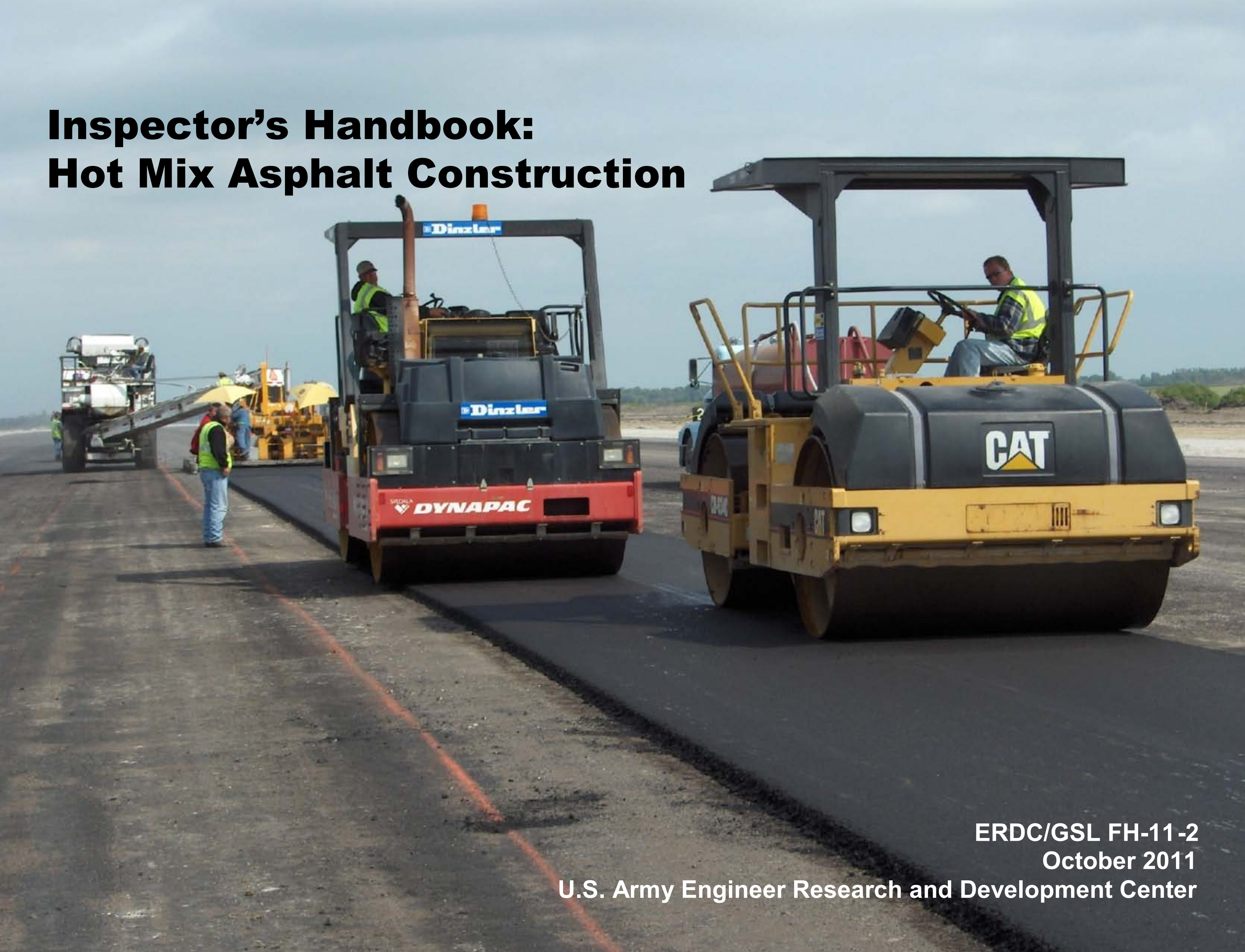
Inspector's Handbook: Hot Mix Asphalt Construction



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AUTHORS

Ray Brown
Vickie Pratt
Jeb S. Tingle
U.S. Army Engineer Research and Development Center (ERDC), Geotechnical and Structures Laboratory (GSL), Vicksburg, MS

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PREFACE

This handbook provides information to support inspectors in performing quality control and quality assurance activities during hot mix asphalt construction. It provides guidance on all aspects of hot mix asphalt construction and knowledge and assistance in understanding contract requirements.

