

TERM PAPER

Rutting of Asphalt Pavement

BY

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Introduction:

One of the main distresses of asphalt pavements is rutting. Rutting is characterized by permanent deformation of the pavement. It generally develops during the hot seasons, when the asphalt is softer. It can be identified by ruts on the wheel path. For improving the rutting performance of an asphalt road, selecting a good quality asphalt binder is a must. The current specifications for asphalt binders (SUPERPAVE specifications) have critical gaps. Binders are not ranked properly in terms of their contribution to rutting resistance or fatigue resistance. A new proposal for rutting and fatigue evaluation was presented in a project sponsored by the National Highway Research Program (NCHRP 9-10 project). Two new parameters were proposed for improving the characterization of rutting and fatigue performance of asphalt binders. The rutting parameter is called G_v (viscous component of the creep stiffness) and the fatigue one is called $N_{p_{50}}$ (number of cycles for achieving 50% damage of the asphalt).

While Hot Mix Asphalt (HMA) has continually proven to have superior life-cycle cost benefits, special attention, in some cases, should be focused on intersections to ensure the same outstanding performance. Some mixes that have a history of good performance in posted-speed applications may not perform well in intersections, climbing lanes, truck weigh stations and other slow-speed areas.

Slow moving or standing loads occurring at these sites subject the pavement to higher stress conditions, which may be enough to induce rutting and shoving. In addition, the increase in the number of trucks and heavier wheel loads can also play a significant role in the premature failure of some pavements.

Recognizing that some traditional mixes may not always be successful at meeting this challenge, the opportunity exists to implement a strategy for ensuring good performance at

slow-speed applications. Specifically, the pavement must be designed and constructed to withstand the more severe conditions.

The materials available today offer the designer many choices in attaining improved performance. Careful selection of the asphalt binder will go a long way toward providing desirable performance.

Recognizing that a more rutting-resistant binder is needed, the use of Superpave's Performance Graded (PG) asphalt binder system is highly recommended. The advantage of using this system is that the binder is characterized based on its ability to perform in the climate in which it will serve.

The AASHTO, Joint Task Force on Rutting (۱۹۸۷) identified four types of rutting:

۱. Mechanical Deformation is the result of insufficient structural capacity. Alligator cracking usually accompanies it.
۲. Plastic Flow can result for various reasons:
 - High pavement temperatures
 - Materials and mixture design (rounded aggregate, too much binder and/or filler, insufficient VMA)
 - Asphalt production
۳. Consolidation in the wheel paths occurs because of insufficient compaction of the pavement. A number of factors can contribute to lack of compaction:
 - Too few roller passes
 - Material cooling prior to achieving target density
 - High fluid content (asphalt, moisture, dust) contributes to tender mixes

- ❧. Surface Wear is a result of loss of surface aggregate. Moisture damage or raveling will also occur if proper drainage is not obtained.

A visual check for rutting can be made by placing a straight-edge across the wheel path area. Ruts can cause problems with the directional control of aircraft which can become very critical should water accumulate in the ruts during rainstorms and lead hydroplaning problems.



◀ Severe rutting over 2" caused by poor mix design.



◀ Severe rutting caused by poor base or subgrade.

Types of Pavement Rutting

Rutting throughout the entire asphalt pavement structure is caused by overstressing the underlying base or subgrade layers. This overstressed condition can be the result of inadequate thickness design for the applied traffic or for the strength properties of the underlying materials. Moisture infiltration into the base or subgrade can also weaken these layers to the point that they deform permanently under repeated traffic. The rutted condition in the underlying layers is then reflected to the pavement surface, as shown in Figure ١.

