FROST INSULATING PROPERTIES OF ASPHALT-TREATED BASES

MICHIGAN
HIGHWAY RESEARCH LABORATORY SECTION

MICHIGAN DEPARTMENT OF STATE HIGHWAYS

FROST INSULATING PROPERTIES OF ASPHALT-TREATED BASES

R. C. Mainfort
E. C. Novak

Research Laboratory Section
Testing and Research Division
Research Project 69 E-45
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Michigan State Highway Commission
Charles H. Hewitt, Chairman; E. V. Erickson,
Vice-Chairman, Claude J. Tobin, Peter B. Fletcher
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This project was undertaken at the request of R. L. Greenman to determine the temperature insulating property of asphalt-treated bases as compared with that of a layer of styrofoam insulation board. An earlier research project (64 E-31) had shown styrofoam to provide an excellent barrier to frost penetration into the subgrade beneath an asphalt pavement structure. However, it had been implied by the Asphalt Institute that an inch or two of hot mix asphalt base might provide more suitable and economical insulation then a layer of styrofoam, particularly if the styrofoam might crush under construction or traffic loads.

Comments concerning possible crushing of styrofoam, and a discussion of the insulating properties of asphalt paving mixtures, were included in a memorandum to Mr. Greenman dated September 3, 1970, a copy of which is attached. This memorandum indicated that, when properly installed, there were no problems to be expected from styrofoam insofar as crushing was concerned and, based on theoretical considerations and work by others, that asphalt paving mixtures provided little, if any, temperature insulation.

To supplement information concerning the insulating properties of asphalt mixtures, frost depth indicators were installed at two separated field locations (near Haslett and DeWitt) at each of which two different thicknesses of asphalt paving mixtures were located in proximity of each other. Periodic measurements of the depth of frost penetration were made throughout the freezing seasons of 1970 and 1971. It was planned, originally, to include additional test sites in this study but construction and installation difficulties prevented this in time for the first winter observations. Based on results obtained from the two sites that could be used there appeared to be no need for expanding the area of operation during subsequent winters.

In selecting the adjoining test sites, attempts were made to eliminate variables, other than the asphalt mixture thickness, such as slope and color of surface, traffic load, design and types of subsoil. Unfortunately, the test sites could not meet these requirements in all respects but were considered to be similar enough to indicate any significant differences in the temperature attenuating characteristics of the different thicknesses of asphalt.

Figures 1 and 2 show the cross sections of the test areas and the periodic maximum frost penetrations. Although these figures show somewhat lesser frost penetration under the thicker asphalt sections the change is not great nor, as in the case of a layer of styrofoam, is it abrupt. In the case of Site Number 1, an increase in asphalt thickness from 4 to 11 in. resulted in a frost penetration reduction of only about 10 percent. For Site Number 2, doubling the asphalt thickness (3-1/2 to 7 in.) resulted in a frost penetration reduction of about 18 percent. In this respect it should be noted that the areas of lesser frost penetration were the newer pavement having the darker surfaces and, consequently, the warmer subgrades due to increased solar heat absorption.

Based on the results of these field tests it is concluded that:

1) Frost depth measurements tend to verify existing information indicating that no appreciable frost insulation is obtained from asphalt paving mixtures.

2) The temperature insulating properties of a black base do not compare favorably with those of a styrofoam layer when used for frost attenuation beneath a pavement.

3) Although some frost attenuation is indicated beneath the thicker asphalt layers tested in this study, the amount is not sufficient to justify a design change in base or subbase construction.

4) At least part of the frost attenuation found beneath the thicker asphalt layers is due, probably, to the darker asphalt surface found for the more newly constructed thicker asphalt sections.

5) No further study in this area is recommended.

