ISSUES IN MIX DESIGN AND CONSTRUCTION OF HOT MIX ASPHALT FOR AIRFIELDS

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ABSTRACT

The quality of hot mix asphalt (HMA) is significantly affected by the qualifications of personnel and condition of equipment used for mix design, construction, and quality control/quality assurance testing. This paper addresses some of the issues involving materials, mix design, and construction that have resulted in performance problems in the past. The paper includes some of the new test methods being used to improve the evaluation of the mix being produced as well as some of the construction methods that have been adopted to solve some of the construction related problems.

Some of the most common performance problems that have been observed on airfields include rutting, raveling, cracking due to aging of the HMA, and cracking of longitudinal joints. The primary causes of these problems are poorly constructed longitudinal joints, segregation, low in-place density, or overall lack of quality control/quality assurance. Using good construction methods and good testing techniques during quality control/quality assurance can minimize each of these performance problems.

Several improvements have been made in materials and mix design for hot mix asphalt. The Superpave system is an improvement over the Marshall method but it was developed for highways and should not be adopted for airfields without some modifications. Some airfield projects have used the Superpave procedures for mix design but more specific guidance for airfield pavements is needed before this new mix design system is widely used. This report addresses some of the issues facing the specifying agency when considering the use of Superpave for Airfields.

Mix types such as stone matrix asphalt (SMA) and open graded friction courses (OGFC) have been used on some airfield pavements but these mix types can be more widely used. SMA, which has not been used at all in the US on airfields, can be used to provide longer lasting mixes. Developments with polymer modified asphalts and fibers have improved the quality of OGFCs.

There are many new construction related techniques being adopted to improve the overall quality of hot mix asphalt. Some of these new techniques will be addressed in this report. Some of the techniques addressed include: use of material transfer vehicle for placement of HMA, use of vacuum sealing

procedures for measuring bulk density, use of cutting wheel in constructing longitudinal joints, and comparison of cores and nuclear gauges for measuring density. Other issues that will be addressed will be the status of performance testing and quality control/quality assurance charts.

KEY WORDS

SUPERPAVE / MIX DESIGN / QUALITY CONTROL/QUALITY ASSURANCE / HOT MIX ASPHALT / CONSTRUCTION

1. INTRODUCTION

Most hot mix asphalt problems that occur on airfield pavements can be traced back to problems with materials, mix design, and/or construction procedures or equipment. Hence, it is very important that those involved with design and construction of HMA have a good understanding of the basics so that decisions can be made during the construction process to ensure that a satisfactory pavement is built. Training is very important and consideration should be given to developing a certification program for technicians and inspectors.

The biggest problem with aggregates that has been observed is the use of an excessive amount of rounded materials (natural sands and improperly crushed gravels). These rounded materials can cause a mixture to lose stability and hence may result in some rutting. Another problem that is sometimes observed is the use of too much dust in the mix resulting in lower than desired optimum asphalt content. This low optimum asphalt content can cause loss of durability in the HMA mixture.

There have been a lot of questions in the past about the grade of asphalt binder to specify for HMA. There have also been many questions about whether a binder should be modified with a polymer or not. The new Superpave PG grading system has provided answers to some of these questions but there are still many questions to be answered. Since state DOTs have begun to specify PG graded asphalts, much technical support can be provided by the state DOTs since they have some experience with this new grading system for asphalt binders. Generally the asphalt binder grade is bumped to a higher grade for high traffic areas or in areas with slow moving traffic.

In the past, most pavements (highways and airfields) were designed with the Marshall mix design procedures but most state DOTs have begun to use the new Superpave mix design procedures. It is getting more and more difficult to find HMA contractors with personnel that are knowledgeable with Marshall procedures. Since most of the work that contractors do is for state DOTs or for city or county governments that use DOT specifications, it is becoming more difficult to find contractors with experience with the Marshall mix design procedures. It is believed that Superpave provides some improvements in the mix design system and thus should eventually be adopted for airfield pavements.

The most critical point for ensuring quality of HMA is in the quality control/quality assurance area. If an error is made prior to the QC/QA process it will likely be identified with a good QC/QA process and steps can be taken to correct the problem. One of the biggest problems during QC/QA is the lack of adequate inspection and oversight by the Government. It is also becoming more and more difficult to have Inspectors with a good understanding of what is necessary to ensure quality. At one time in the past the Government did all of the testing and made all decisions concerning mix adjustments to improve quality. The Government performed all of the mix designs and the quality control/quality assurance testing. During that time the quality of Government Inspectors and Technicians was excellent. Now the Contractor performs the mix designs and performs most of the testing during construction resulting in less and less experience within the Government. This has resulted in a lack of personnel working with the Government with significant experience in mix design and quality control.