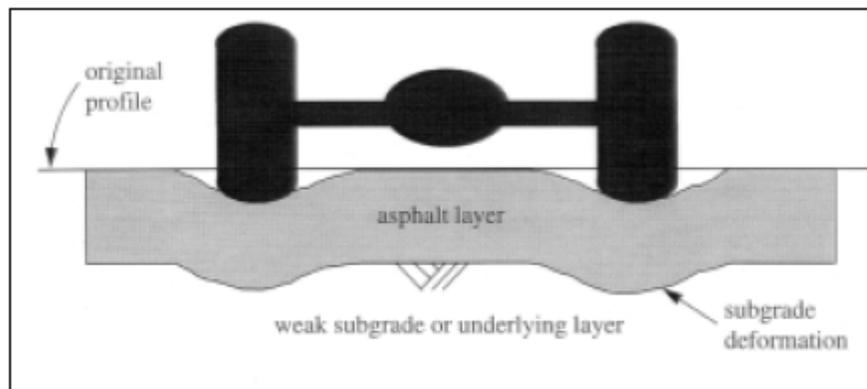


FIGURE 1:
Rutting in Subgrade or Base

A more common form of pavement rutting occurs in the asphalt mix itself. Here the underlying layers perform fine and their boundary lines are unaffected by the distress occurring near the surface of the asphalt pavement, as shown in Figure ٢. Rutting, in this instance, can be the result of an unstable asphalt mix, heavy vehicle traffic, and/or high pavement temperatures. Rutting of this type is often observed at intersections, bus stops, freeway off ramps, or under extreme loading situations on airport runways and dock loading facilities.

How can an engineer determine whether rutting in the asphalt pavement surface is due to distress throughout the entire pavement structure or due to failure in the asphalt layer only? A closer examination of Figures 1 and 2 shows that, in pavement structure rutting, the profile at the pavement surface is depressed fairly uniformly in the wheel paths of the pavement lane. Rutting in the asphalt mix, however, is generally accompanied by mix displacement next to the wheel loaded areas. Where this distinction is not obvious, the engineer should cut some trench sections across the pavement lane and examine the boundary lines of the various layers to determine the source of rutting.

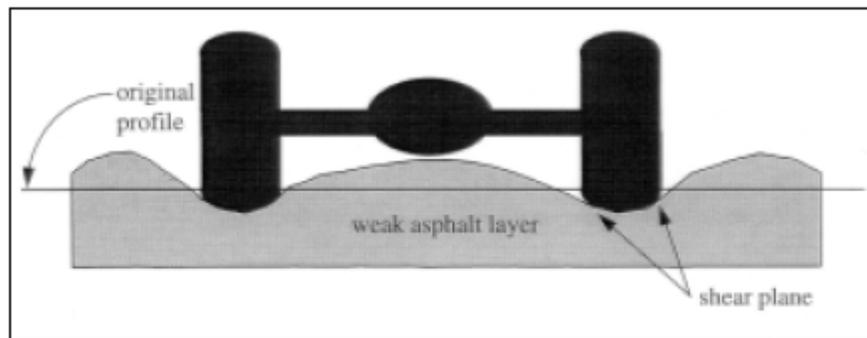


FIGURE 2:
Rutting in Asphalt Layer

Causes of Rutting

The three constituents of HMA are aggregate, binder, and air. All can have an effect on rutting of an HMA pavement. Aggregate makes up about 90 percent of a dense-graded HMA. The shape and texture of the aggregate can influence the performance of the mixture. In general, a rough-textured cubical-shaped aggregate performs better than a smooth, rounded aggregate. The rougher texture and cubical shape aid in providing aggregate

interlock. This aggregate interlock reduces the potential for rutting as movement of the aggregate under loading is reduced by the interlocking mechanism. The binder is also an important factor in rutting. At higher temperatures, the asphalt binder becomes less viscous. This lower viscosity produces a less stiff pavement that can be susceptible to lateral movement attributable to traffic loads. Compaction during construction is a vital part of producing a more durable pavement. The final constituent is air. If a mixture has a high air content, it can be susceptible to rutting in the sense that it will compact more under traffic loading. However, if the air content is too low, there is probably too much binder in the mixture. Too much binder produces a less stiff pavement and increases the probability of rutting.

