Study of Temperature Variation in Hot-Mix Asphalt Base, Surface Course and Subgrade

GLENN P. MANZ, Assistant Executive Secretary, Michigan Asphalt Paving Association

•A STUDY of temperature variation in a 7-in. thick asphalt pavement and the underlying soil has been carried on in Michigan through the cooperative efforts of Leonard Refineries of Alma, Michigan, and the Michigan Asphalt Paving Association. The study was conducted from June 1963 through April 1965.

An experimental hot-mix base or black base pavement was constructed by The Hicks Company for the Gratiot County Road Commission. Thermocouples were placed at 4 levels in the pavement and at 3 levels in the subgrade. Temperatures were read each day to determine the maximum temperatures in the black base and the wearing course.

Because of the erratic results obtained from stability tests of the black base mixes, it was felt necessary to know the maximum temperatures which could be expected in the base courses. Laboratory mixes tested at the standard 140 deg temperature varied widely, and were of little value. Stability tests were run on the same mixes at 100 deg and 120 deg with results which were reproducible. The mix used had a Marshall stability at 120 deg, which was equal to surface course mixes at standard temperature. What we were attempting to determine then was that 120 deg would be greater than the highest expected temperature in the base mix.

After a few weeks of reading temperatures manually, it was decided to install a recording pyrometer which would record not only maximum temperatures but the variation between maximum and minimum on a 24-hr basis. Although the original purpose of the study was to determine maximum temperatures, it was soon apparent that there was considerable interest in knowing more about winter temperatures. Because of this, 3 more thermocouples were placed in the subgrade under a 7-in. gravel surface driveway, so that a comparison could be made between temperatures under the 7 in. asphalt pavement and under 7 in. of gravel during the cold winter months.

The following figures show the maximum temperatures during the hot summer weather and the minimum recorded during the coldest days of the winter.

Figure 1 shows the wide range of maximum temperatures which occurred during a 30-day period when the highest temperatures of the summer were recorded. This indicates a 13-deg drop in temperature in the top 2 in. of the pavement. In the next 3 in. of depth a further reduction of 5 deg was recorded.

The average drop in temperature in the 7-in. asphalt pavement was 25 deg, although the minimum differential was 9 deg and the maximum was 34 deg. The maximum surface temperature recorded was 130 deg. This peak was reached on the day after the highest atmospheric temperature of the summer was recorded.

The temperatures recorded at the pavement surface and at a depth of 2 in. are practically identical to those reported in a study made in 1924 and 1925 by W. J. Emmons and B. A. Anderton for the Bureau of Public Roads.

The single dash line in Figure 1 shows the temperature range in the top of the base course. The lowest temperature was 80 deg and the maximum was 115 deg, which occurred on 3 different days.

This maximum 115-deg temperature is important because it bears out our assumption that 120 deg would be the highest expected base temperature. The average temperature in the top of the base was 100.9 deg.

Paper sponsored by Committee on Bituminous Aggregate Bases and presented at the 45th Annual Meeting.

