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COMPACTION - THE ONLY WAY TO QUALITY ASPHALT PAVEMENTS

Background

Experienced engineers generally agree that compaction of asphalt concrete is one of the most critical factors affecting the performance of bituminous pavements. Asphalt mixes consist of asphalt cement, aggregates, and air voids. Good asphalt mixes contain carefully selected proportions of each of the three. MATES issues Nos. 2 and 4 contained discussions of how mix designs are used to determine proper materials in the right proportions. If good compaction is not achieved, however, diligent selection of materials and the best mix design will not result in a long lived pavement.

Definition

Compaction is the process whereby the asphalt-aggregate mixture is mechanically forced into a smaller volume causing: 1) air voids to be reduced, 2) aggregate particles to be reoriented and forced into close contact creating granular interlock and causing the particles to be strongly cemented together, and 3) increased density. Density itself is not the important engineering property but simply indicates when low air voids and intimate particle contact have been achieved with a particle mix.

Importance of Compaction

The late Ward Parr, vice-president of Chicago Testing Laboratories, reported that of all investigations of premature failure of asphalt pavements, more than 80 percent were due to poor compaction of mats placed during the late fall construction season. These findings have been confirmed by a number of other investigators. Common problems when asphalt pavements fail prematurely are stripping (loss of asphalt-to-aggregate bond due to moisture), raveling (disintegration of the asphalt matrix), rutting or shoving, and asphalt hardening leading to brittle fatigue failure. These problems can have a variety of causes but in most cases are a result of poor compaction. If there is insufficient compaction, air void content will be high and—of great importance—voids will be interconnected. With high air void content, both water and air can flow through the mat, each causing harm. Water can create hydrostatic pressures under traffic causing debonding of particles at or near a surface of mat and also can cause damage during freeze-thaw cycles. Both water and air intrusion rapidly increase the rate of oxidation of any asphalt mat causing the material to become brittle.

Asphalt concrete mixes are designed so that after proper compaction, sufficient air voids remain in the mat to allow a small amount of further densification under traffic. Voids also provide space for asphalt movement when the mat is kneaded by traffic loading and when the asphalt cement expands due to temperature changes. Insufficient voids result in overfilling with asphalt causing flushing of the binder to the surface and loss of pavement stability as aggregate particles are forced apart. Thus, a good mat should have some air voids but not too many.

What Affects Compaction?

The ease of compaction is affected by both the materials used and construction practices.

Aggregates - Aggregates influence compaction through both shape and surface texture. Angular particles are more difficult to compact than rounded ones. Particles with harsh surface texture are more difficult to compact than smooth ones and block-shaped particles are more difficult to compact than those that are plate-shaped. However, those particles having shapes or textures that cause difficulty in compaction are the same ones that give high stability. For example, aggregate consisting of marbles would provide a mix that would be easy to compact but would have low stability.

In addition to particle shape and texture, gradation also influences ease of compaction. Mixes with high proportions of coarse particles are difficult to compact. With other factors being equal, a mix that is graded uniformly from large through small size aggregate will be easiest to compact. Don't be fooled by the easy workability of a finely graded or oversanded mix. Although easily worked, they will tend to shove under a roller and will be difficult to compact. Such mixes are said to be 'tender.' Mixes with excessive material near the size of the No. 30 sieve are often tender.

Particle strength and absorbency also affect compaction. Weak particles will crush under rolling creating uncemented faces that decrease the tensile strength of the mat and provide open surfaces for water penetration. Absorbent aggregates can increase particle-to-particle friction by soaking up hot asphalt cement that otherwise would act as a lubricant during compaction.

Asphalt Cement - The grade (based on penetration or viscosity) of asphalt cement influences the viscosity of the hot binder in a mat. Binder is a mixture of asphalt cement and dust (aggregate particles passing the No. 200 sieve). Mixes with low viscosity binders will compact easier of course. If compacted while hot enough, however, any grade of asphalt used by MDOT should have a viscosity low enough to act as a lubricant. High asphalt film thicknesses make compaction easier. However, as discussed above, excessive asphalt will fill all the voids and begin forcing particles apart, creating an easily worked but unstable mix.

