Superpave Mix Design: Verifying Gyration Levels in the N_{design} Table

RESEARCH SYNOPSIS–NCHRP REPORT 573

Problem Statement

The asphalt content of hot-mix asphalt (HMA) is critical to the mixture's performance. If there is too much asphalt, the mixture is likely to suffer excessive permanent deformation. If there is too little asphalt, field compaction may be difficult, and the pavement may develop premature cracking, raveling and/or other distresses related to lack of durability.

There is concern that the design gyration (N_{design}) levels used with the Superpave gyratory compactor (SGC) have not been optimized to maximize field performance. The original N_{design} table released in 1994 with 28 different Ndesign levels was based on a limited data set for which the as-constructed densities were not available. The N_{design} table was consolidated in 1999 to four N_{design} levels based on a laboratory study designed to evaluate the sensitivity of volumetric properties to N_{design}. Further research was needed to evaluate the current N_{design} values and relate them to field densification and performance.

Objective

The three objectives of this research were (1) to evaluate the field densification of pavements designed using the Superpave mix design system, (2) to verify or determine the N_{design} levels to optimize field performance, and (3) to evaluate the locking point concept. This concept is defined as the gyration number at which the aggregate skeleton "locks" together and further compaction results in aggregate degradation and very little additional compaction.

Description of Study

This study included a literature search as well as extensive laboratory and field testing. The literature review confirmed that there is a concern that N_{design} levels have not been optimized to maximize field performance. The research test plan was created to relate N_{design} to the in-place densification of pavements under various traffic loadings while also monitoring field performance.

Asphalt mixture samples were collected, tested and analyzed from 40 field projects at the time of construction. The field projects were located in 16 states. They represent a wide range of climate, traffic levels, binder grades, aggregate types, lift-thickness-to-NMAS ratios and gradations. Each project was visited five times after construction: at three months, six months, one year, two years and four years. Coring and distress surveys were conducted at each evaluation interval. In total, approximately 4,085 SGC samples and 5,670 cores were tested. Data obtained from the SGC samples and field cores along with traffic data provided by the agencies were analyzed to provide recommendations for the N_{design} compaction levels.

Figure 1 Compaction of an asphalt mixture in the Superpave Gyratory Compactor.

For each of the projects, core densities were measured and in-place air void contents were calculated. This allowed the densification of each project to be tracked over time, until an ultimate in-place density was reached. These results were then compared with the SGC compaction data to assess how well the N_{design} level matched the ultimate pavement densification achieved under traffic. Three different analyses were performed to relate N_{design} levels to the ultimate in-place density to determine where the levels should be set. Evaluations of the effectiveness of $N_{initial}$, $N_{maximum}$ and locking point were also conducted.

Key Findings

In many cases, as-constructed densities were lower than desired. Pavements appear to reach their ultimate density after two years of traffic. The majority of pavement densification, approximately 66 percent, occurs during the first three months after construction.

The ultimate in-place densities of the pavements evaluated in this study were approximately 1.5 percent less than the densities of the laboratory-compacted samples at the agency-specified N_{design}.

Analyses indicated the N_{design} levels could be reduced. Field performance also supported slightly reduced N_{design} levels, as the field pavements were rut resistant. The maximum observed rutting for the field projects was 7.4 mm, with an average rut depth of 2.7 mm after 4 years of traffic for all projects. Indications of durability problems suggested that increased asphalt contents would be beneficial.

The number of gyrations to match the ultimate in-place density was calculated for each project. The calculated values for the compactors from the two manufacturers used in this study differed by approximately 20 gyrations. This was attributed to differences in their dynamic internal angle (DIA). The predicted gyrations adjusted to a DIA of 1.16 degrees showed good agreement between the SGC from two different manufacturers.

The locking point concept was evaluated as an alternative to N_{design}. The density at the 3-2-2 locking point is weakly correlated to the ultimate density of the pavement. The locking point appears to be related to aggregate type, with softer aggregate producing higher locking point values.

Recommendations for Implementation

Based on the research conducted in this study, the following recommendations are made:

- The N_{design} levels should be reduced slightly, and the levels shown in Table 1 should be adopted for the design of Superpave HMA. In addition, there should be further reductions in N_{design} when the mix design is prepared with an asphalt binder with a performance grade of PG 76-XX or greater. Such binders are typically modified, and HMA prepared with them can provide superior performance.
- If the desire is to provide more asphalt content as a result of the reduced number of gyrations, the reduction in N_{design} should be accompanied by a small increase in minimum voids in the mineral aggregate (VMA) to ensure higher asphalt content and not a gradation change. An increase in minimum VMA of 0.5 percent accompanied by the proposed reductions in N_{design} should improve the compactibility of the mix in the field and increase the optimum asphalt content.
- The specification for angle of gyration should be revised to allow a DIA of only 1.16 ±0.02 degrees.
- The criteria for $N_{initial}$ and $N_{maximum}$ should be eliminated.

20-Year Design Traffic, ESALs	2-Year Design Traffic, ESALs	N_{design} for binders < PG 76-XX	N_{design} for binders ≥ PG 76-XX or mixes placed > 100 mm from surface
< 300,000	<30,000	50	N/A
300,000 to 3,000,000	30,000 to 230,000	65	50
3,000,000 to 10,000,000	230,000 to 925,000	80	65
10,000,000 to 30,000,000	925,000 to 2,500,000	80	65
> 30,000,000	> 2,500,000	100	80

Table 1 Recommended N_{design} levels.

Acknowledgements and Disclaimer

The research reported herein was performed under NCHRP Project 9-9(1) by the National Center for Asphalt Technology, Auburn University. This research synopsis provides a brief summary of the study's final publication. This document is for general guidance and reference purposes only. NCAT, Auburn University, and the listed sponsoring agencies assume no liability for the contents or their use.