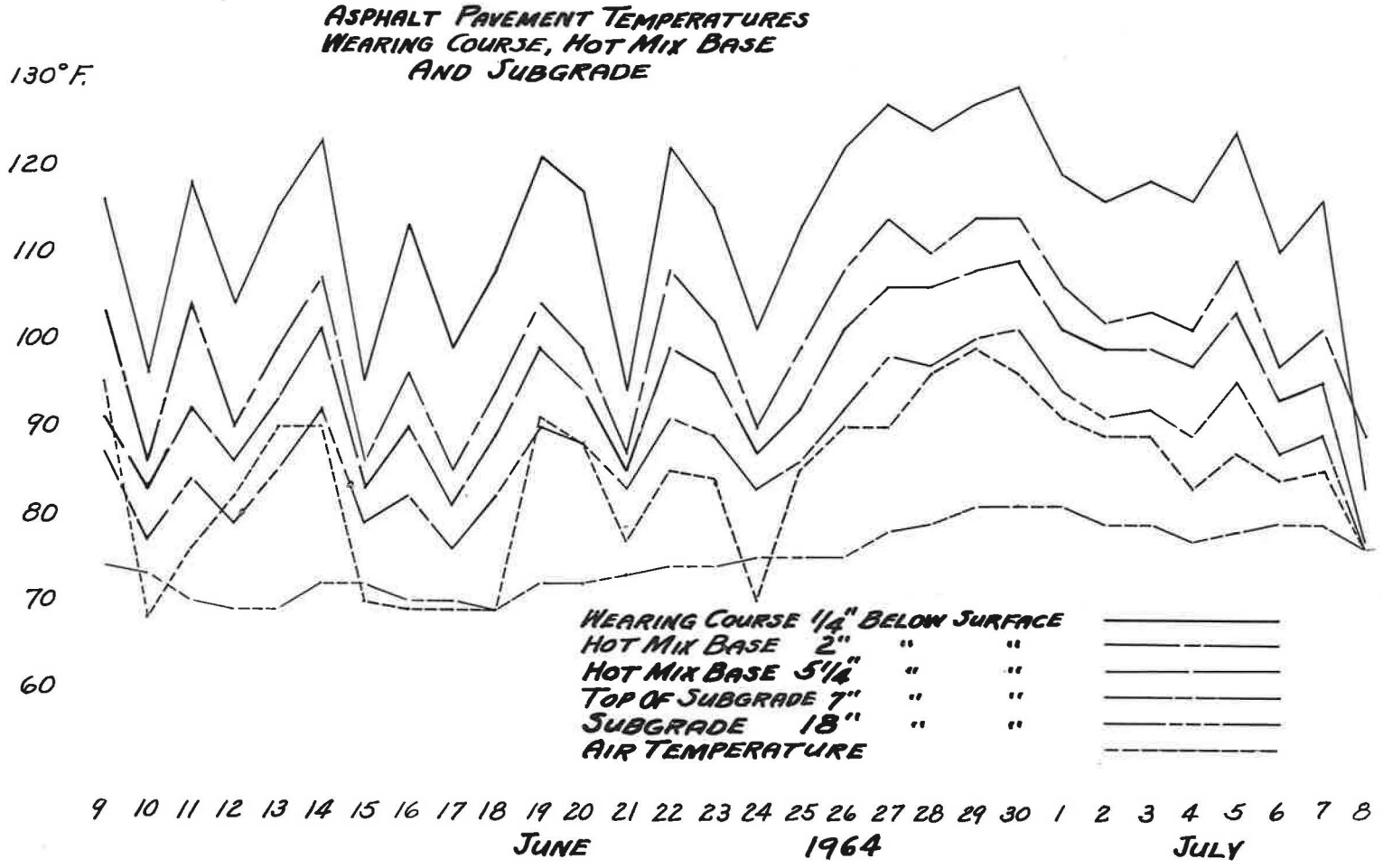
ASPHALT PAVEMENT TEMPERATURES
WEARING COURSE, HOT MIX BASE
AND SUBGRADE
130° F.
120
110
100
90
80
70
60
WEARING COURSE 1/4" BELOW SURFACE
HOT MIX BASE 2" " "
HOT MIX BASE 5 1/4" " "
TOP OF SUBGRADE 7" " "
SUBGRADE 18" " "
AIR TEMPERATURE
9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 1 2 3 4 5 6 7 8
JUNE
1964
JULY

Figure 1.