The primary purpose of this paper is to provide some information about particular areas that will help the Government ensure that a quality product is designed and constructed.

2. MATERIALS

It is essential that high quality materials be used in the design and construction of HMA. Otherwise the performance will not be adequate. Good mix design and construction techniques cannot correct the problem of using poor quality materials.

One of the biggest problems with performance of HMA is the use of excessive amounts of rounded aggregates. Rounded aggregates typically come from two sources---uncrushed gravel and natural sand. These materials are readily available in many locations and they typically are less expensive than crushed materials so there is a tendency to use too much of these uncrushed materials. The specifications provide guidance about the use of rounded materials but these requirements are often overlooked.

For best results the HMA airfield specifications require that a high percentage of crushed aggregates be used for producing HMA. Rounded aggregates tend to produce mixes with inadequate strength and the use of rounded aggregates also often result in the asphalt stripping from the aggregate in the presence of moisture. Producing crushed aggregate from gravel requires that some amount of the finer portion of the gravel be removed prior to crushing the larger particles.

This is necessary to make sure that the aggregate is large enough prior to crushing to ensure that particles are adequately fractured (ASTM D5821) after crushing. Generally speaking to produce 12.5mm nominal maximum size aggregate requires that the material finer than 12.5mm be removed from the gravel prior to crushing. This procedure ensures that a large percentage of the material that is produced from crushing is fractured.

The specifications require that the coarse aggregate be crushed so that some minimum percentage of the aggregate has two or more fractured faces. Of course, this fractured face requirement is only an issue with gravels. Crushed stone will not have a problem with the particles being rounded since by its nature it has to be crushed. Gravels that meet the specification requirements may sometimes still be only marginally fractured due to the large amount of the surface area of a crushed aggregate particle that still may be rounded.

Many mixes are designed and placed with excessive amounts of natural sands. Most natural sands tend to be round which can result in loss of stability and an increase in rutting. One test that has been used to evaluate the shape of the fine aggregate is the fine aggregate angularity test (ASTM D1252). This test is an indirect measure of shape and texture of fine aggregates and can be helpful in evaluating the overall effect of the fine aggregate on predicted rutting of the mixture.

Generally natural sands would have a low fine aggregate angularity (often below 40) while fractured sands would generally have a higher fine aggregate angularity value (often above 45). There has been some criticism of this test because it sometimes rejects a good aggregate and it also occasionally accepts a poor aggregate. However, this is true for other tests as well and hence is not reason enough to drop this test from use. The fine aggregate angularity test has been shown to be useful in identifying poorly performing aggregates

A new method for grading of asphalt cements has been recommended by the new Superpave system. In this new grading system the asphalt cements are referred to as performance graded asphalts (PG graded ACs). The performance-graded asphalts specify the asphalt cement properties at high-expected pavement temperatures and at low expected temperatures.

A PG 64-22 is probably the most commonly used AC in the US. The grading indicates that this asphalt will perform at a pavement surface temperature up to 64 degrees C and down to –22 degrees C. This allows the designer to select a grade of asphalt cement that should perform satisfactorily at high temperatures (rutting) and at low temperatures (thermal cracking). With the penetration and viscosity grading systems the properties of the asphalt cement were specified at either high or intermediate temperatures (140 degrees F for viscosity and 77 degrees F for the penetration classification system) and the properties at other temperatures were essentially extrapolated.

3. MIX DESIGN

The Marshall mix design procedure was developed by the US Army Corps of Engineers for design of airfield pavements during World War II. The primary advantages of this mix design system were its portability, low equipment cost, ease of use, etc. This Marshall mix design method has proven to be a very effective method for designing mixtures. Many HMA mixtures have been designed over the last 60 years using the Marshall mix design procedures.

When performance problems have occurred, these problems are seldom the result of deficiencies in the Marshall mix design method. Performance problems are typically the result of lack of good QC/QA procedures and/or lack of enforcement of the specification requirements. This mix design method has been adopted in many countries throughout the world and is still widely used in many countries.

Mix design testing is sometimes performed on samples that are not representative of the materials to be used on a project. When this is done the mix design will have little or no use. Steps must be taken to ensure that representative samples of the aggregates and asphalt cements to be used are obtained in order to conduct an acceptable mix design.

It is always difficult to obtain representative samples from stockpiles. Stockpiles are typically where aggregate samples are obtained for mix design purposes. Taking these samples require that samples be taken at a number of locations around the sides of the stockpiles, about ½ up the side of the stockpile.

