Effect of Mix Temperature

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●THE EFFECT of temperature of mix, or viscosity of asphalt, has long been known to have a great influence on the compaction of bituminous concrete mixtures. Modern pavers are now equipped with compaction devices which do much in obtaining initial compaction.

The laboratory has been studying compaction of bituminous mixtures for many years, especially compaction at various temperatures. Attempts were made to obtain cores from actual pavement construction that were constructed at various temperatures. However, there were so many variables that results showed poor correlation. It was found that when compaction temperatures were in the range of 275 F the densities obtained closely approached the density obtained with the Marshall compaction method. For that reason it was decided that a study of compaction temperatures could be conducted at a higher degree of correlation when compacted in a laboratory by the Marshall Method than by cores from actual pavement construction. This study was conducted on both a surface mix and a binder mix in accordance with Table 1.

TABLE 1

Sieve	Percent Passing: Binder Course	Percent Passing: Surface Course
¾ in.	100	
½ in.		100
No. 4	30.5	68.3
No. 10	24.5	44.4
No. 20	20.3	31.6
No. 40	15.1	23.0
No. 80	8.5	13.9
No. 200	3.1	4.7
Asphalt % of Mix (85/100 Penetration)	5.1	6.3

Several methods were studied for evaluating the data from this experiment and it was felt that if it were assumed that ideal conditions would have been attained if the compaction was at 275 F then all other values could be shown in terms of the percent obtained at 275 F.

Specific Gravity

Figure 1 shows the relationship of specific gravity to the compaction temperature. This is based on 100 percent at a compaction temperature of 275 F. Although there is a reduction almost immediately, rapid loss starts at a temperature of 225 F. This indicates that compaction should largely have been accomplished before the temperature was below 225 F and while the mix is still in a plastic state.

Figure 2 shows a similar relationship for the binder mix. This relationship is very similar to that for the wearing course. However, the compaction temperature is not nearly as critical in the lower range as that shown for the wearing course.

Percent Voids

Figure 3 shows the relationship of percent voids to the compaction temperature based on 100 percent at a compaction temperature of 275 F. This chart is a striking example of what occurs when the mixture is rolled at too cold a temperature and largely accounts for the difficulties in fall paving in northern climates. There is only a slight reduction of voids at temperatures of 300 F and 350 F. However, at 200 F the voids have doubled and at 150 F they have increased four times, while at 125 F the voids have increased over six times the value obtained at 275 F. This shows that the danger of cold weather construction lies in the ability to accomplish a maximum amount of compaction before the temperature of the mix has reached 225 F.

Figure 4 shows similar results for the binder mix. Although there is a similar increase in void content when compacted at various temperatures the results are not nearly as critical as with the finer surface mixture.

Marshall Stability

Figure 5 shows the relationship of the stability value from mixtures compacted at various temperatures. These mixtures were all tested at the standard temperature of 140 F. The results, as in other cases, are based on a 100 percent value with a compaction temperature of 275 F. This experiment indicated that the stability of the mixtures would be increased about 20 percent if the compaction temperature was above 300 F. This would, of course, be related to the viscosity of the asphalt which in this case was an 85 to 100 penetration grade. The stability falls rapidly when the compaction temperature goes below 250 F. At 150 F less than 20 percent of the value at 275 F was obtained.

Figure 6 shows similar results for the binder mix and there is a remarkable similarity between the results obtained by the Marshall Method on both the binder and surface mixtures.

Hveem Stabilometer Values

Figure 7 shows the relationship of the Hveem Stabilometer values on mixtures compacted by the Marshall Method at various compaction temperatures and tested at the standard temperature of 140 F in accordance with the standard Hveem stability test. This chart indicates that with this method of compaction the

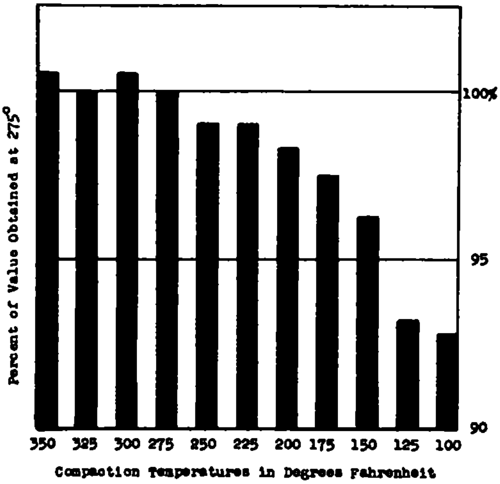


Figure 1. Bituminous concrete wearing course specific gravity. Effect of Marshall compaction at various temperatures.