Other factors that influence rutting in HMA pavements include truck speed, contact pressure, HMA layer thickness, and truck wheel wander. As truck speed is decreased on an HMA pavement, the stresses are increased because of longer pavement contact times. These higher stresses increase the probability of rutting. The contact pressure also influences the performance of the pavement. Higher tire pressure creates higher stresses in the pavement. A thicker HMA layer is better able to resist rutting in the sense that the layer is usually stiffer. Finally truck wheel wander can influence rutting. The increase in wheel wander can increase the amount and distance of lateral movement in the pavement. Excessive wheel wander has the potential to create wider and possibly deeper ruts in an HMA pavement.

Rutting can also manifest because of the poor pavement subgrade. Two of the causes of a weak subgrade are moisture and poor compaction during construction. A weakened subgrade is susceptible to higher stresses attributable to traffic loading; thus, there is an increased probability of rutting in the pavement.

Determining the Mode of Failure

Before attempting to correct these defects it is necessary to conduct an investigation to verify the type of deformation present. This investigation may be as simple as a visual inspection on small and relatively low cost projects, all the way up to an extensive program of sampling and testing. There are several methods that may be used.

Trenching is the most effective method to determine the cause of rutting. In this method, parallel, transverse, full-depth saw cuts are made across the pavement, and the intervening material is removed to expose the full cross-section of the pavement. It is then straightforward to identify the deforming pavement layers and determine the mode of failure. In the case of plastic deformation (Plastic Deformation is a material failure of the asphalt concrete. The mix is displaced from under the tires and typically humps up outside the wheel tracks) it is usually possible to identify which individual pavement layers are deforming. The correction of plastic deformation involves removing all of the asphalt material to a depth that includes the deformed layers, and replacing it with stable mix.

Where trenching is not feasible, it is usually possible to make the same determination from cores. In this method, cores are taken across the rutted lane at the points of maximum rut and at maximum heave and at relatively un-deformed areas for comparison of the layers. The surface of the cores should be referenced in elevation so that the deformation can be accurately plotted. By using the surface elevations of the cores, and measuring the visible layers in the cores, it is possible to graphically represent the cross-section of the pavement, determine the mode of failure and identify the deforming layers. An analytical method for determining the mode of failure was developed under the National Cooperative Highway Research program (NCHRP) project 1-34A (1) by researchers Thomas White and John Haddock at Purdue University. This method uses the numbers from a measured transverse-

surface profile to calculate coefficients that indicate the mode of failure. This method may be most useful where destructive methods of testing are not feasible.

TEST METHODS FOR RUTTING EVALUATION

Numerous test methods have been used in the past and are presently being used to characterize the permanent deformation (or Rutting) response of asphalt pavement materials.

These tests can generally be categorized as:

1. Fundamental Tests:

- 1) Uniaxial and triaxial tests: unconfined (uniaxial) and confined (triaxial) cylindrical Specimens in creep, repeated loading, and strength tests
- 2) Additional shear tests - shear loading tests:
 - (a) Superpave Shear Tester - Shear Dynamic Modulus
 - (b) Quasi-Direct Shear (Field Shear Test)
 - (c) Superpave Shear Tester - Repeated Shear at Constant Height
 - (d) Direct Shear Test
- 3) Diametral tests: cylindrical specimens in creep or repeated loading test, strength test

2. Empirical Tests

- 1) Marshall Test
- 2) Hveem Test
- 3) Corps of Engineering Gyrotory Testing Machine
- 4) Lateral Pressure Indicator

3. Simulative Tests

- 1) Asphalt Pavement Analyzer (new generation of Georgia Loaded Wheel Tester)
- 2) Hamburg Wheel-Tracking Device

- ϣ) French Rutting Tester (LCPC Wheel Tracker)
- ξ) Purdue University Laboratory Wheel Tracking Device
- Ϟ) Model Mobile Load Simulator
- ϧ) Dry Wheel Tracker (Wessex Engineering)
- Ϩ) Rotary Loaded Wheel Tester (Rutmeter)

Direct Shear Strength Test

The shear strength test was originally developed to determine the shear strength of bonded concrete. It has also been used to determine the shear strength of Hot Mix Asphalt. Molenaar, Heerkens, and Verhoeven have used the shear test to evaluate the shear resistance of several pavement structures. The schematic of the device is shown in Figure ϣ.