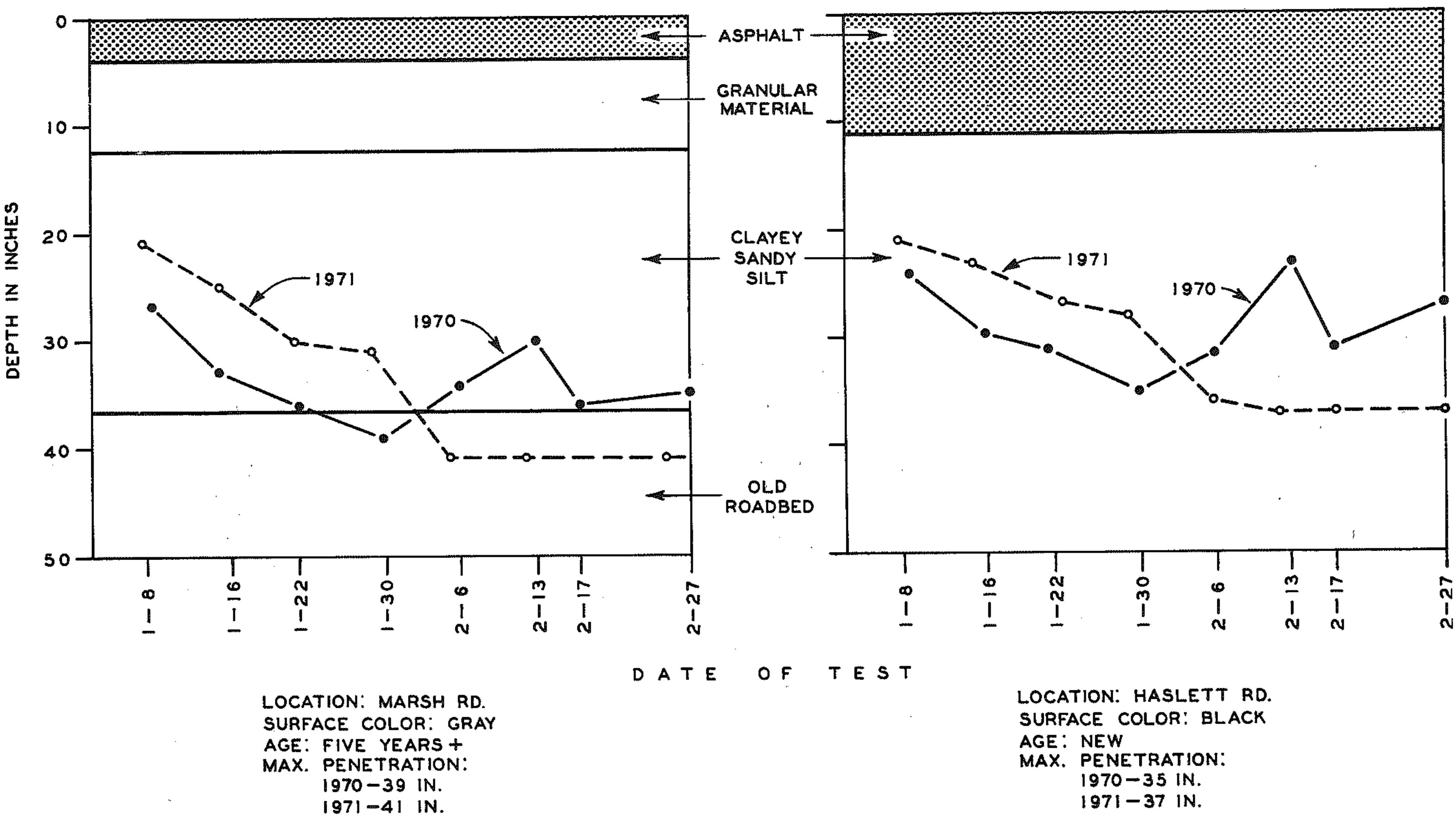

Figure 1. Frost penetration for pavements of different asphalt thicknesses at Site Number 1.