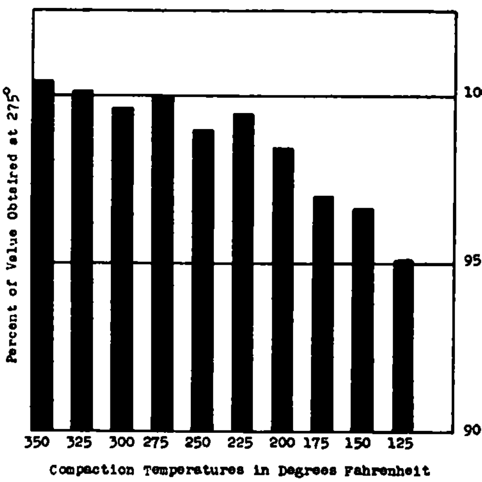


Figure 2. Bituminous concrete binder course specific gravity. Effect of Marshall compaction at various temperatures.

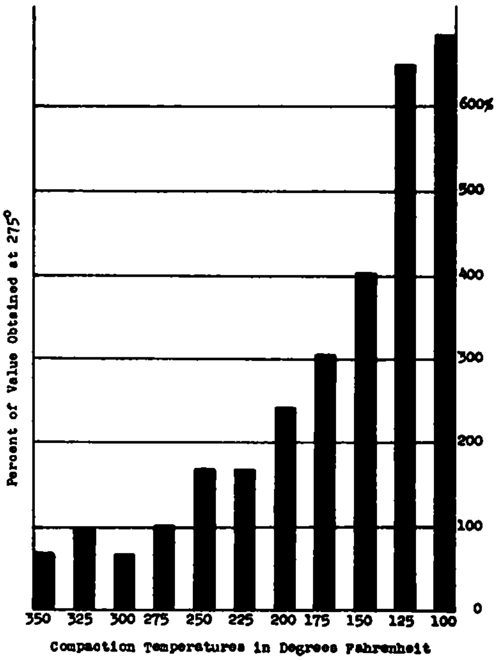


Figure 3. Bituminous concrete wearing course percent voids. Effect of Marshall compaction at various temperatures.

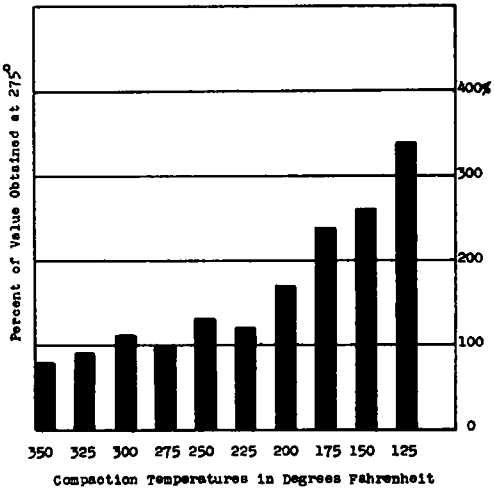


Figure 4. Bituminous concrete binder course percent voids. Effect of Marshall compaction at various temperatures.

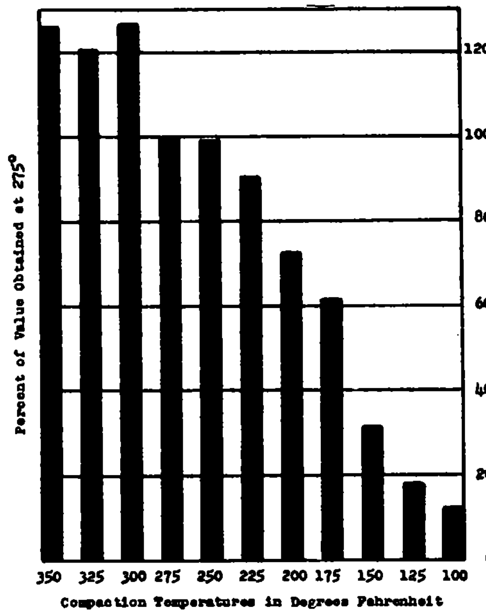


Figure 5. Bituminous concrete wearing course Marshall stability. Effect of Marshall compaction at various temperatures.

compaction temperature is not as critical as with the Marshall stability values. An increase in stabilometer values was obtained at lower temperatures than 275 F and a fast drop off occurred below 225 F.