There are always issues caused by the mix being produced during construction having somewhat different properties than the mix designed in the laboratory. Use of improper sampling techniques is one potential cause for this difference. Another reason for differences between the mixes produced during mix design and construction is the breakdown of the aggregate during handling and plant production (this generates more material passing the No. 200 sieve). Rounding of the edges around the particles during the production process can also result in changes in the mixture properties.

This rounding of edges and generation of material passing the No. 200 sieve will result in a reduction in the VMA in the mixture and will likely cause low air voids in the compacted mixture if no adjustments are made to the mix design. Many mixes are placed where the mix design is used to set the mixture proportions and no verification testing is performed prior to the mix being produced and placed in the field. In most cases this will result in low laboratory air voids in the produced mix and will be very likely to rut under high tire pressures typical of many types of aircraft.

One of the biggest problems that occur during mix design is the lack of adequate compactive effort applied to the mixture. This can result from several items including the type of hammer used (mechanical hammer will almost always give a lower density than the manual hammer), condition of compaction pedestal (pedestal must be solid and must be tightly fastened to the floor and to the top plate), lack of adequate underlying support, or condition of hammer. Any of these problems will result in lower density during compaction resulting in higher optimum asphalt content. This higher asphalt content has often led to the design of mixtures that become unstable under the high aircraft tire pressures resulting in rutting and shoving of the mixture.

The test method (ASTM D1559) specifies that a manual hammer be used of compaction of the mixtures during the mix design process but almost everyone uses a mechanical hammer. If a mechanical hammer is used it should be calibrated to give the same density as that provided by manual hammers. This is very often not done. If the mechanical hammer is not calibrated to provide the same density as that produced with a manual hammer then the mix will be designed with a higher optimum asphalt content due to the lower density. This higher asphalt content has lead to rutting and shoving on a number of projects.

Compaction pedestals are often placed on floors in trailers or in other locations where the support is not firm. The preferred location to place a compaction pedestal is on a concrete slab placed directly on the underlying soil. If the pedestal is placed on a trailer floor it is essential that support be added directly underneath the floor by jacking against the floor or using some other technique. If this support is not provided the density of the compacted sample will again be too low. On some occasions it has been observed that the wood pedestal was cracked thus no longer providing the needed support. Careful inspection of the pedestal and underlying support is essential.

A new mix design method called Superpave has been developed, has been adopted by most state highway departments in the US, and has also been adopted in a number of other countries. This new mix design method uses a gyratory compactor to prepare specimen for testing. Early indications are that this new mix design procedure has some advantages over the Marshall procedure.

It is recommended that Superpave be adopted for airfields but this new design method should not be adopted for airfields until a thorough evaluation has been made and clear recommendations made about how it should be used. Some of the questions include: what is the recommended PG grade of AC to use? What is the correct number of gyrations to use? What should the gradation requirements be?

When Superpave was first envisioned, it was anticipated that it would include a performance test that could be used to help evaluate mixture quality. So far a performance test is not available, however much work is underway to develop and adopt a test(s) to predict performance. At this point the mixes designed with Superpave are primarily controlled by the material properties and the volumetric properties of the mix.

4. QC/QA OF HMA

It is essential that good QC/QA procedures be used to ensure that a quality product is obtained. Lack of adequate QC/QA has been one of the biggest reasons for poor performance in HMA mixes.

One of the leading problems has been the lack of full time inspection by the Government. Government inspectors are often assigned a number of projects to monitor making it difficult or impossible to ensure that a quality product is constructed. When personnel have to be involved in several technical areas it makes it much more difficult to specialize in any area. If a quality product is expected then it is absolutely essential that those technical personnel that are involved in a project be very knowledgeable with the product. This makes it very important that adequate training be available.

Quality control charts should be plotted and analyzed to ensure that mix properties are maintained in control. The two most common types of plots include plot of individual values and plot of running averages. Parameters that are often plotted include aggregate gradation (typically 3 critical sieve sizes), asphalt content, voids in laboratory compacted samples, Marshall stability and flow, and in-place density. Plotting these results on control charts allows the data to be summarized in a concise way that can be easily viewed and evaluated by anyone involved with the project. These plots also allow one to look at the plots and to very quickly determine if a property is out of control or going out of control. Control charts are an excellent way to summarize all of the data that is being collected on a project. More effort is needed to ensure that control charts are plotted and carefully evaluated to understand how well the mixture is being controlled.

In-place density is one area of construction that often does not meet the specification requirements. HMA pavements with low density will tend to have a loss in durability resulting in early cracking and raveling. The most common reason for low density is lack of the required number and quality of rollers. It is important that good rolling techniques and rollers of sufficient size and in good shape be used. Problems that are typically observed are rollers traveling too fast, insufficient roller weights and tire pressures (for rubber tire rollers), and poor condition of rollers.

