An Introduction to Warm-mix Asphalt

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Background

The hot-mix asphalt industry is constantly exploring technological improvements that will enhance the material's performance, increase construction efficiency, conserve resources, and advance environmental stewardship. It is logical that one approach to achieving these goals would involve methods to reduce material production temperatures. The concept of warm-mix asphalt has been introduced over the last few years as a means to these ends. Warm-mix asphalt is produced at temperatures in the range of 30^{o} to 100^{o}F lower than typical hot-mix asphalt (HMA).

The production and placement of HMA pavements has evolved over the last 130 years from hand mixing and manual placement with rakes and shovels to computerized plants feeding highly automated remixing, placement, and compaction equipment that track location and material quality. During this period, it has become recognized that temperature control is crucial to aggregate coating, matrix stability during production and transport, ease of placement, compaction, and ultimately the performance of the pavement. During construction, the temperature must be high enough to ensure the workability of the mix and yet below the temperature at which drain-down and excessive binder hardening occur.

Modern performance requirements often dictate the use of polymer-modified asphalt binders, more angular aggregate, and higher levels of in-place density than have been used before. With the Superpave Performance Grade (PG) system, polymer modification is often used as insurance against permanent deformation at high temperatures on high-volume roads. Mixes made with polymer-modified binders have been viewed by some as more difficult to work than mixes made with unmodified asphalts. A common response to this lack of workability is to raise production and placement temperatures.

For higher-volume pavements and surface courses in medium-volume pavements, greater angularity is required by aggregate specifications. The use of angular aggregate increases the internal friction of the material, which in turn increases the force required to mix and place it, especially in coarse gradations. Again, the answer to reduced workability is often increased temperature in an attempt to reduce the viscosity of the binder and improve the flow.

Along with material requirements that reduce the workability of HMA are increased in-situ density specifications. Density is often used as a measure of pavement quality for dense- and gap-graded HMA. Higher levels of density are associated with lower permeability to air and water, improving performance with these mixtures. If a mixture shows resistance to compaction, the normal response is to raise the temperature of the mixture to improve its ability to compress during construction.

Increasing production temperature to address these concerns is often times expedient but not effective. For little or no improvement in workability, increasing the mix temperature often results in increased plant emissions and fumes at the paving site. The Asphalt Paving Environmental Council addressed this issue in a publication entitled “Best Management Practices to Minimize Emissions during HMA Construction” (available from NAPA’s online store; order number EC-101). Guidelines are provided on the proper temperature range for various grades of binders, and advice is given on overcoming workability problems without raising temperature. The best practices may result in a modest temperature drop of at most 10^{o} to 15^{o}F (6^{o} to 8^{o}C). While this temperature reduction could substantially reduce emissions and result in energy savings, greater temperature reduction is possible and may be prudent at some point in the future.

Environmental Driving Forces

Current and impending regulations regarding emissions are making it more attractive to consider greater reductions in HMA production temperature. While stack emissions have decreased significantly over the last 35 years due to improved pollution control features, further reductions in the emission of greenhouse gasses will likely be required in the future. In addition, current state and local regulations are such that in some ozone non-attainment areas, hot-mix plants are sometimes required to curtail operations in daylight hours during certain times of the year when ozone formation is problematic. Recently adopted new ozone standards will create additional ozone non-attainment areas, along with new, more stringent demands for emission reductions in the future and the demonstration that transportation plans and projects are in conformity with the Clean Air Act.

Working conditions in the production and placement of HMA are also important to the industry as improvements lead to an enhanced work environment, higher-quality work, and better employee and workforce retention. An important innovation regarding this was the implementation of engineering controls on pavers for fume reduction in 1997. These devices removed fumes from the immediate area of paver and screed operators. Significant HMA temperature reduction would have two benefits for the workforce: it would further reduce fumes in the vicinity of all paving workers and it would make for a cooler work environment.

Complaints of odor sometimes occur in plants located near residential areas. While there is no scientific evidence that odors pose a threat to the surrounding community, such perceived annoyances can create community relations problems. However, if production temperatures were drastically reduced, the production of odors sometimes associated with plant and paving operations could drop to an inconsequential level.

Performance Impact

Reducing the production temperature of HMA may have several implications for performance. These potentially include reduced rates of cooling, improved compaction, reduced mixture aging, and improved crack resistance. However, there is concern by some that the potential exists for greater moisture susceptibility, increased rutting, and delays in trafficking due to cure time.