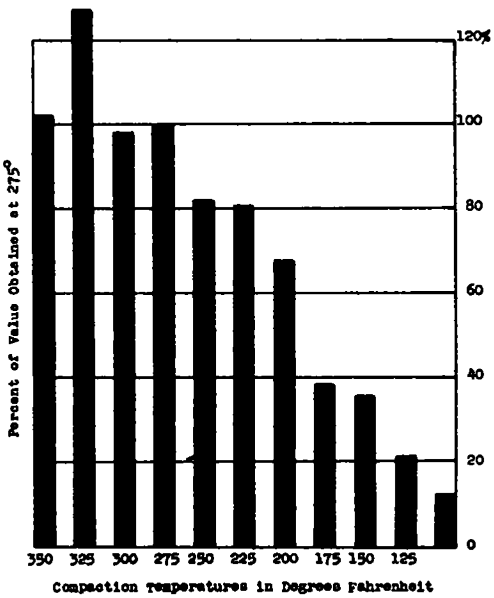


Figure 6. Bituminous concrete binder course Marshall stability. Effect of Marshall compaction at various temperatures.

Figure 8 shows a similar study with the Hveem Stabilometer for the binder mixture. The characteristics of the curve with the binder mixture are radically different from those obtained with the finer wearing course mixture. The maximum result was obtained at 350 F and there was nearly a straightline relationship in the drop from the maximum temperature to the low temperature of 125 F.

General

All of these tests indicated the importance of compaction at high temperatures. A practical example of results that were obtained under actual pavement construction when compaction was at a low temperature is shown in Figure 9. This pavement was constructed in the fall during cold temperatures and the resulting density was very low. Extractions showed that the mix was well within tolerance limits. However, due to the low density and late fall construction which did not permit any further compaction by traffic, this raveling occurred during the winter months. Cores taken the following year also showed the same low densities.

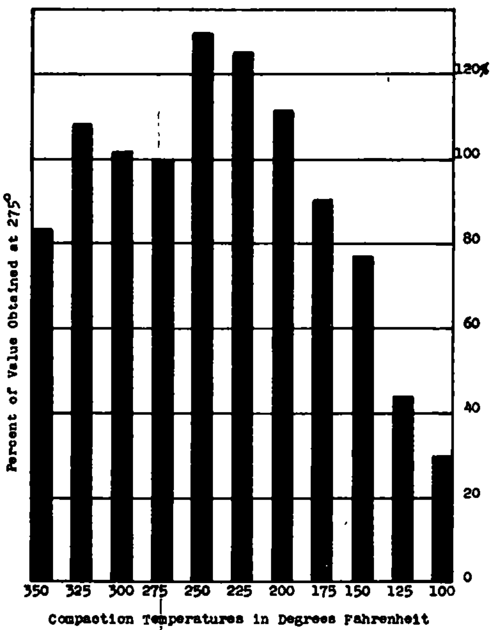


Figure 7. Bituminous concrete wearing course Hveem stabilometer values. Effect of Marshall compaction at various temperatures.

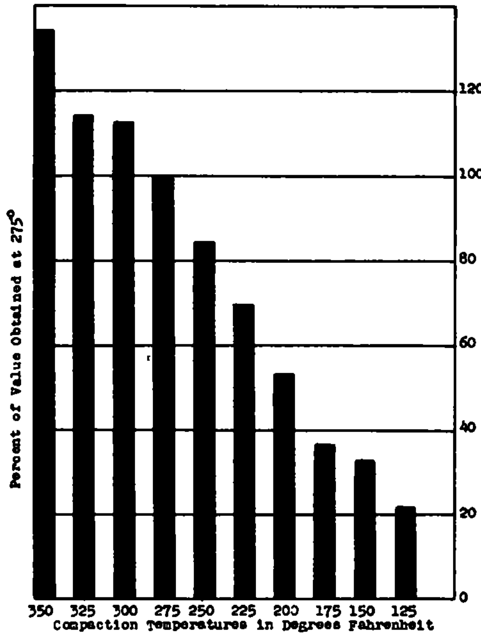


Figure 8. Bituminous concrete binder course Hveem stabilometer values. Effect of Marshall compaction at various temperatures.