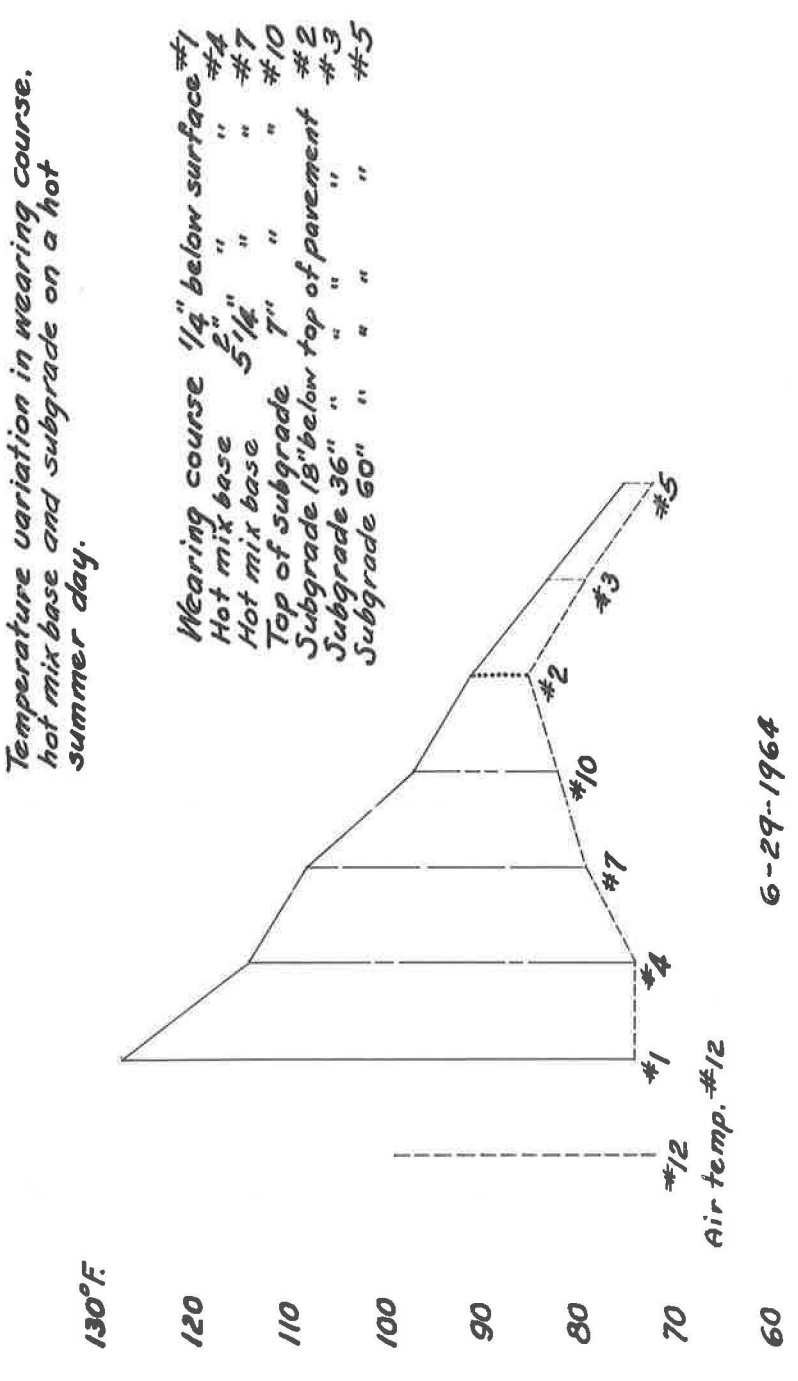
Temperature variation in wearing course, hot mix base and subgrade on a hot summer day.
Wearing course 1/4" below surface #1 #4
Hot mix base 2" " " " #7
Hot mix base 5 1/4" " " " #10
Top of subgrade 7" " " " #2
Subgrade 18" below top of pavement #3
Subgrade 36" " " " " #5
Subgrade 60" " " " " #5
130°F.
120
110
100
90
80
70
60
#12
#1
#4
#7
#10
#2
#3
#5
Air temp. #12
6-29-1964

Figure 2.