DISTRIBUTION

Approved for public release; distribution is unlimited.

SAFETY

Recommendations provided in this document are intended to provide guidance for inspecting pavement construction. Standard personal protection equipment should be worn while performing any of the basic inspection steps. Personnel should wear hard hat, gloves, safety shoes, and safety goggles to prevent any injury.

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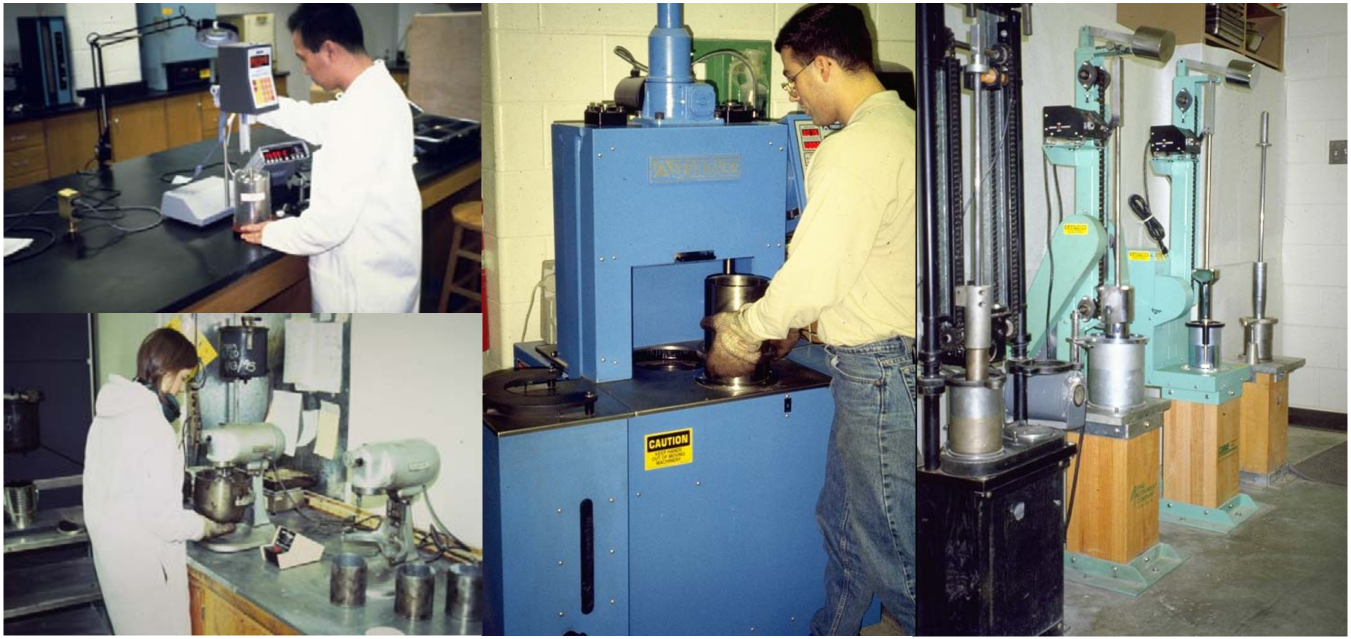
CAUTION

MATERIALS & MIX DESIGN

The materials used to produce hot mix asphalt (HMA) need to be of good quality. Once it has been established that the materials are of good quality, a mix design is developed to determine the optimum aggregate and binder proportions. The mix design determines the optimum asphalt content. Inspectors should ensure control of the following items in materials and mix design:

- Gradation of each aggregate used
- Percentage and properties of each aggregate used
- Amount of natural sand
- Fractured face count
- Gradation and plot of blend
- Compactive effort
- Plot of air voids vs asphalt content
- Optimum asphalt content
- Asphalt binder grade

Gradation of Each Aggregate Used

The gradation of each aggregate (coarse and fine) should be periodically checked to ensure it remains consistent and the total aggregate being produced meets design requirements.

Percentage and Properties of Each Aggregate Used in Designed Mixture

A trial and error procedure is used to determine the percentage of each aggregate to use in the designed mixture. The percentages should be checked and verified at the plant and samples of the aggregate should be collected from laboratory extractions performed on samples of the produced mixture.

