Ontario Hot Mix Producers Association
365 Brunel Road, Unit 4, Mississauga Ontario L4Z 1Z5
Phone: 905-507-3707 Fax: 905-507-3709 web: www.ohmpa.org

SPECIAL BULLETIN 3-A

QUALITY OF ASPHALT PAVEMENT TASK FORCE

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Re: Optimization of Asphalt Cement Content to Improve Durability of Asphalt Mixes

The introduction of Superpave Technology in Ontario provided us with a possibility of improved volumetric mix design methodology and enhanced quality requirements for aggregates used in HMA mixes. Superpave designs have significantly improved the performance of our pavements in terms of resisting rutting, shoving and flushing on our high volume highways, major arterial roads as well as intersections and bus lanes. However, there has been growing concerns among agencies over the last several years that the asphalt cement content of many Superpave mix designs may have been reduced to below optimal levels for durability. Asphalt content or more specifically Effective Asphalt Content of HMA mixes has significant influence on pavement performance in terms of fatigue and thermal cracking. However, we have to be certain that any changes we make do not adversely affect other aspects of durability such as rutting.

It is not the asphalt cement content that determines the durability of the mix; rather, it is the effective asphalt cement and the thickness of the film of asphalt cement that surrounds the aggregate particles. The effective asphalt cement is the asphalt cement that coats the aggregate particles in the mix and excludes the asphalt cement absorbed into the aggregate. Film thickness is the actual thickness of the asphalt film between the aggregate particles and it is this film that binds the aggregate particles in the mix.

Unfortunately, effective asphalt cement content is difficult to measure and thus specify. The absorption of asphalt is controlled by the aggregate properties. We are fortunate in Ontario to have aggregates with low absorption (less than 2 per cent for water absorption) and that limits asphalt absorption. However, asphalt absorption is also affected by temperature. Highly modified asphalt cements require higher mixing and compaction temperatures. This tends to increase absorption and reduce effective asphalt cement content and should be accounted for during mix design.

Film thickness is also difficult to measure. There is a theoretical calculation but the value does not necessarily represent what is actually happening in the mix. The asphalt cement does not remain as a simple film coating the aggregate. Instead, the asphalt combines with the ultra-fine aggregate particles to produce a mastic and it is this mastic that binds all particles in the mix together.

This Bulletin will outline the various methods of increasing the asphalt cement content and thus the effective asphalt cement content and the film thickness without compromising other performance properties of the mix. This is an optimization process and is not as simple as just increasing the asphalt cement in the mix. The issue is that mixes are required to meet both mix design requirements and specification requirements. It is then impossible to simply add more asphalt cement to the mix with no other changes and still be sure to meet all the desired properties.

The following sections will discuss a partial list of the work being carried out across North America.

ONTARIO MINISTRY OF TRANSPORTATION INITIATIVES

The Ministry of Transportation (MTO) has long recognized the benefits of increased asphalt cement contents and have been innovative in their tendering and specifying practices to achieving this goal. MTO tenders call for fixed asphalt cement values for each mix type at time of bidding. The price of the HMA is then adjusted based on the actual asphalt cement content used as determined by the acceptance testing results.

MTO has recently modified their specification to use fine graded surface course mixes as the default mix type. Fine graded mixes will tend to have higher asphalt cement content. Finer graded mixes meet the same overall Superpave gradation envelope but have a higher proportion of smaller aggregate. Thus they have a higher specific surface area and hence may require additional asphalt cement.

MTO is also allowing the percent of Theoretical Maximum Specific Gravity at $N_{initial}$ to be increased by 0.5 per cent to ≤ 89.5per cent at the Contractor's option in order to move away from a prescriptive limit on a parameter that is not used for acceptance.

Although these are viewed as hopeful steps, it is unclear at this time how effective these initiatives will be in increasing asphalt cement content.