If the temperature of the mixture is closer to atmospheric temperature and the cessation temperature for compaction is subsequently decreased, the rate of cooling for the mat will be much lower than it would be at high production temperatures. Because the mix cools more slowly, more time would be available for compaction. This would mean more opportunity to compact the mix during the normal paving season, and the ability to pave and compact at cooler temperatures, which would allow an extended paving season.

Lower production and paving temperatures would necessitate the enhancement of compaction characteristics of the asphalt mixture. It is possible that by lowering the viscosity of the binder at lower temperatures, compaction characteristics could actually be improved, allowing for greater in-place density. This would decrease the permeability of asphalt mixtures, which would decrease the amount of aging in the mixture and improve performance from the standpoint of cracking and moisture susceptibility.

Binder aging is directly related to the production temperature of the mixture. In fact, the majority of binder hardening due to aging takes place in the hot-mix plant. If the plant temperature is reduced, the oxidative hardening of the binder will be reduced. Less hardening of the binder during construction could mean more flexibility and resistance to cracking in service. This could have implications concerning the specification of the low-temperature level for PG binders as well as better potential resistance to top-down and bottom-up fatigue cracking.

If mechanisms for reducing the viscosity of the binder such as foaming or emulsions are used in the approach to temperature reduction, there is some fear that the moisture used in the process will displace asphalt in coating certain kinds of aggregate. This could result in increased stripping. However, this problem would not be unique to mixes produced at lower temperatures, and effective means of treating mixes to resist stripping have been implemented.

Reduced aging of the binder may be a benefit to reducing the cracking of the pavement, but there is the potential for reduced aging to contribute to loss of stability in hot weather and lead to increased rutting. There are two ways to counteract this. First, the use of more angular aggregate will provide increased internal friction to the mix, which, in turn, increases its shear strength without relying on the cohesion of the binder. Another approach is to consider using a higher high-temperature PG binder, essentially using grade bumping, to counteract the effects of reduced oxidation.

Finally, there may be some concern that certain additives or processes could result in a "cure time" for the pavement prior to opening it to traffic. The approach to address this issue is to conduct performance tests, such as rut testing, to see if there is a time-dependent early hardening that should take place prior to allowing traffic access to the pavement.

Warm-mix Asphalt

Technology is now available to decrease HMA production temperature by 30^o to over 100^oF (16 to over 55^oC). These relatively new processes and products use various mechanical and chemical means to reduce the shear resistance of the mix at construction temperatures while reportedly maintaining or improving pavement performance.

The development of these technologies began in Europe with the German Bitumen Forum in 1997. At that time, the Kyoto agreement on green house gas reduction was in the process of being adopted by the countries of the European Union. Since then, a number of products and processes for HMA temperature reduction have been developed in both Europe and the United States. These are the subjects of ongoing laboratory and field evaluations.

In the interest of exploring the usefulness of these technologies, the National Asphalt Pavement Association began investigating them in 2002. First, a contractor scanning tour of Europe was conducted where the processes and products in use at that time were demonstrated and discussed. Next, representatives of European companies were invited to make presentations at the NAPA Annual Convention in 2003. A demonstration project was constructed at the World of Asphalt Show and Conference in 2004. In that same year, jointly funded research was initiated at the National Center for Asphalt Technology by NAPA, the Federal Highway Administration, and some warm-mix technology suppliers on various methods for reducing asphalt mixture production and placement temperatures.

Before widespread implementation of this technology can occur, however, engineers must be satisfied that the resulting asphalt mixtures will be at least as strong and durable as what is currently being provided. Technicians and construction personnel must acquaint themselves with the characteristics and behavior of the new materials. Finally, further research is needed to measure the degree of environmental improvement, fundamental mix characteristics, and the impact on performance from the new technology.

Warm-mix asphalt is distinguished from other asphalt mixtures by the temperature regimes at which they are produced and the strength and durability of the final product. Cold asphalt mixtures are manufactured at ambient temperatures, on the order of 20^{o} to 50^{o}C (68^{o} to 122^{o}F), while hot-mix asphalt is typically produced in the range of 140^{o} to 170^{o}C (284^{o} to 338^{o}F). Warm mixes are those generally produced in the temperature range of 105^{o} to 135^{o}C (220^{o} to 275^{o}F). Hot-mix asphalt has higher stability and durability than cold-mix asphalt, which is why cold mix is used in the lower pavement layers of low-volume roadways. The goal with warm mix is to obtain a level of strength and durability that is equivalent to or better than hot-mix asphalt.

