MATES

MICHIGAN DEPARTMENT OF TRANSPORTATION

Issue No. 29 March 1989

PREMATURE RUTTING CAN BE PREVENTED

At the fall 1988 Materials and Technology - District Field Engineers meeting, repeated concern was expressed about rutting in recently built asphalt pavements. Without looking at each of the rutted projects in detail, certain general causes can be inferred: a) last summer contained long periods of record hot days causing asphalt roads to soften more than in the past, b) there were more than the usual number of construction projects and if a certain percentage are expected to rut, the total numbers of rutted projects would be higher, and c) because of the large number of projects, both MDOT and contractor personnel were pushed to complete them even when weather conditions made it extremely difficult to achieve high quality. This article discusses the causes of rutting and illustrates how care in design, selecting proper materials, and careful construction can reduce or prevent it.

Highway engineers are well aware of the increase in numbers of heavy trucks carrying heavier loads and some know that tire pressures, hence unit pressures on pavements, have increased significantly. A few years ago, tire pressures of 75 psi were considered reasonable for design, but recent surveys showed tire pressures in Texas averaging 110 psi with a maximum of 155 psi and in Illinois averaging 96 psi with a 130 psi maximum. This factor alone can significantly increase the rate of rutting of asphalt roadways.

Causes

Rutting is caused by the progressive movement of materials under repeated loads, either in the pavement layers or in the underlaying base. Since many of our problems today are primarily due to movement in the asphalt layers, base movement will not be discussed in this article. The largest proportion of asphalt construction by MDOT is the overlaying of old surfaces. Progressive movement of asphalt pavement layers is usually the cause of rutting in overlays. The following discussion will cover how movement of asphalt layers can occur through either consolidation or plastic flow.

Consolidation

Consolidation is the compression of a given quantity of materials into a smaller volume. Here, consolidation means further compaction of asphalt mix by traffic after construction. MDOT asphalt mixtures are designed so pavements will ultimately have 3 percent total air voids in the surface layer. Under usual conditions, however, construction rolling achieves no less than 5 to 6 percent air voids; the repeated kneading action due to traffic gradually completes compaction during the next two to three years. Since traffic is channeled into wheelpaths, a small amount of rutting is almost inevitable since compaction by traffic is not uniform across the surface. When compaction is poor, sometimes leaving 10 to 12 percent air voids, channelized traffic completes consolidation to 3 percent air voids as designed, leaving ruts of about 3/8 in. depth in an overlay of 4-in. thickness. Poor compaction during construction is usually due to rolling a mat that has cooled below 185 F and commonly occurs when paving in cold weather, especially in thin lifts, or in rain that cools the mixture before rolling. AASHTO specifications recommend that wearing courses less than 1-1/2 in. thick not be placed unless the temperature of the underlying surface is at least 60 F. It can also happen when rollers get too far behind the paver, not having enough rollers to keep pace with the paving operations or using the wrong rollers, or placing material that is not hot enough when delivered.

Excessive consolidation by traffic can also result if a mix design is not done properly. Lab preparation of samples for a mix design attempts to duplicate the consolidation of construction rolling and further compaction by traffic. A standard compactive effort is used in the laboratory under carefully controlled conditions. However, this sometimes underestimates or overestimates field consolidation. A lab can underestimate field consolidation if:

a) Traffic loading is more severe than indicated by past experience. This increased severity can be due to more heavy load repetitions, heavier loads than in the past, or higher tire pressures.

b) Traffic is allowed on a mat before it has cooled; this is a common cause of overconsolidation and can cause both severe rutting and flushing. Traffic should not be allowed on a mat until the temperature of the surface is below 150 F. If a roadway must be promptly opened to traffic on a hot day, the compacted mat may be cooled using sprinkled water. Water, however, will cool the surface before the interior of the mat so surface temperature should be well below 150 F before allowing traffic.

Paving over existing ruts also leads to rutting through excessive consolidation by traffic since rollers cannot adequately compact the thicker layer of material in the existing ruts.

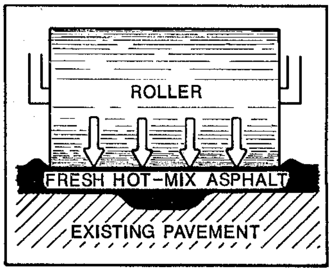

Figure 1

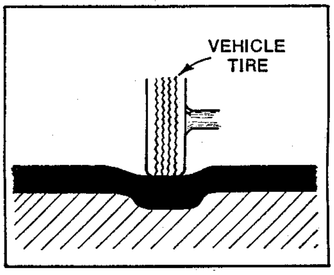

Figure 2

Figure 1 shows how a roller bridges an existing rut during construction leaving poorly compacted mixture in the old ruts. Figure 2 shows how traffic completes compaction of the mixture leaving a rut in the new mat.

Plastic Flow

Deep ruts can also result from lateral plastic flow of the mixture from the wheel tracks. One of the most common causes of severe plastic flow is the use of excessive asphalt cement. Asphalt technologists try to get as much asphalt cement into a mixture as possible (for thick coating giving high durability), but not too much. If too much asphalt cement is put into a mixture, friction between the aggregate particles is reduced or lost and loads are resisted only by the asphalt cement. The asphalt cement then flows under repeated load stresses causing permanent deformation. In general, when air voids in the mat are filled to less than 2 percent, flushing and rutting may result.

On the other hand, mats with asphalt cement content that is much lower than design optimum will be stiff and thus be rut and flush resistant but will be prone to raveling and cracking. Asphalt mix design is a balancing act between long durability and high stability — if we overemphasize one, we sacrifice the other. That is why field changes in asphalt mixtures should always be discussed with bituminous laboratory personnel.

