Relationships between Laboratory-Measured Characteristics of HMA and Field Compactability

RESEARCH SYNOPSIS

Problem Statement

Achieving target density is vital to building long-lasting hot mix asphalt (HMA) pavements that resist distresses such as rutting and moisture damage. However, meeting specified density levels can be challenging, as some mixes require greater compactive effort than others.

Compactability describes the relative ease of compacting an HMA mixture to reach acceptable density levels. Several laboratory-measured parameters have been suggested as indicators of HMA compactability, but most have not been correlated with actual pavement construction data. A practical approach is needed to evaluate lab compactability and to estimate the required field compactive effort for HMA mixtures. This would enable mix designers to make adjustments as needed during the mix design process to improve field compactability.

Objective

The primary objective of this study was to evaluate the following laboratory-measured mixture parameters and determine correlations with field compactability:

1. Percentage of theoretical maximum specific gravity (Gmm) at the initial number of gyrations (Nini)
2. Compaction slope, determined from the Superpave gyratory compactor (SGC)
3. Number of gyrations required to achieve 92% Gmm (N92)
4. Compaction energy index (CEI), determined from the SGC
5. Number of gyrations required to reach the locking point of the mixture
6. Coarse and fine aggregate ratios, determined by using the Bailey method
7. Mix characteristics, including gradation, aggregate shape, binder grade and volumetric properties
8. Primary control sieve index (PCSI), representing the relative coarseness or fineness of the gradation

A secondary objective was to use mix characteristics, including gradation and binder grade, to explain differences in compactability.

Figure 1 Monitoring field compactability.

Description of Study

The study was carried out in five steps:

1. Data from Superpave mixes placed on the NCAT Test Track during the 2000 and 2003 cycles were used to evaluate laboratory-measured compaction parameters. Both surface and binder mixes, representing a wide variety of aggregate and binder types, were included in the analysis.
2. Accumulated compaction pressure (ACP) was used to quantify compactive effort applied during rolling operations on test sections at the track. ACP was then related to laboratory compaction parameters.
3. Laboratory specimens were compacted to determine the number of gyrations to reach 92 percent Gmm at the field lift thickness. The results were compared with the number of gyrations to reach 92% Gmm for normal height (115 $\pm$ 5 mm) specimens.
4. A number of mixes placed on the track in 2003 and 2006 were used to obtain ACP at 92 percent Gmm, and the results were correlated with laboratory-compaction parameters using multiple regression analysis.
5. One of the final compaction models was validated using data from the NCHRP 9-27 study, which included a variety of mixes placed and compacted on projects across the U.S.

Key Findings

CEI, N92, compaction slope and locking point were found to be simple laboratory compactability parameters. PCSI and the fine aggregate ratio (FAC) determined by the Bailey method, both of which describe gradation properties, can also be used to indicate laboratory compactability. Laboratory compaction was significantly affected by gradation type, and to a lesser degree, aggregate type and aggregate size. As expected, the most easily compacted mixes in the lab were fine-graded, while the most difficult to compact were stone matrix asphalt (SMA) mixes.

ACP was found to be a simple measure of field compactability. Mixes with lift thicknesses less than 50 mm required more compactive effort to achieve target density due to a more rapid loss of mix temperature. Temperature substantially affected ACP for lift thickness to nominal maximum aggregate size (t/NMAS) ratios less than 3:1, whereas the effect of temperature was minor for t/NMAS ratios greater than 4:1. Although binder grade, binder content and gradation did not have a significant effect on ACP, mixes with higher binder contents and finer gradations required less compactive effort, as expected.

Due to the complexity of factors affecting field compaction, a single factor correlation could not be found to effectively describe the relationship between laboratory and field compaction. However, multiple-regression analysis resulted in a model (R2 = 0.82) that includes four significant factors: FAC, PCSI, surface temperature at the start of field compaction and the number of gyrations to reach field density for specimens compacted to field lift thickness (NFTFD). NFTFD had the greatest effect of all the significant factors on predicted ACP, indicating that an additional step in the mix design process–compacting specimens at field lift thickness–may help predict required field compactive effort. This model was also verified using data from 16 surface mixes placed across the U.S. as part of the NCHRP 9-27 study.

Another model (R2 = 0.92) was developed to predict the ACP required to achieve a reference density level of 92 percent Gmm. This model, which was not independently validated, includes the following terms: FAC, PCSI, percent passing the 0.075 mm sieve, binder grade, compaction slope, locking point, lift thickness and surface temperature at the start of field compaction.

Recommendations for Implementation

Mix designers can use the models developed in this study to predict the compactive effort required to meet target density in the field. Thus, adjustments can be made to avoid designing mixes that require unnecessarily high field-compaction energy.

Acknowledgements and Disclaimer

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