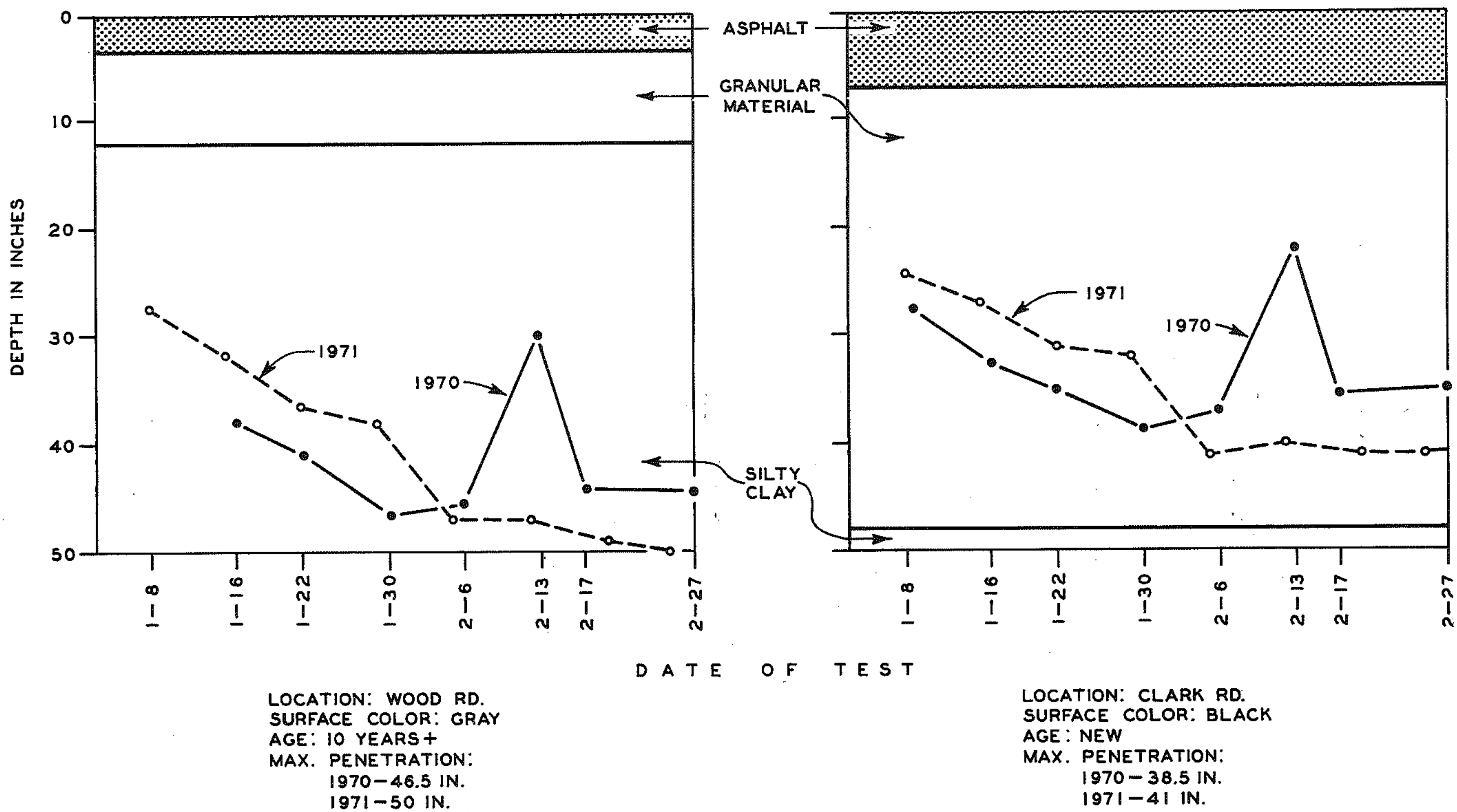

Figure 2. Frost penetration for pavements of different asphalt thicknesses at Site Number 2.

OFFICE MEMORANDUM

MICHIGAN
DEPARTMENT OF STATE HIGHWAYS

September 3, 1970

To: R. L. Greenman
Engineer of Testing & Research

From: L. T. Oehler

Subject: Comments Concerning Charles R. Foster's Letter of July 27, 1970.

After reading Mr. Foster's letter of July 27, 1970 concerning the possible crushing of styrofoam and the insulating properties of hot mix asphalt base (HMAB), the Soils and Aggregates Unit has prepared the following comments.