Amount of Natural Sand

Determine the amount of natural sand used by measuring it from the rate of feed during the mixture production process. Too much sand can be a problem. For airfields, the amount of natural sand is limited to a maximum of 15%.

Fractured Face Count

This is only a problem with aggregates that are used from existing gravel sources. The gravel tends to be rounded and must be properly crushed to provide the required number of fractured faces. For airfields, it is required that at least 75% of coarse aggregate particles have two or more fractured faces.

Compactive Effort

For airfields, laboratory samples should be compacted with 75 blows with a Marshall hammer (manual) or 75 gyrations with the Superpave gyratory compactor. For roads, unless they have lots of trucks or other heavy vehicles, the number of blows or gyrations should be reduced to 50. If a mechanical hammer is used, check to see that it has been calibrated to provide the same density as the manual hammer.

Plot of Air Voids vs Asphalt Content

The mix design is typically accomplished to provide 4% air voids in the laboratory compacted samples. If the air voids are greater than 4%, durability problems might occur due to low asphalt content and the mix being permeable. If the air voids are less than 4%, rutting or bleeding problems might occur because of too much asphalt in mix.

Optimum Asphalt Content

A mix design is conducted prior to start of construction of a project to determine the optimum asphalt content. The optimum asphalt content may be adjusted once plant production starts since materials produced at the plant are not usually the same as those used in the mix design. The factor that primarily controls the optimum asphalt content is the air voids in laboratory compacted samples. This should be controlled near 4%. The asphalt cement content should be checked at the plant by testing loose mix (we typically use solvent extraction or ignition test). This can also be verified from laboratory extraction or ignition test of core samples.

Asphalt Binder Grade

The performance grading system specifies the grade of asphalt using the upper and lower ambient temperatures where the pavement is being constructed. Adding the high temperature and low temperature grades together will help determine if the asphalt cement is modified with a polymer. If the sum of the two numbers exceeds 90, the asphalt cement has likely been modified. A test certificate for each load of asphalt binder should be obtained and verified that it meets the specification requirements.

Plant Production

PLANT PRODUCTION

The production plant must be inspected from time to time so that the government personnel will know that the project quality is being controlled. Lack of control during plant production will result in mixture variability and reduced overall mixture quality. The items below can easily be checked during mix production.

- Handling of stockpiles
- Proportioning of materials being added
- Feeding aggregates into plant
- Continuous running operations
- Satisfactory mixture temperature
- Proper operation of storage bins and truck loading procedures

Handling of Stockpiles

Minimize Segregation

Stockpiles should be constructed to minimize aggregate segregation. The new material should be added in layers on top of the existing stockpile to ensure uniformity. No material should be added over the back or side of a stockpile. The coarse and fine aggregate sources should be kept in separate stockpiles. Stockpiles should not be handled excessively otherwise segregation and aggregate breakdown occurs. Once the material is delivered to the job site, the material handling should be minimized.

Photo 1. Improper addition of material. to a stockpile.

Photo 2. Coarse Aggregate Stockpile.

Photo 3. Fine Aggregate Stockpile

No Contamination

Contamination of stockpiles affects performance of the materials, so any stockpile that appears to be contaminated should be rejected until the contamination problem has been solved. The loader operator should properly work the face of the stockpile. The bucket loader should stay several inches above the underlying materials when loading the materials from the stockpile to prevent contamination. This is not a problem when stockpiles are placed on a paved surface. The natural sand stockpile should be observed for organics or clay balls. If these are observed, the stockpile needs to be rejected.

Photo 4. Stockpile contaminated with underlying materials.

Photo 5. Stockpile contaminated with deleterious materials.

Stockpiles Built to Ensure Good Drainage

Building a stockpile on a paved surface has some advantages. The paved surface allows water to drain out of and away from the stockpile faster. It also minimizes waste material and contamination at the bottom of the stockpile.

Proportion of Materials Being Added

Plant should be properly calibrated so that the desired percentage of each material is fed into the plant. If not properly calibrated, the specified aggregate gradation is not likely to be produced. Without calibration the contractor has to adjust the plant by trial and error which results in higher variation in the materials.