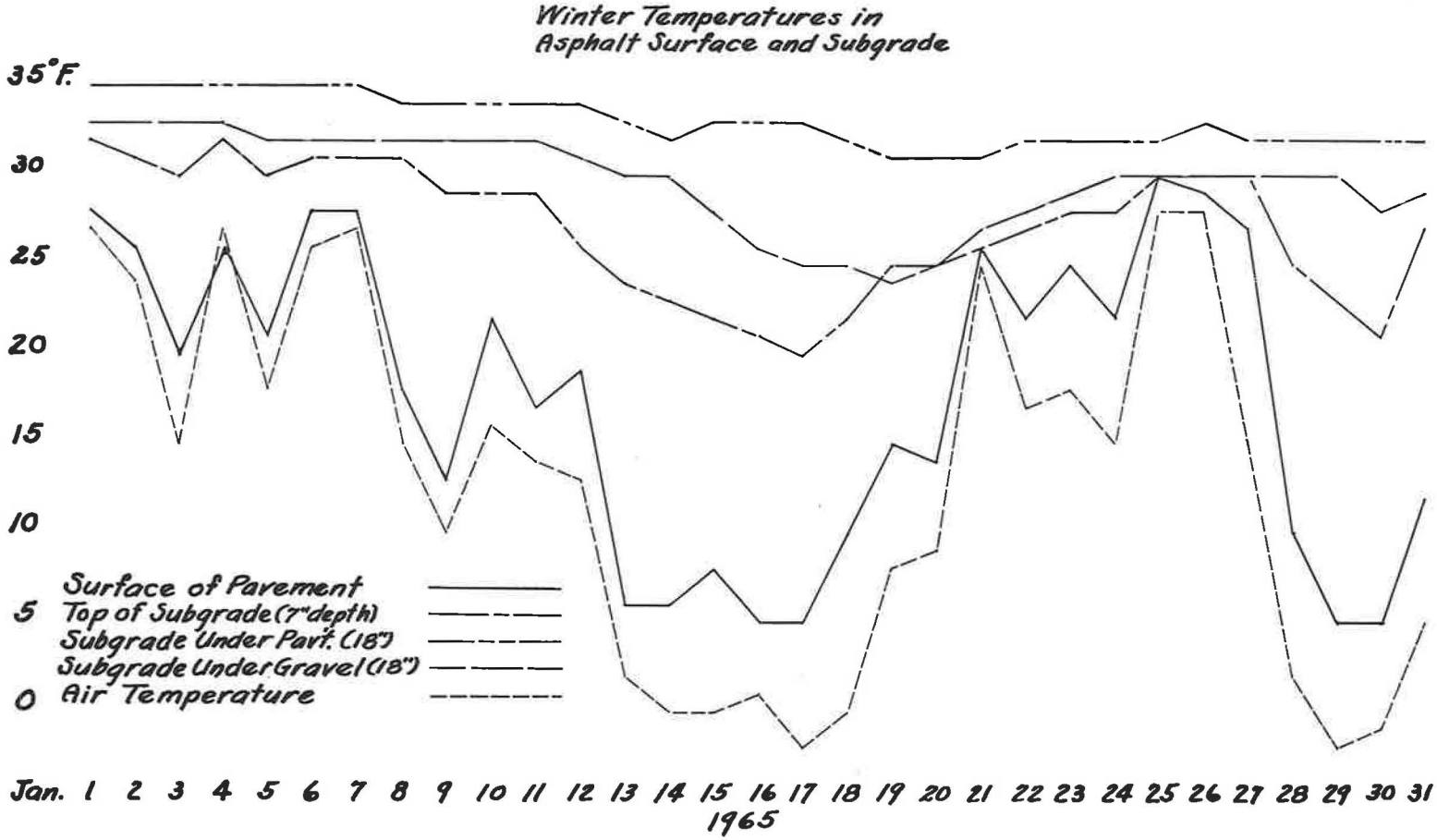
Winter Temperatures in
Asphalt Surface and Subgrade
35°F.
30
25
20
15
10
5
0
Surface of Pavement
Top of Subgrade (7" depth)
Subgrade Under Pavt. (18")
Subgrade Under Gravel (18")
Air Temperature
Jan. 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
1965

Figure 3.