INITIATIVES BY OTHER AGENCIES

Other agencies in Ontario, across Canada and the United States have been looking to modify their design and acceptance requirements in response to their own observed performance issues. Specifications are changing rapidly as agencies search for ways to improve durability.

Lowering Gyration Levels

Higher traffic category roadways (Traffic Category C, D and E) require higher gyration levels. The higher gyration levels tend to reduce the amount of space available for asphalt binder in the mixes and yet still meet the specified volumetric properties.

It has been suggested that lowering the gyrations for Category D and E mixes will result in the additional asphalt cement in the mix. This would only be true if the gradations were fixed.

There is an additional concern that reducing gyrations may increase rutting. However, many mixes reach a "locking point" defined as the gyration at which the aggregates skeleton "locks" together and further compaction may result in aggregate gradation degradation and very little additional compaction. Locking point will have an impact on the required aggregate properties. Some agencies, such as the Illinois DOT, have used this concept to limit gyrations for certain mixes. However, it is difficult to specify as the number of gyrations to the locking point will likely increase as asphalt cement content increases due to the added lubrication. Fine graded mixes are typically less susceptible to aggregate degradation.

Increasing Minimum VMA

VMA represents the volume available for effective asphalt cement in a mix and it is the effective asphalt cement that coats the aggregates. VMA is high at low asphalt cement contents and drops as asphalt cement is added until it reaches a minimum value after which additional asphalt cement causes the VMA to increase as the asphalt cement forces the aggregate particles apart. This approach may work with Marshall mix designs where volumetric parameters are different but it is difficult to apply to the Superpave system that has a specified parameter known as Voids Filled with Asphalt (percent of the VMA filled with effective asphalt). This value decreases with increasing gyrations to guard against rutting.

The minimum VMA of the mix can only be changed by changing the aggregate blend to make more space in the mix. There is the possibility that the change in gradation may reduce the stability of the mix. Aggregate changes may require the use of manufactured aggregates to ensure mixes remain stable.

Lowering Design Air Voids

Lowering the design air voids may end up increasing the asphalt content but it could also mean that the mix designer adjusts the gradation and that the effective asphalt content and the film thickness would not be changed.

A Combined System of Lowering Gyrations and/or Increasing VMA and/or Lowering Air Voids

As mentioned earlier, the principal issue with each of these first three options is that there may be other ways of meeting a single parameter without affecting the durability of the mix. In order to have more control on the choices that mix designers make, it is likely that a combined system that changes two or more properties would be required. The issue is that the combinations would have to be evaluated in the laboratory with some form of performance prediction testing and validated in a controlled field experiment.

Lowering Acceptance Air Voids

In this scenario, the Superpave mix design is performed in the standard method with the existing specifications to arrive at a design asphalt cement content at 4 per cent air voids for a particular gradation. Once the job mix formula (JMF) and aggregate proportions are locked in, the air voids content for acceptance in the field is reduced from the 4 per cent value used for design to a lower value. As the gradation has already been fixed, this will result in increased asphalt cement content, increased effective asphalt and increased film thickness.

Some jurisdictions that have adopted this approach have changed the mix design procedure slightly to address acceptance issues. The mix design is performed so that there are sufficient data points from 2.5 per cent air voids to 4.5 per cent air voids. The gradation and asphalt cement content are chosen to meet all the volumetric requirements at 4.0 per cent air voids. Once chosen, the increased asphalt cement required for a lower air void content is used for production (i.e. 3.5 per cent air voids). This methodology avoids issues with changing of the gradation and also avoids issues with acceptance properties by having the volumetric information available at the mix design stage.

When this methodology is used, the asphalt cement content typically increases by 0.3 per cent for each 0.5 per cent reduction in air void content used for acceptance. This will typically be within current air void tolerances. However, some adjustment of the air voids for acceptance may be required.

Performance-Based Mix Design

The performance-based mix design concept involves using performance predicting tests in conjunction with the standard mix design procedure to choose the gradation and asphalt cement content. Typically, this procedure results in a compromise in the air void content at a value lower than 4 per cent.