The Future of Warm-mix Asphalt

Temperature reduction in the manufacturing of asphalt mixtures is highly desirable from a number of aspects. Reduced fumes and emissions, and reduced energy consumption, are important environmental reasons to continue pursuing the goal of temperature reduction. There are important construction and performance advantages as well. For instance, improved workability results in better compaction; lower production and placement temperatures may improve prospects for cold weather paving; and lower temperatures will result in less binder aging and possibly better cracking resistance.

While there is a great deal of promise that comes along with lower temperatures, there are concerns also. More research is needed on a number of issues, including:

Mix Designs: Modifications to Superpave mix technology, if required, for designing WMA, need to be established. Selection of binder grades for lower production temperatures needs to be examined.

Long-term Performance: The durability of asphalt pavements constructed with WMA needs to be investigated in terms of binder effects (because the binder is either foamed or chemically modified) and increased potential for moisture damage.

Cost Benefits: Reduction in fuel consumption and emissions need to be quantified to ascertain cost benefits.

Plant Operations: The suitability of WMA for high production rates in the U.S. needs to be examined.

Control of Mixing Process: Since WMA has a mixing process that is different from conventional HMA, new guidelines need to be developed for proper QC/QA of the mix.

Workability at Paving Site: Although the WMA may appear workable and easily compactable when produced, it should remain workable at the paving site as well. This needs to be investigated on field demonstration projects.

Quick Turnover to Traffic: More field demonstration projects are needed to verify that WMA pavements can be opened to traffic as soon as possible after construction, in a time frame similar to or earlier than conventional HMA pavements.

Conclusion

Warm-mix asphalt presents an opportunity for the asphalt industry to improve its product performance, construction efficiency, and environmental stewardship. The challenge is to thoroughly research and implement this new technology in the least restrictive manner possible in order to encourage innovation and competition.

Bibliography

Davidson, J.K. (2005a). Evotherm trial – Aurora Ontario. Report by McAsphalt Engineering Services. Toronto.

Davidson, J.K. (2005b). Evotherm trial – Ramara Township Road 46. Report by McAsphalt Engineering Services. Toronto.

de Groot, P.C., C. Bowen, B.G. Koenders, D.A. Stoker, O. Larsen, and J. Johansen (2001). A comparison of emissions from hot mixture and warm asphalt mixture production. Proceedings of the International Road Federation, Part B, S.00469. International Road Federation Congress. Paris.

Hurley, G.C. and B.D. Prowell (2005). Evaluation of Aspha-min® zeolite for use in warm-mix asphalt. NCAT Report 05-04. National Center for Asphalt Technology. Auburn, Alabama.

Hurley, G.C. and B.D. Prowell (2005a). Evaluation of Sasobit® for use in warm mix asphalt. NCAT Report 05-06. National Center for Asphalt Technology. Auburn, Alabama.

Kandhal, Prithvi (2005). NCAT evaluates warm mix. *Asphalt Technology News*. Vol. 17, No. 2. National Center for Asphalt Technology. Auburn, Alabama.

Koenders, B.G. , D.A. Stoker, C. Bowen, P.C. de Groot, O. Larsen, D. Hardy, and K.P. Wilms (2000). Innovative process in asphalt production and application to obtain lower operating temperatures. Proceedings of the Second Eurasphalt & Eurobitume Congress, Book II. Barcelona.

Koenders, B.G., D.A. Stoker, C. Robertus, O. Larsen, and J. Johansen (2002). WAM-Foam, asphalt production at lower operating temperatures. Proceedings of the Ninth International Conference on Asphalt Pavements. Copenhagen.

Larsen, O.R., O. Moen, C. Robertus, and B.G. Koenders (2004). WAM Foam asphalt production at lower operating temperatures as an environmentally friendly alternative to HMA. Proceedings of the Third Eurasphalt & Eurobitume Congress. Vienna.

McKeon, B. (2006). Aspha-min in warm asphalt mixes. Presentation at the 51st Annual Convention of the National Asphalt Pavement Association. Lanham, Maryland.

Romier, A., M. Audeon, J. David, and Y. Martineau (2004). The low-energy coating technique (EBE) offering the performance of hot-mix asphalt. *Revue Generale des Routes et Aerodrome*. RGRA No. 831. English Translation.

Romier, A., M. Audeon, J. David, and Y. Martineau (2006). Low-energy asphalt (LEA) with the performance of hot-mix asphalt. Paper presented at 2006 Annual Meeting of the Transportation Research Board. Washington.