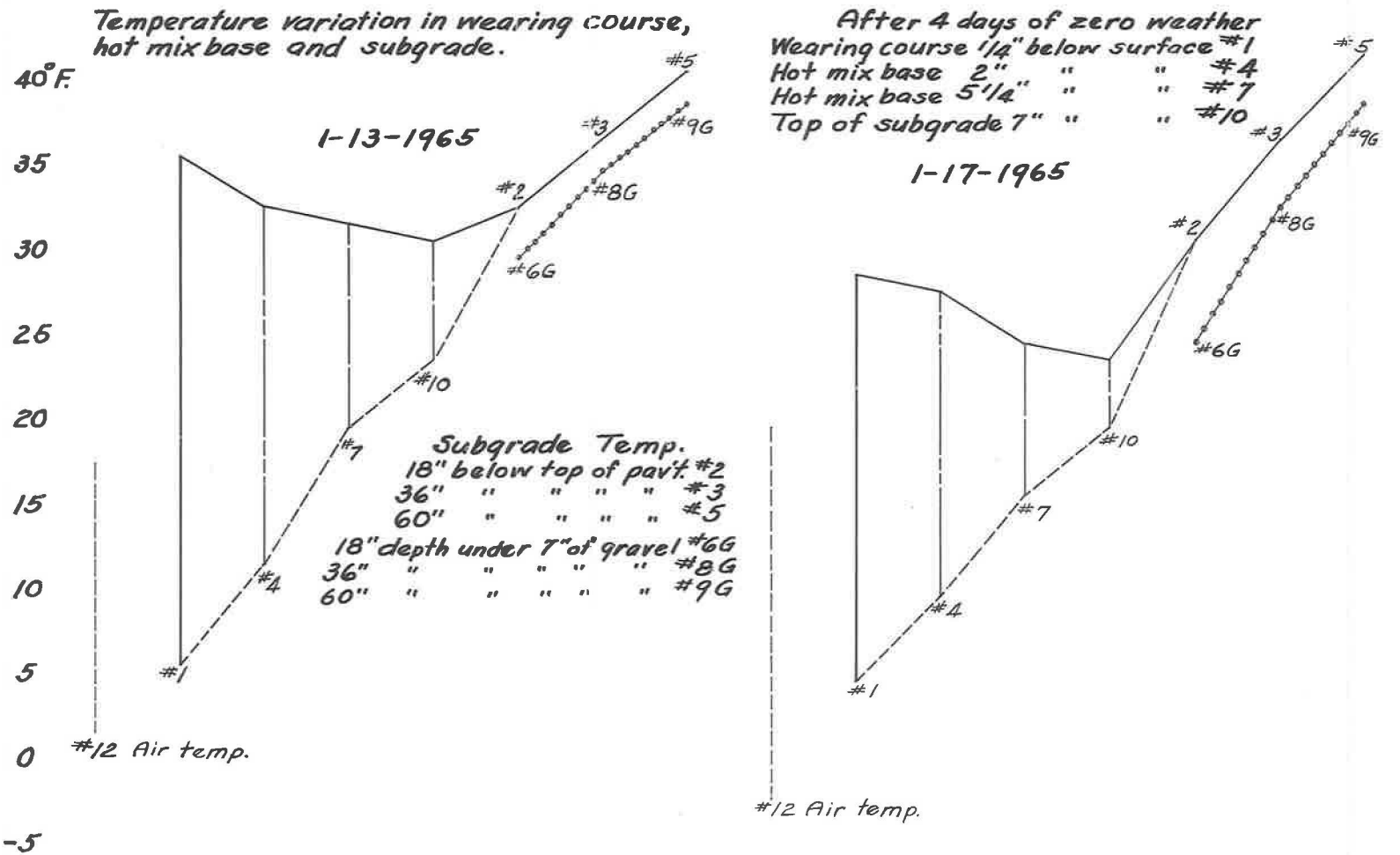
Temperature variation in wearing course, hot mix base and subgrade.
40° F.
35
30
25
20
15
10
5
0
-5
1-13-1965
#1
#2
#3
#4
#5
#6G
#7
#8G
#9G
#10
#12 Air temp.
Subgrade Temp.
18" below top of pavt. #2
36" " " " " #3
60" " " " " #5
18" depth under 7" of gravel #6G
36" " " " " #8G
60" " " " " #9G
After 4 days of zero weather
Wearing course 1/4" below surface #1
Hot mix base 2" " " #4
Hot mix base 5 1/4" " " #7
Top of subgrade 7" " " #10
1-17-1965
#1
#2
#3
#4
#5
#6G
#7
#8G
#9G
#10
#12 Air temp.

Figure 4.