The procedure would incorporate a test for rutting and one or more tests for cracking according to the mix type and the project. The rutting test will control the upper limit for the asphalt cement content of the mix while the cracking test will control the lower limit for the asphalt cement content of the mix. In addition, the complex dynamic modulus test will be used in projects requiring mechanistic pavement design (MEPDG). However, there are two issues with the procedure; the tests that are chosen and the increased cost and time to do the testing.

There are many contenders for the cracking prediction test. The leading contenders are some version of the Semi-Circular Beam Test (SCB) and the Disk Shaped Compact Tension Test (DC_T). Both tests use samples initially prepared in the Superpave Gyratory Compactor. The SCB uses a semi-circle sample with a crack inducing axial saw cut tested in three-point loading to produce tension on the lower surface and across the cut. There are several different procedures and alternate calculation methodologies. The DC_T uses a circular sample with an axial crack inducing saw cut tested in tension across the cut. Both tests give a value for the stress needed to initiate failure and a stress necessary to propagate continuing failure.

The Asphalt Mixture Performance Tester (AMPT) and the Hamburg Wheel Tracking Test (HWTT) are the two leading contenders for the rutting prediction test in North America. Both tests use samples initially prepared in the Superpave Gyratory Compactor. The AMPT tests the sample in cyclical axial loading at lower than failure stress and provides a Flow Number (the point at which the sample starts to change at a faster rate) which has been shown to correlate well with rutting in the field. The HWTT exposes the sample to repeated loading from a weighted steel wheel and identifies the point at which the sample starts to change at a faster rate. Two values are obtained, the rut depth at a number of wheel passes and the stripping inflection point (the point at which the sample starts to change at a faster rate).

The issue with both of these tests is there is not enough experience in Ontario to place much confidence in the test results. Further, at this time there is not enough equipment in Ontario to carry out the amount of testing that will be required.

Maximum Limits for Recycled Materials

There is some concern that recycled materials reduce mix durability. The complex issue of recycled material will be addressed in Bulletin 4-A.

RECOMMENDATIONS

Ultimately, some form of performance based mix design methodology is the goal for improving the durability of mixes used in Ontario. It would be beneficial for industry and agencies to work together to adopt a form of performance based mix evaluation. This will involve research into the testing methodologies and mix design practice. The first step is to gain experience with performance testing. It's fully understood that it will take some time to assess the linkage between testing and field performance, but we need to take the first step. This will likely require a form of performance indicator test to evaluate changes in the laboratory and a carefully controlled field trial to validate the results.

From a municipal perspective, this may not be quite as complex. While there may be concern about higher traffic category roadways with higher traffic volumes or loading where Traffic Category E mixes might be specified, most municipal mixes are designed for Traffic Category B, C and D. Using a minimum bid value for asphalt cement should be considered but care must be taken to ensure that the Superpave volumetric properties are considered in choosing this value. In addition, price adjustment clauses should also be considered to encourage increased asphalt cement content.

Whatever short term option is chosen, whether it is lowering acceptance air voids or increasing VMA where it is possible, it is important to note that changes need to be properly evaluated and cannot be made arbitrarily.

The Quality of Asphalt Pavement Task Force

In response to the concerns about the quality of asphalt pavement in Ontario, OHMPA formed the Quality of Asphalt Pavement Task Force. The purpose of this group comprised of industry experts, consultants and academics and representatives' municipalities and MTO is to assess these concerns and propose workable solutions that are scientifically sound and also practical. In response to this challenge, the task force has road owners' concerns in mind and has drawn on the expert options of the members of the group.

These and other findings and recommendations of the Quality of Asphalt Pavement Task Force will be published on OHMPA's website (www.ohmpa.org). For more information, please contact the OHMPA office at 905-507-3707 or by email at info@ohmpa.org.