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TOTAL ASPHALT VERSUS GRANULAR BASE

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INTRODUCTION

During 2001-2002 Minnesota Asphalt Pavement Association (MAPA) commissioned ERES Consultants to evaluate the performance history of pavements (ie. Full-depth, deep strength, aggregate base and pcc) on the Mn/DOT highway system.(1)

Full-depth pavements are performing well, under variable conditions of traffic, subgrade soil and environment, throughout Minnesota. FACT: Full-depth HMA pavements have service lives similar to HMA pavement using aggregate base.(1) FACT: HMA pavements have average service lives of approximately 18 years.(1) FACT: The data indicates that pavements constructed in recent years are performing better, showing the benefit of improved design and quality control techniques of Quality Management (QM)(1).

THE THEORY OF PAVEMENT DESIGN

When an asphalt pavement structure is loaded by traffic it bends. The heavier the load on a particular pavement, the more the structure will bend, or deflect. A pavement built on a weak subgrade soil (clay) will bend more under a given load than will the same pavement cross-section built on a good subgrade (sand and gravel). The more the pavement deflects, the greater will be the chance that it will crack under the applied load. Once a pavement begins to crack, due to fatigue, failure of the whole structure can follow.

In pavement design, there should be enough strength in the pavement structure so that the deflection of the Hot Mix Asphalt (HMA) under a given load can be controlled.(2) The tensile strain (bending) at the bottom of the asphalt layer should be limited. If the tensile **strain** produced by loading and deflecting the pavement under traffic can be kept to a value less than the tensile **strength** of the asphalt material, the asphalt material (HMA) can be kept from cracking. Thus, in simplified terms, in pavement design theory, a pavement structure must be built to a minimum structural capacity, yet sufficient to deflect only a slight amount when loaded by cars and especially trucks.

DEFLECTION OF ASPHALT BASES

Water and Deflection

When dry, a granular base course material is quite strong. A pavement structure consisting of HMA and an aggregate base will support traffic in a satisfactory manner as long as water can be kept out of the granular base material. Once the aggregate base becomes saturated, however, the water begins to act as a lubricant. When loaded, the wet granular materials start to move under an applied traffic [facility] load. The aggregate base will deflect much more when wet than when it is dry. This deflection, in turn, causes more bending in the overlying asphalt treated and/or HMA layers. The increase in bending of the asphalt allows the tensile strength at the bottom of the asphalt layer to exceed the tensile strength of the material – cracking will follow.

To keep a granular base course dry, it is normally recommended to provide sub-surface drainage, or under drains. For most typical Minnesota soils, which are clays and silt clays, water is attracted into the aggregate base materials by capillary action. Water also enters the granular base from the sides of the pavement structure and from underground seepage. This water must be removed from the granular base in order to limit its' deflection under load.

Providing under drains for some facilities can be an expensive proposition or may be an impractical design alternative. Also, drains may not always keep the aggregate base sufficiently dry and frost heave can still occur – freezing of water in the granular base and subbase layers under the asphalt surface.

It is no surprise to anyone familiar with pavement failure to find water in pavements with granular base and granular subbase layers. The granular materials become saturated, especially in the springtime. Cycles of freeze and thaw compound the problem. The HMA [or asphalt treated] material supported on a saturated layer of aggregate, bends more due to the lower strength of the wet granular materials beneath it. The pavement soon cracks, due to excess deflection --- the primary cause of pavement failure.

Washington State University research and Minnesota Department of Transportation/University of Minnesota research has found the deflection of aggregate base sections to be two to three times greater in the spring season of the year than in the fall.[3, 4]

DEFLECTION OF GRANULAR BASES

Less Deflection

The primary advantage of a total Full-depth HMA pavement lies in the fact that the HMA pavement structure deflects less under load in the springtime – the aggregate particles are bound together with PG asphalt. The asphalt binder accomplishes two main items. First of all, it makes the base material nearly watertight. Secondly, by holding the aggregate particles together, it provides tensile **strength** to the material.

