ASPHALT MATERIALS &
PAVEMENTS PROGRAM

Validation of Gyratory Mix Design in Iowa

tech transfer summary

An assessment of the adequacy of current asphalt mix design gyratory levels in Iowa would allow for the modification of standards if mixes cannot attain target densification under traffic.

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RESEARCH PROJECT TITLE
Validation of Gyratory Mix Design in Iowa

SPONSORS
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The Asphalt Materials and Pavements Program (AMPP) at InTrans specializes in improving asphalt materials and pavements through research and technology transfer and in developing students' technical skills in asphalt.

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Background

The use of asphalt pavements, which cover about 94% of paved roads, has gradually increased since the late 19th century (Brown et al. 2009). The mix design of asphalt pavements has undergone continual evolution since initial development, relying heavily on empirical knowledge.

In the US, Superior Performing Asphalt Pavement (Superpave) mix design is used in a majority of states. One of the most important factors in mix design is the compaction effort, or number of gyrations, of the asphalt mixture, which is denoted as the design number of gyrations (Ndesign). Ndesign is one of the most significant design considerations/parameters in the laboratory and is selected based on the corresponding equivalent single-axle load (ESAL) levels for the proposed pavement structure.

Problem Statement

Over time, many agencies and researchers have performed studies to validate gyratory design levels. These studies concluded that the N_{design} in the Superpave mix design method is considerably higher than necessary, and, as a result, the compaction effort conducted in the laboratory may not be reasonably attained in the field due to differences in the compaction equipment, compaction procedure, and difficultly of compacting in the field (Harmelink and Aschenbrener 2002).

Project Objectives

- Evaluate the ultimate in-place densities on 300,000 to 30,000,000 ESAL design-level surface mixes in Iowa by performing volumetric testing
- Determine the compatibility of mixes under the existing mix design procedures by recalculating the gyratory slope from the quality control and quality assurance (QC/QA) data
- Estimate and compare the post-construction compaction effort (PCCE) for each selected project and determine the theoretical N_{design} at construction and post-construction
- Evaluate the optimum asphalt contents and aggregate structures due to different Ndesign values adopted for the mixtures under three different traffic levels

Research Description

The researchers selected a total of 20 projects within the six different Iowa Department of Transportation (DOT) districts to evaluate the PCCE and determine if 4% target air voids were being achieved.

Pavement sections constructed in 2011 for 300,000, 1,000,000, 3,000,000, and 10,000,000 ESALs, in addition to sections with varying construction and post-construction years for 30,000,000 ESALs, were selected for the study.

All testing was done in accordance with the American Association of State Highway and Transportation Officials (AASHTO) and ASTM International standards. To get an idea about overall pavement performance, the following was completed:

- Three projects per ESAL level were selected, and pavement cores were removed by the Iowa DOT at three different mileposts per project (excluding the 30,000,000 ESAL projects).
- Pavement conditions were evaluated based on available data using the Iowa DOT's Pavement Management Information System (PMIS) survey information and the *Distress Identification Manual for the Long-Term Pavement Performance Program* (Miller and Bellinger 2003) to determine if the selected pavement sections displayed any anomalies during post-construction.
- The field densities, bulk specific gravity (G_{mb}) and theoretical maximum density (G_{mm}) of the mixes were compared to the QC/QA data to determine the density during post-construction.
- The field densities, in addition to the mix data, were also used to recalculate the gyratory compaction slope.
- With the determination of the compaction slope, the PCCE and the theoretical Ndesign at construction and post-construction were determined for each mix.

Key Findings

The outcome of the study showed that sections at ESAL levels of 1,000,000, 10,000,000, and 30,000,000 displayed the most concern. Furthermore, the majority of the sections at 10,000,000 and 30,000,000 ESALs were unable to densify with traffic due to under-compaction during construction.

Other key findings include the following:

- The current N_{design} compaction levels are higher than the targeted optimal value, creating mixes that do not reach 4% air voids after traffic densification at 4 years post-construction.
- The majority of the mixes did not achieve 96% G_{mm} (or 4% air voids) at 1, 2, 4, and 12 years post-construction (Note: Only ESAL levels below 30,000,000 were analyzed at 4 years post-construction).
- The overall pavement conditions displayed no signs of premature distress on the pavements studied. Pavement distresses showed that the overlay construction placed in 2011 provided significant improvements in pavement performance.
- The G_{mm} from the QC/QA data can be used to determine the density of the pavement since the values of G_{mm} tested in the laboratory using field cores were close to the hotbox Gmm values from the QC/QA data.
- Air void analysis showed that traffic volumes at the 300,000 and 3,000,000 ESAL levels compacted better post-construction; whereas, the 1,000,000, 10,000,000, and 30,000,000 ESAL levels were unable to densify to the target 4% in-situ air voids. The majority of the sections at the two highest traffic volumes were unable to reach ultimate pavement density with the current design gyrations.
- Distribution of the %G_{mm} in the years 2011, 2012, and 2013 indicate that, at 4 years post-construction, there is a high probability that approximately 25% of the hot-mix asphalt (HMA) mixtures will not attain ultimate pavement density.
- In laboratory-produced/laboratory-compacted mixes, the optimum asphalt content of the mixtures for a high traffic level was lowest (at 4.8% for 4% air voids), followed by the medium traffic level (at 5.68% for 4% air voids), and the low traffic level (at 5.8% for 3% air voids).

Implementation Readiness and Benefits

The researchers evaluated the efficiency of the current N_{design} standards for Iowa while considering target densification under traffic. The study showed that when reconsidering peak gyration levels, close attention to the design target air voids, voids in the mineral aggregate (VMA), and aggregate source/type should be addressed.

Future work needs to be conducted to validate and recommend the optimum design number of gyrations in Iowa. The long-standing premise of utilizing the greatest amount of asphalt binder in an aggregate structure without compromising rutting resistance in asphalt mix design is being met, but it is conservative, and pavement life could be extended with an increased amount of binder. This increased life would be a result of improved durability and fatigue cracking performance as well as improved resistance to moisture sensitivity.

The next important aspect of this research is to verify that proposed changes in gyration levels at the various traffic levels is not leading to rutting susceptibility.

References

Brown, E. R., Kandhal, S. P., Roberts, L. F., Kim, Y. R., Lee, D.-Y., and Kennedy, T. W. 2009. *Hot Mix Asphalt Materials: Mixture Design, and Construction*. National Asphalt Pavement Association (NAPA) Education Foundation, Lanham, MD.

Harmelink, D. and T. Aschenbrener. 2002. *In-Place Voids Monitoring of Hot Mix Asphalt Pavements*. Colorado Department of Transportation (CDOT) Research Branch, Denver, CO.

Miller, J. S. and W. Y. Bellinger. 2003. *Distress Identification Manual for the Long-Term Pavement Performance Program*. Federal Highway Administration Office of Infrastructure Research and Development, McLean, VA.