Crushing of Styrofoam

Compressive strength of styrofoam at normal air temperature is 35 psi at 5% strain. (1) The requirements for using styrofoam are that no vehicles be allowed on the styrofoam until it is covered by a minimum of 8 inches of compacted sand. With this much cover the maximum permissible contact pressure would be about 70 psi, which exceeds the contact pressure exerted by normal construction equipment. Inspection during construction of the M-47 job showed no evidence of crushing during and subsequent to the addition of the sand subbase. After the base and surface are applied the pressure on the styrofoam is, of course, further reduced. The absence of moisture in styrofoam and its general structure make it highly unlikely that there would be any reduction in thickness after construction was completed, at which point maximum compressive load would be less than 10 psi. Pavement evaluation studies subsequent to construction of the M-47 job, show no evidence of any change in thickness of the styrofoam. Furthermore, there has been no change in the effectiveness of the layer as a frost barrier which would not be true if the insulating layer were reduced in thickness. (2)

The reduction in thickness mentioned by Mr. Foster was more likely caused by melting of the styrofoam when hot mix asphaltic base (normally placed at temperatures around 300 F) was placed directly in contact with the styrofoam, which melts at temperatures between 165 F and 170 F. (1)

Insulating Properties of Asphalt Base Mixtures

Mr. Foster states in his letter that an inch or two of hot mix asphalt base would provide more insulation than the crushed down thickness of styrofoam. In order to determine the insulating value of asphaltic mixtures the following information was accumulated.

Table 1 lists the thermal conductivity of materials used in normal pavement construction and shows the thermal conductivity of asphalt to be about equal to that of damp sand and only slightly less than that of portland cement concrete. (1, 3, 4) Although the thermal conductivity of soils and asphalt is a very complex subject and there are no constant values for these materials, studies in this area indicate no significant difference between the thermal properties of asphalt treated aggregate and untreated aggregates. The U. S. Corps of Army Engineers has reported that variation in the depth of frost penetration beneath different types of pavements (asphalt or portland cement concrete) is negligible and may be neglected when using their charts for estimating depth of frost penetration. (5) Straub, et al, also show that thermal properties of asphaltic concrete and subgrade materials are similar. (6) Studies at the College Park, Maryland test site of the Asphalt Institute, conducted during January 1965, showed the temperatures immediately beneath a 6-inch and 12-inch thick asphalt concrete pavement to be the same. (7) These data indicated that no significant change in frost penetration depth would be gained by increasing the thickness of asphaltic concrete or black base. A similar study at the Clarkson College of Technology showed no important differences in temperatures measured at 2, 4, 6, and 12 inches in depth beneath a 6-inch and a 12-inch thick bituminous pavement. Here again, no insulating advantage was obtained using the thicker asphalt layer.

Thus, on the basis of considerable research, it appears that little or no insulation values can be obtained with asphalt paving mixtures.

However, the color of asphaltic surfaces does give them a thermal advantage over lighter colored materials. The dark surface of a bituminous pavement allows absorption of more solar heat than does the lighter surface of portland cement concrete and, therefore, the daily high temperature of bituminous surfaces will be the warmer of the two and much warmer than the ambient air temperature. Straub, et al, concluded, after a one year field study, that "solar radiation has a greater influence on heat flow in the pavement than does air temperature for the increasing or decreasing of bituminous pavement temperatures." Bituminous pavement surfaces may become warmer than portland cement concrete surfaces but never colder, other factors being equal. This could make a difference in the design depth of frost penetration to be expected for each pavement type but any difference would be due to surface color and not to the thickness of the asphalt layer.

It would appear, therefore, that Mr. Foster's letter is more of a sales effort for use among asphalt representatives than it is a factual technical document. We plan to continue our frost depth measurements beneath asphalt and untreated aggregate surfaces and, if still thought to be desirable will core or otherwise obtain measurements of the styrofoam thickness beneath the M-47 pavement.

TESTING AND RESEARCH DIVISION

L. T. Oehler

Engineer of Research

LTO:RCM:bf

TABLE I

Measured Thermal Conductivities of Pavement Materials in BTU/hr-ft^2-F/in.

Material	Conductivity	Reference
Portland Cement Concrete	52.2×10^{-2}	3
Asphalt	43.0×10^{-2}	3
Moist Sand (3.7% H_2O & 120 lb/ft^3 Dry Den)	42.2×10^{-2}	4
Moist Clay (23% H_2O & 84 lb/ft^3 Dry Den)	12.6×10^{-2}	4
Styrofoam	1.9×10^{-2}	1

REFERENCES

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5. Linell, K. A., Hennion, F. B., and Lobacz, E. F., "Corps of Engineers' Pavement Design in Areas of Seasonal Frost," HRR No. 33, 1963.

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