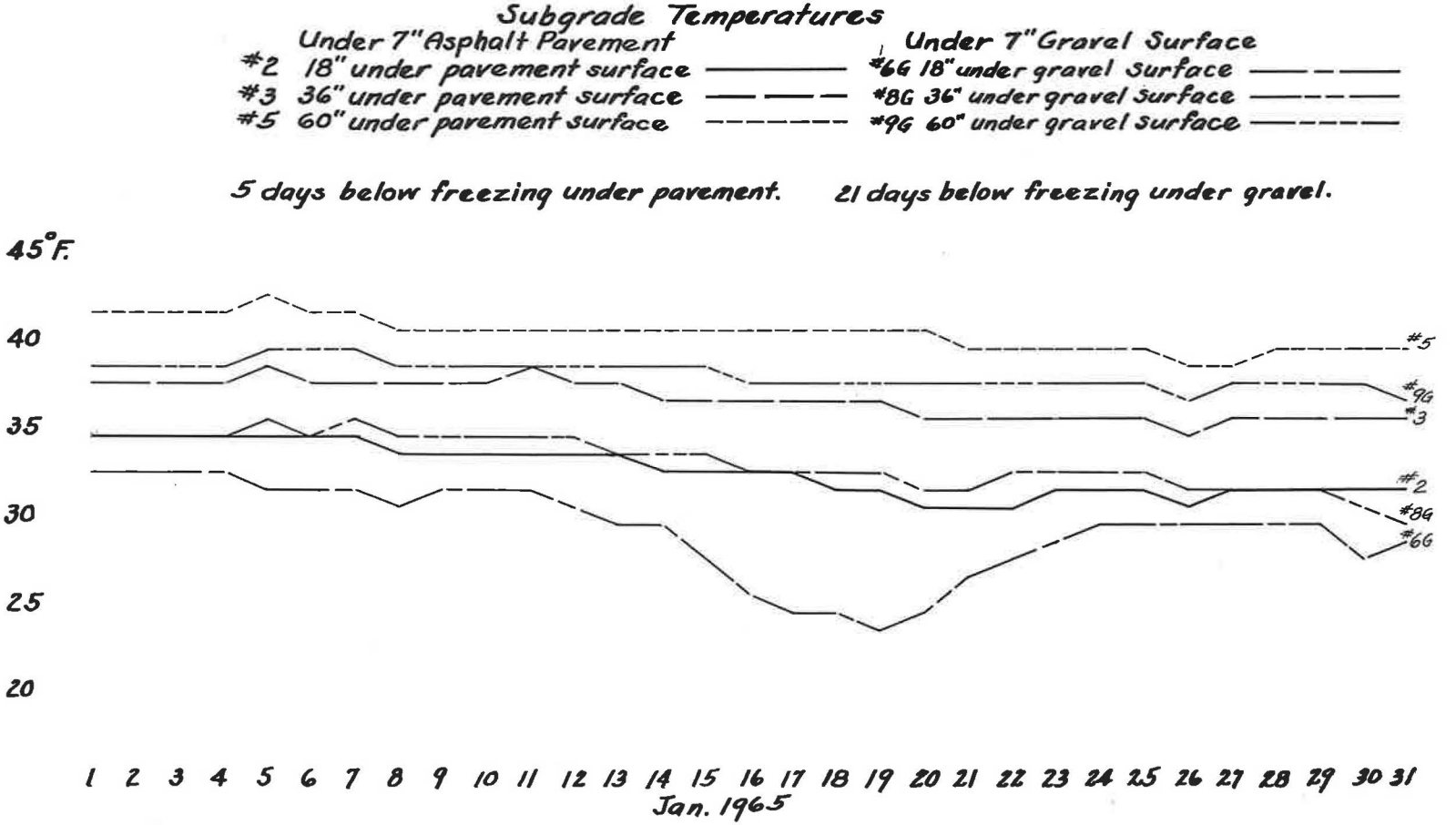
Subgrade Temperatures
Under 7" Asphalt Pavement
#2 18" under pavement surface
#3 36" under pavement surface
#5 60" under pavement surface
Under 7" Gravel Surface
#6G 18" under gravel surface
#8G 36" under gravel surface
#9G 60" under gravel surface
5 days below freezing under pavement.
21 days below freezing under gravel.
45°F.
40
35
30
25
20
#5
#9G
#3
#2
#8G
#6G
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Jan. 1965

Figure 5.