Construction Practices - The hot asphalt binder provides a lubricant for compacting the aggregates. When the binder cools below about 185 F, however, it prevents the particles from being pulled apart—a desirable characteristic for the finished roadway—but also prevents particle movement and thus stops further compaction. Further rolling, instead of compacting, tends to fracture aggregate causing more problems. Thus, although rolling should begin at a much higher temperature, it is essential that compaction of a conventional asphalt mix be completed while its temperature is above 185 F. Asphalt mixes incorporating certain additives such as latex must be compacted at higher temperatures, depending upon the type and quantity of the additive. A steel wheeled roller should not even be allowed to try to compact a mat whose temperature is below 175 F. Temperature of the mix during compaction is a function of: 1) how hot the material comes out of the plant, 2) how much cooling takes place during transportation, 3) layer or lift thickness (thicker lifts hold heat longer), 4) weather conditions (air temperature and wind), 5) temperature of the surface on which the mix is being placed.

Figure 1 shows the relationship between mat thickness, base and air temperature, and time before the material cools to 185 F, when further compaction cannot be accomplished. Mix temperature is that measured behind the paver

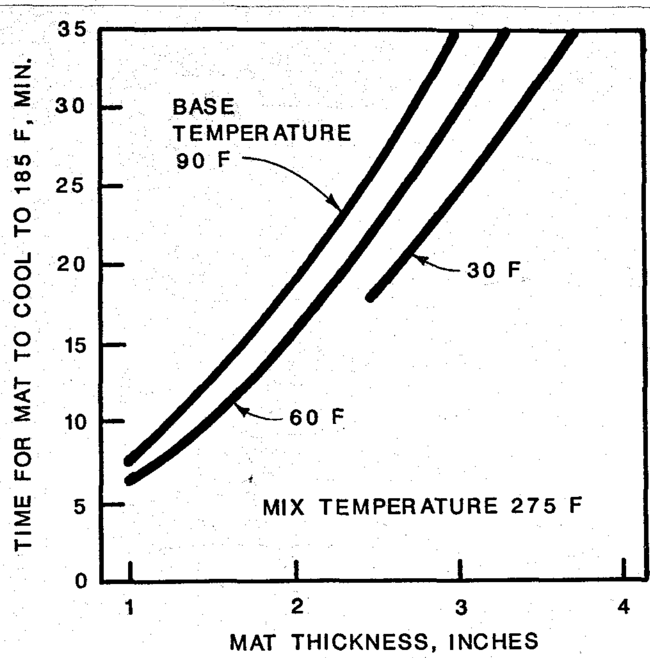

Figure 1. Time for mat to cool to 185 F. (Wind velocity 12 mph, ambient temp. same as base).

at a depth of 1/4 to 1/2 in. below the surface. Notice how rapidly the material cools as mat thickness decreases. For example, at 60 F base and air temperature, a mat 3 in. thick will cool to 185 F in about 30 minutes. A mat 1-1/2 in. thick will cool in only about 10 minutes. This illustrates the importance of early rolling of thin lifts; MDOT often uses lifts less than 1-1/2 in

Rolling - The three types of self-propelled rollers currently used are: 1) steel wheeled static, 2) steel wheeled vibratory, and 3) pneumatic rubber tired. These types will be discussed in detail in a later article, together with rolling patterns. For now, it will only be said that each type does its job by applying pressure over a contact area. As the material is forced into a smaller volume and mix temperature drops, the resistance to further movement increases preventing the roller from penetrating into the mat. Figure 2 shows how this occurrence reduces the roller-to-mat contact area thereby increasing unit contact pressure. Usually, as shown in Figure 3, the largest amount of compaction takes place during the first pass and then rapidly diminishes with subsequent passes. Figure 3 shows a typical compaction curve for conventional rollers. Vibratory rollers should compact much more rapidly.