The shear strength of an HMA mixture is developed mainly from two sources: ϩ) the adhesion or bonding mechanism of the binder, which is referred to as cohesion, “c,” from Mohr-Coulomb plots, and Ϫ) the interlocking capability of the aggregate matrix from the applied loads, which is referred to as the angle of internal friction, “N.” The major role and interaction of both of these terms varies substantially with the rate of loading, temperature, and volumetric properties of the HMA mixture. Triaxial tests are run at different confining pressures to obtain the Mohr-Coulomb failure envelope. The Mohr Coulomb envelope is defined as $\tau = c + \sigma \tan \phi$.

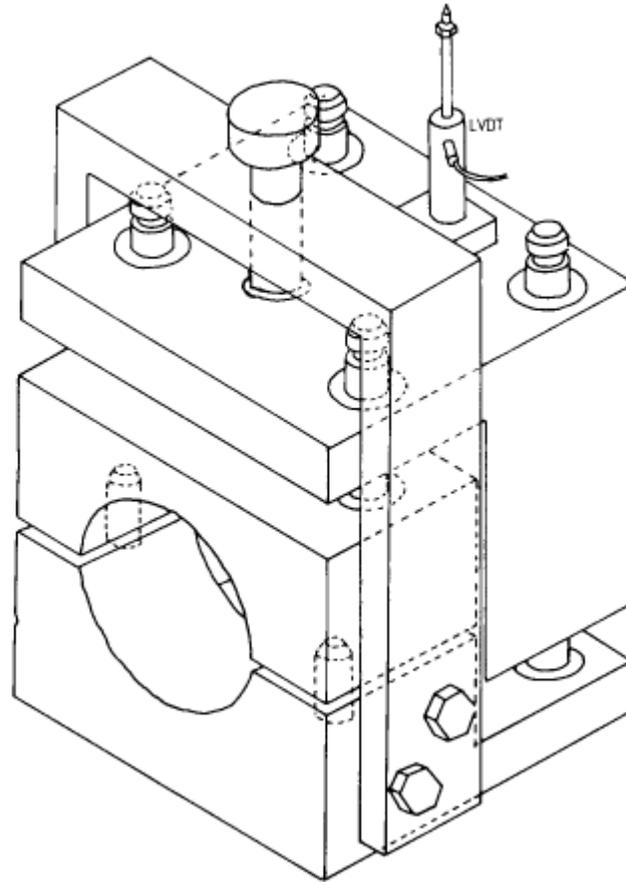
Where:

τ = shear stress

σ = normal stress

c = intercept parameter, cohesion

ϕ = slope of the failure envelope or the angle of internal friction

**FIGURE ۳:****Shear Device Schematic**

The direct shear strength test has been used to a much lesser extent than the dynamic modulus and repeated load test in evaluating an HMA mixture's susceptibility to permanent deformation. It appears that insufficient data is available to consider this test for use in predicting performance of HMA.

CONCLUSIONS

One of the main distresses of asphalt pavements is rutting. Rutting is characterized by permanent deformation of the pavement. Most rutting observed had occurred in the top layers of asphalt concrete. These layers often contained fine aggregate gradations and high asphalt contents.

The shape and texture of the aggregate can influence the performance of the mixture in general, the rougher texture and cubical shape aid in providing aggregate interlock. This aggregate interlock reduces the potential for rutting as movement of the aggregate under loading is reduced by the interlocking mechanism.

Asphalt mixes can be designed and constructed to carry today's traffic. Steps must be taken during mix design to ensure that the asphalt content is correctly selected for the mix being produced and that sufficient quality control tests be conducted to verify mix design and to provide data to make adjustments in mix proportions if needed.

The pavements evaluated which had rutted under traffic in most cases appeared to have rutted due to low air voids (in recompacted samples and/or in the field).