Figure 2 shows the variation in temperature in the wearing course, black base, subgrade and the atmosphere. While the air temperature varied from 73 deg to 100 deg, the top of the pavement had a much greater variation, ranging from a low of 75 deg to a high of 128 deg. The black base variation was 75 deg to 115 deg, and the subgrade ranged from a high of 98 deg at the 7-in. level to a low of 63 deg at the 60-in. level.

Although a preliminary report was made on winter temperatures, no information was available showing the minimums reached during a period of below-normal temperatures for the central Michigan area.

During January 1965, the low temperatures hoped for occurred and Figure 3 indicates the minimums recorded during the month.

Since the temperatures in the black base are not particularly important at this time of the year, only the pavement surface, subgrade and air temperatures are shown.

As expected, an entirely different picture is presented during the winter; the pavement surface is now the coldest part of the pavement. There was a 6-day period when the air temperature was zero or within 2 deg of zero each day. The pavement surface followed along with low temperatures of 5 deg to 8 deg during this period.

Of prime interest in this part of the study are the minimum temperatures occurring in the subgrade. Temperatures below normal experienced during this period resulted in frost penetration to the 18-in. level under the pavement. A minimum temperature of 31 deg was recorded at this level and it was below the freezing point for 5 days, while at the same time and at the same level under the gravel surface, there was a low temperature of 24 deg on one day and below freezing temperatures during 21 days.

In the depth of winter when freezing temperatures are continuous, what happens to pavements and subgrades? Do temperatures fall to some unknown low point and remain stationary until a warming trend occurs, or is there still further fluctuation? What actually happens is shown in Figure 4, which indicates the range of temperature variation on 2 midwinter days. On January 13, the air temperature reached a low of 2 deg and a maximum of 18 deg, while the pavement surface was rising from a low of 6 deg to a high of 36 deg.

The range of temperature variation diminishes rapidly with depth. At the top of the subgrade, 7 in. below the pavement surface, a variation of 7 deg occurs—from a low of 24 deg to a high of 31 deg.

There is little variation at lower levels in the subgrade during one 24-hr period, but several days of zero temperatures do have a definite effect at all levels down to the 36-in. level in the subgrade. This is illustrated graphically in Figure 5. On January 17 the air temperature fell to a low of 2 deg below zero and reached a high of 20 deg. After 4 days of very low temperatures, temperatures fell at every level except at the 60-in. depth, which changed very gradually over a period of several days. The range of temperatures also narrowed—surface 5 deg to 29 deg and top of subgrade 20 deg to 24 deg.

A most interesting change occurred in the subgrade at the 18-in. level—the temperature under the pavement dropped from 33 deg to 31 deg, while at the same level under the gravel surface the temperature fell from 30 deg to 25 deg. This indicates a deeper frost penetration under the gravel surface, and very possibly points up some insulating value in the 7-in. layer of asphalt base and surface.

Figure 5 shows only subgrade temperatures recorded during the month of January 1965. Notice that the temperatures are fairly uniform except during the very coldest part of the month, when a very definite drop occurred at the 18-in. level under the gravel surface.

Under the pavement the temperature fell 2 deg while under the gravel surface a 5-deg drop occurred, and this may have been reduced by a covering of ice over the gravel for a few days.

Some heaving did occur during the coldest weather of the winter, with a maximum of 1.5 in. being recorded. Any movement which occurred must have been quite uniform, since no cracking has developed up to this time.

CONCLUSIONS

1. The data included in this paper indicate that the maximum temperature in the black base will not exceed 120 deg.
2. The insulating value and heat-absorbing ability of the thick asphalt pavement is quite evident in the figures showing winter temperature variation. A definite reduction in frost penetration into the subgrade is indicated.

A great amount of information was accumulated during the months this study was being made. As time permits, much additional information may be derived from a further study of the recorded data.

ACKNOWLEDGMENTS

Credit must be given to Berl Fleury, engineer for Leonard Refineries; Arthur Taylor, Superintendent of the Gratiot County Road Commission; The Hicks Company; and the Michigan Asphalt Paving Association for their assistance and cooperation in making this study possible.

The assistance of Leonard Refineries and their furnishing of the data recording equipment is also appreciated.