When the air voids approach 8-10 percent, the mix often becomes very permeable resulting in some error when using the normal procedure for determining the density. The error occurs because water runs out of the sample when removing from the water and blotting to weigh in SSD condition in air. The error that results from this loss of water will result in the density appearing to be higher than the actual density. So even though the actual air voids are 8-10 percent it will appear, based on test results, that the air voids are lower. There is now a procedure that uses vacuum-sealed bags to seal the sample being tested so that loss of water during measurement of SSD weight in air does not affect the results.

There are a number of non-destructive devices that can be used to measure density of HMA. One type of these non-destructive devices is a nuclear gauge. These gauges are good to use for QC to help set rolling patterns. They do provide quick non-destructive density results. However, for acceptance, cores should be taken and tested to get a more accurate measure of the density. Even if the nuclear gauge is used for acceptance it is essential that the gauge be initially correlated to cores and that the accuracy of the nuclear gauge be continually verified by comparing to the density results of cores to ensure accurate results.

An airfield typically has a large number of longitudinal joints on a project. These joints tend to open and ravel with time if not properly compacted. It is difficult to obtain the desired density in these joints but it is possible if correct procedures are used. The best approach that has been observed is to use a cutting wheel to cut back the unconfined edge of the HMA so that the loose poorly compacted mixture is removed. This cut material can then be picked up and removed exposing a dense vertical edge. The adjacent lane can be placed and the density requirements can be met if the material is compacted using acceptable techniques. It is important that the joint be overlapped with approximately 1-2 inches of material when the adjacent lane is placed. The material should then be luted off the cold side onto the hot side but not broadcasted. It should be placed directly in the joint. It is also important that the thickness of the hot mat adjacent to the joint be approximately 15% greater than the adjacent compacted edge. If sufficient material is not placed adjacent to the joint it will be very difficult to adequately compact the joint to the desired density.

The use of material transfer vehicles (MTV) has increased in recent years. The MTVs have been shown to increase surface smoothness and to decrease segregation problems. The MTVs are operated separately from the asphalt paver and thus allow the paver to operate without having to be concerned with receiving material from the trucks etc. It is essential that the MTV device being used remix the HMA to help remove any segregation and to remix the material to remove temperature segregation. Some MTVs do remix the HMA while others do not remix the HMA.

The MTVs have also shown that the density can be improved with their use. Mix tends to cool on the top of the truckloads and around the sides while being hauled. This cool mix typically does not adequately remix with the remainder of the HMA during the construction process. MTVs have been shown to remix this cooler material with the remainder of the HMA therefore increasing the overall density and reducing the variability in density.

Stone matrix asphalt (SMA) mixtures have been used for over 30 years in Europe and for over 10 years in the US to provide a stable, durable HMA surface that provides premium performance. While most of the SMA mixtures have been used on highways there has been some use in Europe on airfields with very good success. Since these SMA mixtures do tend to provide improved performance it is important that more consideration be given to using these mixtures on airfields.

Open graded friction courses were widely used on airfields in the past but this use has decreased in recent years due to performance issues. A number of changes have been made in recent years that can improve the performance of the open graded mixtures. As a result of these changes consideration should be given to using these mixtures where appropriate. One change that has improved the overall performance of these open graded mixes is the greater use and better way of classifying polymer modified asphalt cements. Also, the use of fibers to minimize draindown has significantly improved the quality of these open graded mixtures.

Technology is now available to conduct some laboratory tests on a near real time basis and to automate many of the tests that are now being conducted. These automated test results along with other test results using conventional procedures can be combined, analyzed, and provided real time to all appropriate individuals through the web. An individual can then quickly review the analyzed test results as it is being collected on a particular project or on a number of projects.

One example of automation is measurement of gradation of the aggregate being fed into a plant. Samples can be automatically obtained and automatically tested in a matter of a few minutes. The data will be available electronically so that its use is maximized.

Another example for collecting real time data is the use of non-destructive density gauges that can measure the density on the pavement surface and electronically relay the results of the density and the location to any desired electronic address. All results can be obtained electronically and combined with other data that is obtained and analyzed to determine the overall quality of the construction.

5. TRAINING AND CERTIFICATION

It is absolutely essential that mix design and QC/QA personnel be properly trained. Too often personnel that are not well trained are placed in charge of work for which they really don't have the ability to properly manage. Training should be a requirement for those that will be involved in the design and/or construction of HMA mixes. It is also desirable that some type of certification program be established. At some point in time it should be required that the government personnel and the contractor personnel involved with any HMA project be certified through some national certification program. This will help to ensure that the personnel are qualified and will help ensure that a quality project is constructed.