time of year at three depths in section 3.

In Figure 7, the 1963-64 readings are plotted to show the comparison between temperatures at depths of 2 and 6 ft below the surface and the temperature above the foam for section 1. Figure 8 shows a comparison for section 2 and Figure 9 for section 3 which had no foamed plastic.

Excavation of several locations in the summer of 1964 indicated that the foamed plastic had not deteriorated or failed structurally following 2 yr of service. There was little moisture absorption and, except for the indentations of a few stones and discoloration of the upper surface, the plastic generally was unchanged since installation.

CONCLUSIONS

The continuously extruded polystyrene foam (Styrofoam) provided sufficient insulation at a 3¼-in. thickness to essentially prevent frost penetration into the subgrade. There was a slight depth of frost immediately below the 2-in. thick foamed plastic layer but it did not exceed a few inches.

Under 12 in. of gravel base course and a 4-in. bituminous surface, the foamed plastic was not affected by traffic loads. Construction traffic loads did not fail the plastic. Loaded gravel trucks were able to traverse the area without failure of the plastic when it was protected by 8 to 12 in. of gravel.

FUTURE RESEARCH

The experimental project described in this paper will continue to be observed and tested until it is removed to make way for the Winnipeg Floodway.

A new installation is nearly completed, on the west side of the Perimeter Highway around Winnipeg, which involves the insulation of a double steel arch culvert. A cross-sectional view of this installation is shown in Figure 10. The insulation used was a continuously extruded polystyrene foam with high density surface skins (Styrospan, Dow Chemical of Canada). It is hoped that this installation will yield useful information concerning differential frost heave at culverts due to the greater frost penetration usually encountered at culvert locations. The foam used in this project was 2 in. thick. The area was instrumented with thermocouples as in the previous test.

Further research is required to determine the structural value of foamed plastic in a highway. A project is presently under consideration incorporating this material into a highway section, protected by various depths of pavement structure.

ACKNOWLEDGMENTS

The author wishes to acknowledge the contribution of the Dow Chemical Company and Dow Chemical of Canada whose interest in this project and provision of essential information regarding the use of foamed plastic assisted greatly in the successful development and completion of this research installation.

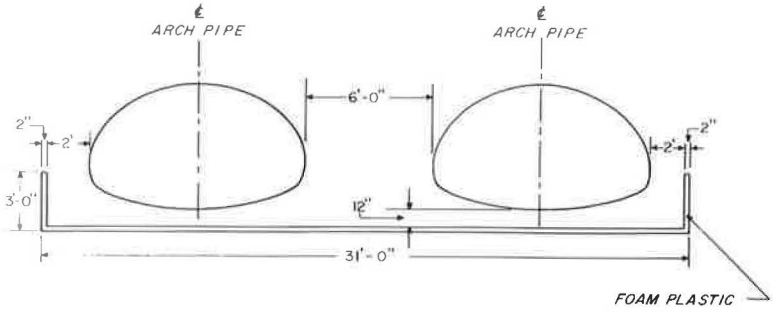

Figure 10. End elevation of arch pipe culvert and foam plastic insulation.

The contribution of R. N. Sharpe to this project is worthy of special recognition. His vision and his interest in the development of new highway design and construction techniques were responsible for this research project.

This project would not have been possible without the efforts of many members of the staff of the Materials and Research Section of the Manitoba Highways Branch. Acknowledgment of all individuals whose contributions are worthy of special mention is not practical.