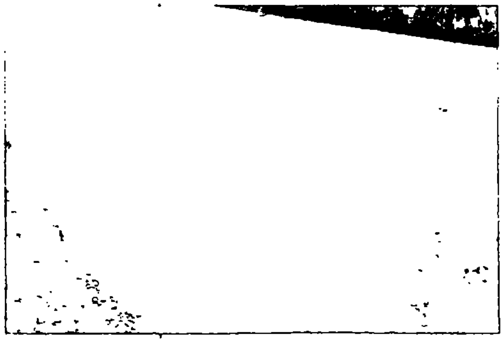


Figure 9.

Compaction

The author has long advocated the use of large diameter rolls on steel tired rollers. With an increase in the diameter of the rolls there would be less horizontal thrust and this would permit compaction at higher temperatures without lateral displacement of the bituminous concrete mixture. Many cases have been observed in which there was a lack of stability in the gravel base courses due to the use of a granular non-plastic material and in such cases many difficulties were encountered in placing the binder course directly on the gravel base course. It has been observed many times that this binder course has been permitted to lose a high percent of its mixing temperature in order that rolling could be accomplished without lateral displacement. By increasthe diameter of the steel tired rollers, even when such unstable conditions did exist, rolling could be accomplished at a much higher temperature without any lateral displacement.

Several years ago the Buffalo-Springfield Roller Co. conducted an experiment

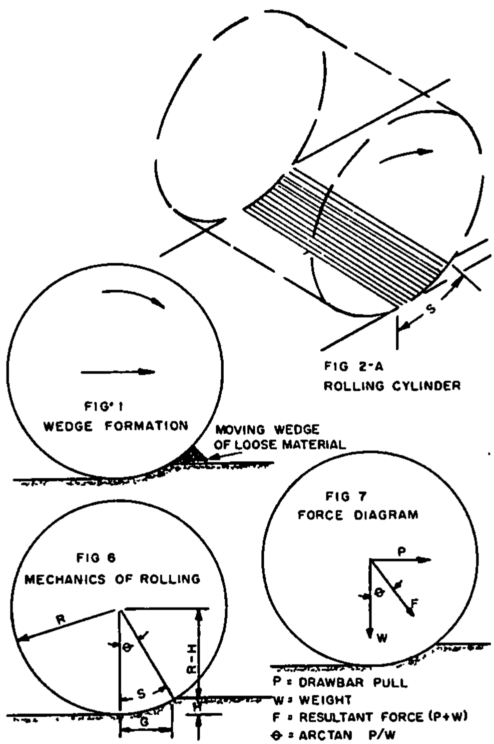
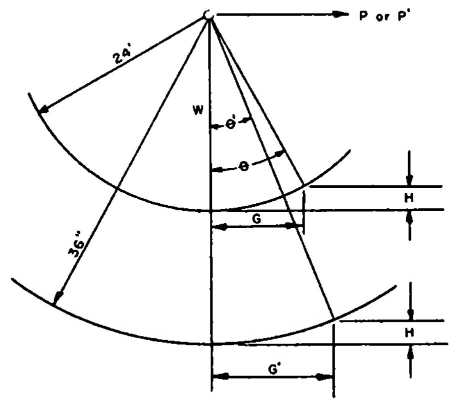


Figure 10.



P = Draw Bar Pull
W = Weight
U = Coef. of Rolling Friction
R = Radius

$P = UW$

$P = \frac{W.G}{R-H}$

$\therefore UW = \frac{W.G}{R-H}$

$U = \frac{G}{R-H}$

$U = \tan \theta$

Assume

H = 3"
H' = 3"
G = 12
G' = 13
W = 1000#

24" RP = $\frac{1000 \times 12}{24 - 3} = \frac{12000}{21}$

36" RP = $\frac{1000 \times 13}{36 - 3} = \frac{13000}{33}$

P = 571#

P = 394#

Figure 11. Mathematical analysis of rolling.

on drawbar pull. In this experiment a roll of 46-in. diameter and weight of 3, 280 lb was used in conjunction with a hydraulic dynamometer to determine the coefficients of various materials. The coefficients obtained were in accordance with the following:

Weight = 3, 280 lb

By Experiment, Using Hydraulic Dynamometer, 46-in. Dia. Roll	Coeff.
Bituminous concrete, compacted	0. 27
Oiled clay, compacted	0. 46
Sandy clay, loose surface	0. 30
Untreated macadam	0. 27

Using these coefficients the drawbar pull was computed theoretically for 53- 60- and 72-in. diameters. A mathematical analysis of this computation is shown in Figures 10 and 11.

