SUMMARY

DEVELOPMENT OF A GYRATORY DESIGN SYSTEM FOR CONVENTIONAL SCDOT HOT MIXED ASPHALT MIXTURES

The Superpave mix design method was part of the Federal Highway Administration's (FHWA) Strategic Highway Research Program (SHRP). Currently, several states and industry organizations have or are attempting to determine a correlation between the Marshall and Superpave mix design methods.

The purpose of this laboratory investigation was to determine if a correlation could be made between the Marshall hammer and the gyratory compactor for South Carolina mixtures. The specific objectives included: a) Determine the physical properties of HMA Marshall specimens for each mix design at three binder contents. These properties include bulk specific gravity (BSG), unit weight, stability, flow, voids in mineral aggregate (VMA), voids filled with asphalt (VFA), and percent air voids. b) Determine the optimum binder content for each HMA Marshall mix design using SCDOT procedures. c) Prepare gyratory samples for each mix design at four binder contents. d) Calculate the number of gyrations required for \( N_{\text{des}} \) for each mix design at each binder content. e) Statistically compare the results for each type of mix design from six quarries and determine a correlation, if any, between the Marshall hammer and the gyratory compactor.

The aggregates were obtained from the respective quarries. A sieve analysis was performed on each aggregate type used in the mix designs according to ASTM C 117 and ASTM C 156. After determining the combined gradation, Marshall samples were made at three binder contents to determine the optimum binder content. Each mix design was then checked against SCDOT specifications for its respective mix type.

Gyratory samples were then made at four binder contents: 1.0% below optimum, 0.5% below optimum, at optimum, and 0.5% above optimum. The samples were subjected to 158 gyrations (\( N_{\text{max}} \)) in the gyratory compactor. The Microsoft Excel computer program was then used to plot percent \( G_{\text{mm}} \) vs. log number of gyrations for each mix design at
each binder content. The equation of the best-fit line was then used to determine the number of gyrations required for $N_{des}$. Three statistical parameters (mean, standard deviation, and coefficient of variation) were calculated for each binder content for the four mixture types.

The comparison was performed using six aggregate sources (Camak, Cayce, Jefferson, Liberty, Marlboro, and Pacolet) and four mixture types (Surface Types 1, 3, 4, and Intermediate Type 2). These aggregate sources are the most widely used aggregates in South Carolina. A total of 207 Marshall and 276 gyratory samples were made and tested. All samples were tested to obtain the bulk specific gravity, voids in mineral aggregate, voids filled with asphalt, and percent air voids. The Marshall samples were also tested to obtain flow and stability.

Optimum binder contents determined by the Marshall mix design method were used in preparing specimens with the Superpave Gyratory Compactor (SGC). Densification curves comparing percent $G_m$ and the number of log gyrations were developed for each specimen compacted with the SGC. Because Superpave$^\text{TM}$ specifications require less than 98% $G_m$ at $N_{max}$, researchers made the decision to make 98% $G_m$ the cut-off point for developing the densification curves and corresponding regression lines. This decision was also made due to the fact that specimens were compacted at a high gyration level (158 gyrations). This gyration level was too high for some of the mixtures and resulted in minimal changes in %$G_m$ over a large number of gyrations. Essentially, the specimens could only be compacted so much before the densification curve would begin to flatten out. Based on this criteria, researchers were able to obtain $R^2$ values from 0.9941 to 0.9996 for all of the mixtures.

Based on these densification curves, $N_{des}$ values were calculated at each binder content and the volumetric properties analyzed. Volumetric properties were also analyzed where gyration levels overlapped between aggregate sources within the asphalt mixtures. A trial and error method was also used to evaluate the volumetric properties for a range of $N_{des}$ values. A range of $N_{des}$ values was established based on a gyration level and binder content exhibiting volumetric properties most closely satisfying SCDOT specifications.

The results of this investigation indicate that no direct correlation could be determined between the Marshall hammer and the SGC. Results showed a distinct difference in volumetric properties of asphalt mixtures prepared with the Marshall hammer and SGC at design binder contents. Though no direct correlation could be found, two gyration levels produced volumetric properties in which a majority fell within the SCDOT specifications for each asphalt mixture. A gyration level equal to 75 gyrations will most closely satisfy SCDOT’s specifications for Surface Type 1, Surface Type 3, and Intermediate Type 2 mixtures, while 60 gyrations will most closely satisfy Surface Type 4 mixtures’ specifications.

It is recommended that the SCDOT conduct more research on this topic. For this second phase of this project, the SCDOT may wish to include some of the following aspects in their research program: a) modifications to volumetric specifications; b) use different aggregate sources; c) use different gyratory compactors; d) use different combined gradations; e) use different binder types; f) evaluation of asphalt film thickness in SCDOT asphalt mixtures; g) field implementation of the findings of this laboratory work with constructing several trial sections with the developed mix design method; and h) make several replicate specimens at the recommended design gyration levels with various aggregate and binder sources used in the state, and test several properties and compare the results.

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