One of the best indicators of rutting is low air voids in the laboratory compacted asphalt mixture. Satisfactory laboratory compaction effort (providing density approximately equal to that under traffic) must be utilized when compacting these samples.

The GSI determined during compaction with the Gyratory Testing Machine was shown to be a good indicator of mixes that had rutted under traffic. Based on the results of several study's, a maximum GSI value of 1.1 is recommended when compacting samples with 1 degree angle, 120 psi, and 300 revolutions.

The Marshall flow appears to be a good indicator of rutting potential. A maximum flow of ١٦ is often specified for mix design and construction control and that appears to be a reasonable number. Mixes having flow values above ١٦ tended to have higher amounts of rutting.

Slow moving or standing loads occurring at those sites subject the pavement to higher stress conditions, which may be enough to induce rutting and shoving. In addition, the increase in the number of trucks and heavier wheel loads can also play a significant role in the premature failure of some pavements. Pavement engineers often do not consider the fact that these slow-moving load applications are much more severe. Consequently, there has not been a plan for addressing the situation.

The goal of the mix design process is to select and proportion appropriate materials that resist rutting. Mixtures meeting Superpave volumetric criteria, or stone mastic asphalt (SMA) mixtures, are good candidates to use at intersections because of their ability to resist rutting.

RECOMMENDATIONS

One of the biggest causes of rutting is excessive asphalt content in asphalt mixtures. Steps should be taken to insure proper asphalt content is selected and provided during mix production. Compactive effort should be selected to provide a density equal to that which will be obtained under traffic (7^o blow with manual hammer or Gyrotory Testing Machine have been shown to be sufficient). The asphalt content should be selected to provide a void content of 4-5 percent in laboratory compacted mixtures for high traffic volume roads. Asphalt content should not arbitrarily be increased to facilitate compaction, to minimize segregation, or for any other reason except to provide satisfactory voids in the laboratory compacted asphalt mixture. The maximum Marshall flow should be specified to be 16. If a Gyrotory Testing Machine is used the GSI should not exceed 1.1 when compacting samples with 1 degree angle, 120 psi, and 300 revolutions.

REFERENCES

- **Hot Mix Asphalt Materials, Mixture Design and Construction National Center for Asphalt Technology, Second Edition.**
- <http://www.techtransfer.berkeley.edu/techtopics/٢٠٠١techtopics.pdf>
- <http://www.eng.auburn.edu/center/ncat/reports/rep٠٤٠٠٤.pdf>
- http://www.txhotmix.org/public_articles.php?article_id=٤&
- http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_٥٠٨.pdf
- <http://www.techtransfer.berkeley.edu/techtopics/٢٠٠١techtopics.pdf>
- http://www.virginiadot.org/vtrc/main/online_reports/pdf/٠٧-r١١.pdf
- <http://www.uctc.net/papers/٤٥٣.pdf>
- <http://www.engr.wisc.edu/centers/wsmatl/WSMTL-WEB-pg٠٢P-NEWS-Delgadillo.htm>
- <http://www.onderzoekinformatie.nl/en/oi/nod/onderzoek/OND١٢٩٦٧٣٣/>
- http://٧٢.١٤.٢٠٩.١٠٤/search?q=cache:LemAMLvk_j٤J:https://www.securewebexchange.com/flexiblepavements.org/admin/assets/newsletters/newsletter_٢.pdf+what+is+rutting+asphalt&hl=en&ct=clnk&cd=١١&gl=us
- <http://www.hotmix.org/pavement.php>
- [http://www.ces.clemson.edu/arts/JMCE_Xiao%٢٠\(resived\)٤%٢٠\(Rut%٢٠Resistance%٢٠of%٢٠CRM%٢٠HMA%٢٠with%٢٠RAP\).pdf](http://www.ces.clemson.edu/arts/JMCE_Xiao%٢٠(resived)٤%٢٠(Rut%٢٠Resistance%٢٠of%٢٠CRM%٢٠HMA%٢٠with%٢٠RAP).pdf)
- <http://www.apao.org/rst.shtml>