HMA materials have been used for many years to prevent water from seeping out of, or into, various structures, such as canals, dams, reservoirs, holding ponds, swimming pools, etc. The HMA when placed and compacted to a relatively low in-place air void content is impervious to water and does not become saturated in the springtime.

Being resistant to water, the aggregate particles in the HMA base course (non-wear layers) are not lubricated by water. The deflection of Full-depth pavement structures will be the same in the springtime as in the fall of the year, with similar subgrade strength conditions. The deflection of the aggregate base pavements, in contrast, increases significantly in the spring, when the granular materials are saturated. On an inch-for-inch basis, the watertight [lower in-place void] HMA base deflects much less under a given load than does an unbound, higher in-place air void, water friendly system.(5)

Because of the tensile strength provided by the asphalt binder, the HMA designed base course material with asphalt (nonwear) can withstand bending under repeatedly applied loads.(5) Granular base and subbase courses, such as untreated aggregate and asphalt emulsion treated base, have minimal if any tensile strength and resistance to bending and deflection. (The latter material contained only 3.0% asphalt, compared to approximately 4.5% binder by weight of mix.) Thus, inch-for-inch, HMA and asphalt cement bound materials are infinitely stronger in tension.

<u>Layer Equivalencies</u>

On an inch-for-inch basis, a HMA designed base course (nonwear) is much stronger than granular base and subbase courses as well as low residual asphalt content treated layers. HMA has greater tensile strength and deflects less under applied loads. For these reasons, pavement design engineers have established layer equivalencies for various materials used as base courses under HMA surface. Mn/DOT uses a ratio of one inch of HMA equal to about two and one-half inches of aggregate base course. Thus, less HMA thickness can be used for the same pavement strength.

In most cases, the value of using HMA recycled pavement materials can also be incorporated by Mn/DOT's current 2350/2360 specification. Supporting data exists to even justify that recycled asphalt pavement (RAP) HMA per inch has a higher layer equivalency than virgin mix. Minnesota has always appreciated optimum utilization of our natural nonrenewable resources through hot mix recycling efforts established some 27 years ago. It is proven technology for our construction culture.

THE NEW ASPHALT

MAPA commissioned ERES Consultants to research and analyze the Pavement Management Database of Mn/DOT to determine service lives of HMA pavements. [As a side note, doweled PCC pavements were also analyzed by ERES.](1) This research has been completed and the final results published. For additional information, visit the MAPA website at www.asphaltisbest.com for the facts obtained and conclusions drawn from these studies.

Based on the above, the ERES analysis shows beyond a doubt that QM has substantially improved the performance/service life of HMA pavements. It seems logical to conclude that Superpave technology and particular PG-Asphalt will further this performance along with performance testing capabilities. MAPA can say, and prove through documented research, that the performance of HMA pavements has improved substantially over the last decade and can continue to show improvement for the following reasons:

1. Increased material uniformity through process control under QM.
2. Enhanced testing and categorization with the PG-Graded Binder (Asphalt) System.
3. Improved Pavement Structural Design Process.
4. The Full-depth HMA Pavement is a viable design concept.
5. Improved materials specifications and mix design procedures have and will continue to improve HMA pavement performance through enhanced durability.
6. Warranties will assure owner satisfaction.

SUMMARY

A pavement structure which will withstand more repetitions of applied load will be one which deflects less under a given load. Higher in-place connecting voids such as nonwear base pavement layers, become saturated in the springtime, have a tendency to lose strength and increase significantly in deflection after cycles of freezing and thawing. Full-depth HMA pavements, on the other hand, do not become saturated in the spring. Total (Full-depth) HMA pavement structures maintain their strength and deflect less under load. More information on Full-depth HMA pavement structures can be found in MAPA's asphalt paving design manual.[6]

REFERENCES

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(3). Terrel, R.L., and Krukar, M., *"Evaluation of Test Tracking Pavements*," Proceedings of the Association of Asphalt Paving Technologists, Volume 39, 1970, pp. 272-296.

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