Overcompaction

Although *overcompaction is a common worry*, it is seldom a real problem. Overcompaction occurs when a mix is reduced in volume to a point where air void content is lower than the design value. MDOT designs for about 3 percent air voids on interstate highways and usually the best compaction efforts during construction can reduce the mix to about 5 percent air voids. Traffic, over a period

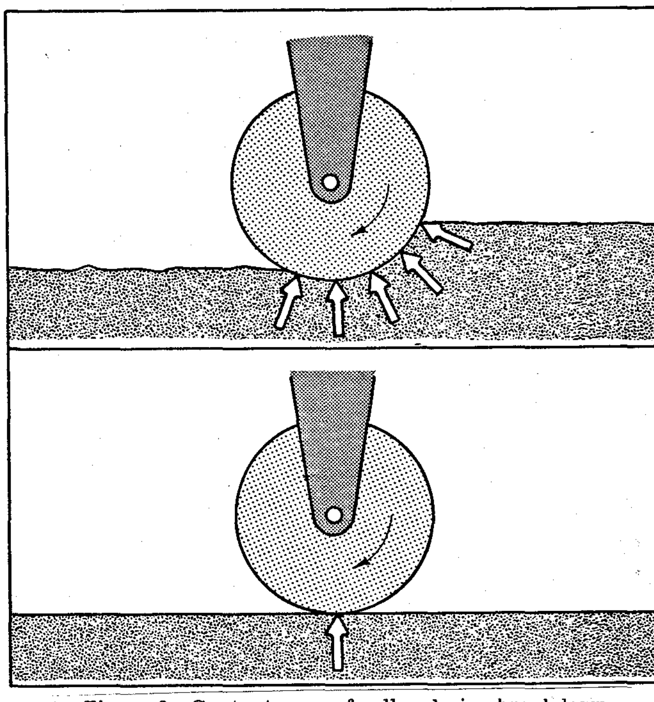

Figure 2. Contact area of roller during breakdown rolling (above) and after mat is compacted (below).

of years, provides the additional compaction to achieve design air void percentage.

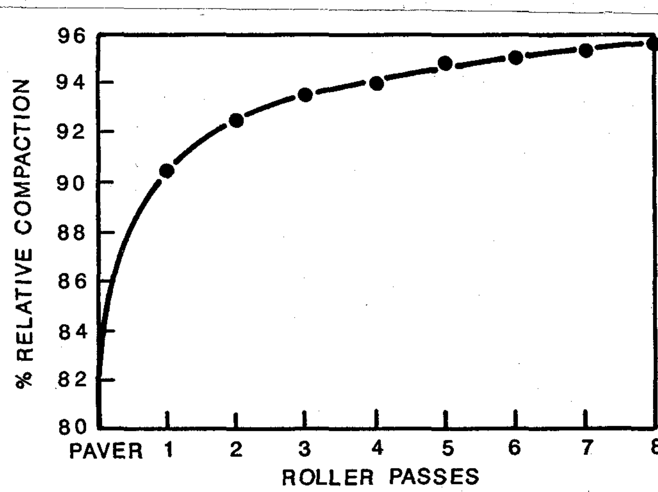

Figure 3. Typical compaction under conventional rolling.

Crushing of aggregate, perceived by some to be overcompaction, is really caused by poor practices. Aggregate crushing can be caused by: 1) using aggregate that is too large with respect to lift thickness, 2) using aggregate with low strength, 3) improper use of a vibratory roller, and 4) using a steel wheeled roller on a mat that is too cold to be compacted. When mat temperature falls below 175 F, steel wheel rolling for compaction should cease. In general, overcompaction should be of very little concern, while poor compaction is of major concern. Adequate attention to this single detail can add several years to the service lives of many pavements.

-Fred Copple

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