Figure 12 shows the relationship of the drawbar pull to the diameter of the rolls for various types of materials. With all

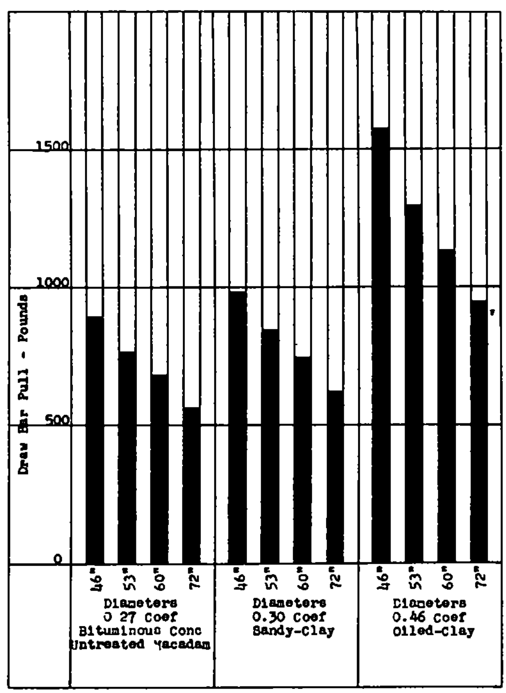


Figure 12. Draw bar pull—various diameters and conditions.

of the materials there is a rapid drop in drawbar pull with slight increases in the diameter of the rolls. This is what largely accounts for the ability to roll bituminous mixtures at higher temperatures when there is an increase in the diameter of the rolls. If these diameters were increased there would be a necessary increase in the weight of the rollers which would have to be compensated for by increasing the width of the roll. This would also be a distinct advantage as it would increase the capacity of the roller in terms of square yards rolled per unit of time. This increase in the rate of rolling would in turn be reflected in the ability to roll at higher temperatures as the rolling procedure could be completed in a much shorter interval of time. This is illustrated by Figure 13 in which the percent of value obtained with a 6-in. lap as compared with the result obtained when the lap is reduced to ⅓ W and ½ W for both a 54-in. width roll and a 60-in. width roll. This chart indicates that it is entirely possible that if the diameter of the rolls were increased and the width also increased within reasonable limitations, the rolling capacity in square yards per hour would be greatly increased for the larger type roller, resulting in initial compaction at higher temperatures and a much faster rate.

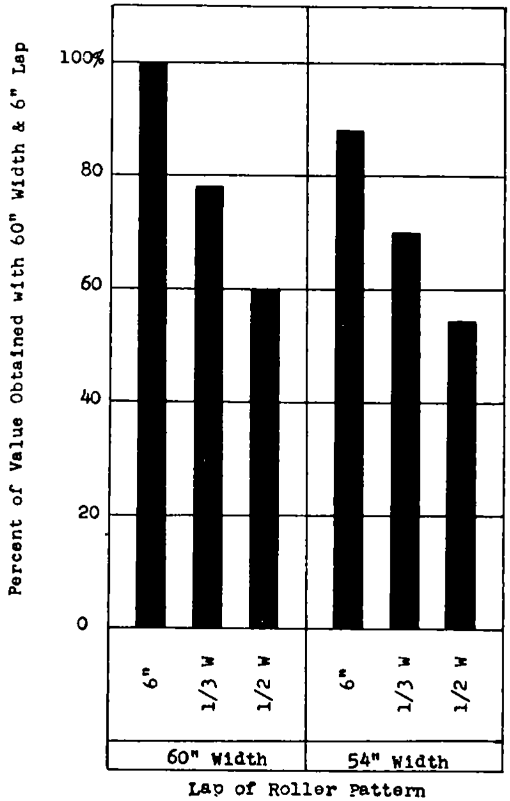


Figure 13. Percent square yards rolled per hour two coverages.

Conclusion

Not enough attention has been given to the compaction temperatures. It is believed that a much more practical limitation on the construction season in northern climates would be to specify rolling temperatures together with seasonal limitations than by merely limiting the paving season to calendar dates.