Effects of Aggregate Temperature on Properties of Bituminous Mixtures

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●THIS SUBJECT might be disposed of simply by stating that the temperature of the aggregate controls the temperature of the mixture. Actually, on a pound-for-pound basis the asphalt at 300F will have a somewhat greater heat content than the aggregate. The specific heat of asphalt is about 0.5, and for aggregates about 0.2—that is, 0.2 calories per gram per degree Centigrade or Btu per pound per degree Fahrenheit. However, the mass of the aggregate will be from 10 to 25 times that of the asphalt, so the aggregate temperature will control the temperature of the mix.

For hot mixtures, the critical temperatures are those required for mixing and for compaction. The proper temperatures and effects of improper temperatures will be discussed by others at this conference.

One aspect that should be mentioned, however, is the effect of mixing temperature on asphalt absorption. For absorptive aggregates, the higher the temperature, the greater will be the amount of asphalt absorbed by the aggregate. This is due to the decrease in viscosity of the asphalt with increase in temperature. Due to variations in asphalt absorbed, a too high temperature may result in a mix with a lean appearance, whereas a too low temperature may give an overly rich appearance. Also, in cold weather is it usually necessary to raise the mixing temperature in order to maintain the proper compaction temperature. To offset the increased absorption, it may be desirable to increase the asphalt content. Thus, there can be interaction between temperature and required asphalt content.

Wet Aggregates

All aggregates, whether absorptive or not, will contain some moisture while stockpiled, depending on humidity, wind, and time since the last rain. The moisture content is important, as the heat required to raise water from ambient temperatures to 300F is 25 to 30 times as great as that required to raise the temperature of the aggregate the same amount. Variations in moisture content during production may result in variable aggregate temperatures.

The foregoing values are based on the assumption that the moisture is present as free water. Thelen[1] has discussed the adsorbed layers of water on quartz. He stated that to remove all of the water from quartz requires temperatures above 1000C; that is above 1800F. Temperatures in the vicinity of the flame may be higher than 1800F and may remove all of the adsorbed surface water. This could account for certain discrepancies that have been observed in the study of the water resistance of aggregates. One case is recalled where an oven-dried laboratory sample of quartzite showed a poor resistance to water, but a sample taken from the plant drier, kept dry and hot, showed much better stripping resistance.

Heating of the aggregate may have other incidental effects, such as calcination of the surfaces of limestone aggregates, the induration of dust coatings on wet aggregates, the baking of clay balls, and the deposition of soot on the aggregate.

Absorptive Aggregates

Aggregates which absorb and retain relatively large amounts of water have given trouble in hot mixes. The phenomenon is not too clearly understood, but the effects are quite evident, as follows:

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[1] Thelen, E., "Surface Energy and Adhesion Properties in Asphalt-Aggregate Systems." HRB Bull. 192, p. 63 (1958).

1. The mix slumps in the truck and appears rich and slick.
2. There may be foaming and flushing of the asphalt.
3. Water drains from the mix in the truck and in the paver.
4. Aggregate particles are stripped of asphalt.
5. Shoving occurs under the roller due to reduced adhesion and cohesion.
6. Segregation of the mix occurs, causing roughness and "fat" spots.

The phenomenon may possibly be explained as follows: A wet and absorptive aggregate particle, in passing through the drier, is first heated at the surface. The heat conductivity of aggregate is very low and during the two or three minutes that the aggregate is in the drier, the heat does not penetrate to the interior of the particle. Penetration of the heat continues in the hot elevator, screens, and bins. Eventually the moisture within the pore spaces of the particle is vaporized. This vaporization may force moisture farther into the particle, and steam will be evolved into the mass of the aggregate. This steam remains with the aggregate until it comes into contact with some colder medium. The hot mix is dumped in the truck and covered with a tarp. Moisture condenses on the sides of the truck and under the tarp; the steam within the mix migrates toward the cold surface and in so doing causes stripping of the aggregate, foaming, and flushing of the asphalt.

Another important aspect is that after leaving the drier the over-all temperature of the aggregate decreases, due to heat consumed in vaporizing pore water and other heat losses. As the temperature decreases, water condenses from the saturated vapor and may be adsorbed on the surface of aggregate particles. This moisture layer may retard or prevent thorough coating and adhesion of the asphalt.

There are several possible remedies to overcome these effects. The first is to apply more heat; however, this may not be effective in all cases. More rapid heating will create a steeper temperature gradient, which might actually accentuate the ill effects. A second alternative is to increase the drying time. This is very effective, but will reduce production unless tandem driers are used. A third solution, reported by Heacock,[2] is to use less heat. He cited a case where foaming of the asphalt was observed in the truck with a mix temperature of 285F, but when the temperature was reduced to 265F the foaming disappeared. Apparently, reducing the heat overcame the difficulty by leaving more moisture within the aggregate pores. A fourth solution is to increase the ventilation wherever possible.

To insure against trouble from water, specifications may require a maximum moisture content of the heated aggregate. Michigan uses a limiting value of 0.05 percent; the Corps of Engineers specifies 0.15 percent for aggregates with absorptions of 2.5 percent or less, and 0.25 percent for absorptions greater than 2.5 percent. Such restrictions have been criticized by Nevitt,[3] who believes that it is extremely uneconomical to require very low moisture levels, and that the best solution is to merely heat the aggregate sufficiently to dry surfaces and to give good mixing.

There is no question that the temperature of the aggregate is an important factor in bituminous mixtures. However, it would appear that further research is needed to develop more information on the effects of moisture and the moisture levels that are permissible with different types of aggregates.

Discussion

W.H. CAMPEN, Owner, Omaha Testing Laboratories, Omaha, Nebraska — In discussing the effects of aggregate absorption during the mixing of bituminous paving mixtures, Mr. Rice suggested that low temperatures be used in order to minimize the absorption of asphaltic cement. This suggestion is a dangerous one. Experience has shown that absorptive aggregates continue to absorb asphalt after the mixtures have been prepared and laid. The process has the effect of drying up and embrittling the

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[2] Heacock, R., "Discussion of Plant Control of Bituminous Concrete." Proc. Assn. of Asphalt Paving Technologists, 23:330 (1954).
[3] Nevitt, H.G., "Drying." Roads and Streets, 101:1, 115 (Jan. 1958).

mixtures, with consequent cracking and raveling. Instead of minimizing asphalt absorption during mixing, therefore, it would be better to thoroughly dry the aggregate before adding the asphalt and thereby accomplish most of the absorption during the mixing and laying operations.

It should be pointed out that highly absorptive aggregates are inherently dangerous. It is difficult to thoroughly dry them by normal dryers. It is difficult, also, to predict the ultimate asphalt absorption. Unless there is no alternative, aggregates having a water absorption of more than 2 percent should not be used.