Asphalt mixtures, because of their asphalt cement binder, have stress-strain or load-deflection relationships that are dependent upon time and temperature. That is, if a load is applied to an asphalt pavement, it will cause a strain or deflection that continues to grow if the load is allowed to remain for a longer period of time. The strain or deflection also is greater at higher temperature. Further, recovery from the strain is also time and temperature-dependent. Strains in asphalt may include both an elastic or recoverable component and a plastic flow component. If plastic flow takes place, (the type of non-recoverable strain that occurs in putty), the material will not return to its original dimensions. Stresses applied over a longer period of time or at higher temperature cause a greater non-recoverable strain. That is why areas of slow moving or parked vehicles show greater rutting than do roadways where traffic flows freely. Loads are applied for longer periods of time causing higher strains that do not allow complete elastic recovery.

A typical paving grade asphalt cement can change from a viscous liquid to a brittle solid within the range of temperatures commonly experienced by Michigan pavements. These changes in physical properties must be expected and dealt with and are not experienced by any other road construction material. Because asphalt shows this degree of temperature sensitivity, the problems in flushing and rutting experienced during the past record-hot summer become more understandable.

Plastic flow also increases with numbers of wheel load applications. As mentioned earlier, certain strains are not completely recoverable after unloading and leave permanent deformations. Such deformations may be very small for one load but they accumulate and, after many load applications, leave ruts. If a mat is well constructed, such ruts will not be deep enough to be noticeable. Sometimes, ruts become noticeable only after several years. Sometimes, as in this past summer, ruts suddenly become apparent because record hot temperatures softened the asphalt leading to increased load strains and in particular increased non-recoverable strains.

Plastic flow or permanent deformation is also affected by the sizes, shapes, and textures of the aggregates in a bituminous mixture. The intent with good asphalt mixtures is to maximize the shear strength of the mixture without making it too harsh to compact. Just as a human body uses a skeleton to bear loads, a good asphalt pavement uses stone and sand. First, the largest size aggregate consistent with good construction practices (about one-half the layer thickness) should be used. This reduces the amount of asphalt cement needed and provides a rugged skeleton. Second, angular blocky particles with rough textured surfaces should be used for all sizes of aggregate. Some particles, even when crushed, have smooth slippery surfaces and should not be used as a large proportion of the mix. Sand size particles have a major influence on stability and those with angular rather than rounded shapes should be used, as a significant part, in all mixtures. Although some natural sands are of angular shape and can provide high stability by preventing one particle from easily sliding across another, most are rounded and create unstable mixtures. Until a proven method of evaluating the angularity of natural sands is available, the conservative procedure is to use sands produced by crushing larger particles. The Federal Highway Administration recommends that natural sands be limited to 15 to 20 percent of the total weight of aggregates for high volume roads and 20 to 25 percent for medium and low volume roads. The remainder of the sand size particles are to consist of material produced by crushing.

Compaction

As discussed earlier, poor compaction during construction can lead to rutting because of further consolidation caused by the kneading action of traffic loads. An even more serious complication resulting from poor compaction is the plastic flow that can result due to the undesirable engineering properties (strength, stiffness, and elasticity) of a poorly compacted mixture. Such engineering properties as stiffness and internal friction are dramatically affected by poor compaction. Thus, because of the adverse effect on engineering properties, a poorly compacted mixture will not only consolidate further under traffic but may also show a shear failure manifested by rutted wheel paths with adjacent areas heaved up.

Binder

The binder gluing an asphalt concrete mixture together is a mastic of both asphalt cement and dust (material passing the No. 200 sieve). A certain amount of dust is necessary in the mix to provide stiffness and improve rut resistance. MDOT targets around 5 percent dust in most asphalt mixes. As with sand and stones in the mix, the character of the dust (gradation and shape) also plays a major role in affecting stiffness. Although sometimes given little attention, the quality and quantity of dust is about as important as the asphalt cement; too little and the mixture may lack stability, too much and the voids are overfilled causing flushing and leading to rutting.

The importance of controlling dust quantities at a plant cannot be overemphasized. Modern plants feed back into the mixture, dust collected by their pollution control systems. If this is not done uniformly, a road can exhibit rutting and flushing in some areas and apparent dryness in others. Also, if soft aggregates subject to breakdown during handling and mixing are used, excessive dust can be generated, again leading to rutting.

Asphalts range in grade from soft to hard, as measured at 77 F. It is only common sense that harder asphalts should provide more rut resistant pavements. Unfortunately, these harder asphalts are more prone to cracking during the cold winter time than softer ones. However, if well graded, high quality aggregates with sharp edges and good surface friction are used in a mix, the grade of asphalt cement plays a relatively small role in the rut resistance of a mixture. Thus, a soft, crack resistant asphalt can be used and still provide high rut resistance. Again, the engineer must perform a balancing act in doing a mix design. Of course, it is preferable to develop high stability through the use of well selected aggregates than through harder asphalt cements that may crack during the winter.

Summary

This has been a description of the causes of asphalt pavement rutting. Now, what can be done to minimize rutting problems? Designers must always consider the balance of adequate stability versus winter cracking by calling for the proper mix stability and grade of asphalt for each job and by requiring milling of rutted surfaces before overlayment.

The laboratory must carefully design the mix to ensure that the proper amount of asphalt is required and that only high quality materials are allowed.

Field engineering personnel must then ensure that the materials used in the mix are the same, and used in the same proportions, as in the mix design. Changes in proportioning should always be discussed with the laboratory. **Finally, and of extreme importance, ensure good compaction and don't open the road to traffic until the new surface has cooled to below 150 F.**

-Fred Copple

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