Feeding Aggregates Into Plant

The feed rate of materials is different when wet and dry. Pay close attention to moisture changes in the stockpile which will affect the final product. When there has not been rainfall for a period of time, the moisture content will not change significantly and there is little need to measure the moisture in the stockpile. After a significant rainfall, it should be checked, if using a drum mix plant, so that the moisture correction can be made to the aggregate and the proper asphalt content can be metered into the mixture. If the stockpile moisture content is high, it should be checked again on a 24-hr frequency until the moisture content stabilizes. The feeders need to be routinely inspected to ensure that they are feeding properly. This can help fix problems identified by visual observation before the mixture quality becomes unacceptable.

Continuous Running Operations

On many projects, the HMA is produced during the day with many startups and stops at the plant. Each time the plant stops and restarts, some of the mix produced will not have adequate quality. Minimizing stops and starts is preferred to try to ensure a continuous running operation, otherwise some material needs to be wasted during stop and during start up.

Satisfactory Mixture Temperature

Asphalt mixtures should never be heated over 350 deg F. Non-modified mixtures are typically heated closer to 300 deg F and modified mixtures are heated approximately 25 deg F higher. The temperature should always be high enough so that the mixture can be properly placed and compacted to the desired density without pulling and tearing of the mat.

Proper Operation of Storage Bins

Mixtures for airfields should be used the same day as produced. If the silo is insulated, the mixture can be stored for up to 8 hr. If not insulated, the mixture can be stored for no more than 3 hr. The asphalt mixture should be fed into a gob hopper at the top of the silo and dumped into the silo in batches to prevent segregation. The gob hopper needs to be inspected to make sure it is functioning properly. When the material is loaded into the truck from the silo, it should be dropped in batches. The gate at the bottom of the silo should be opened and closed repeating several times to minimize segregation of the mixture in the truck.

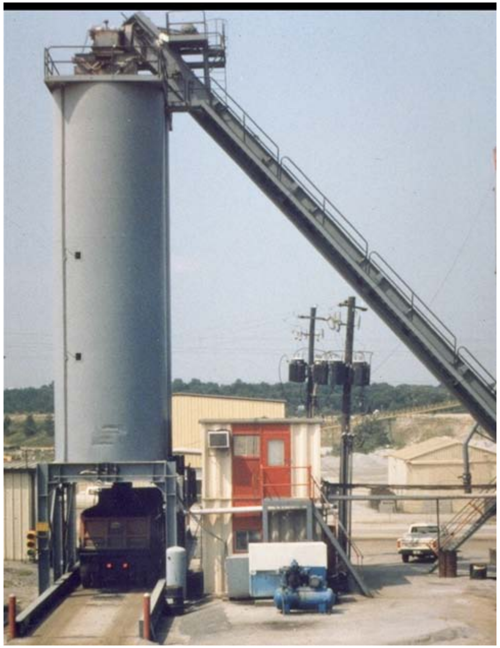

Photo 6. Storage silo.

Photo 7. Gob hopper.

Truck Loading Procedures

Minimize Segregation

Observe proper loading procedures to minimize segregation. The best way to load the truck is front or back first, the other end second, and the middle third. The HMA should be dropped in small batches into the truck.

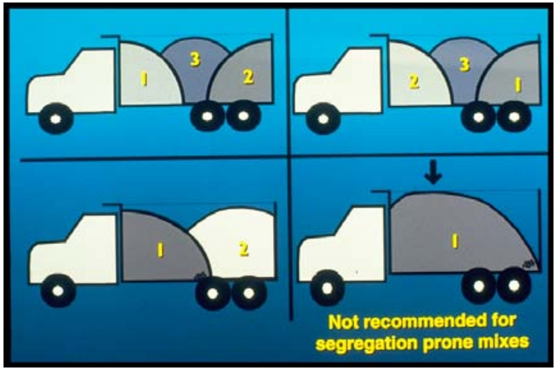

Photo 8. Load front first, back second, and middle third.

Photo 9. Dropping asphalt in small batches.

Contamination

Truck beds need to be cleaned before adding the asphalt mixture to avoid contamination.

Release Agent

Check to see that an acceptable release agent is being used to coat the truck bed so that the mix does not stick to the truck. Diesel fuel is NOT an acceptable release agent. Contractor is responsible for selecting an agent that is satisfactory.

Photo 10. Clean truck bed.

Covered Trucks

Trucks should be covered to help hold heat in and to prevent contamination while hauling to the site. The cover should be in good shape and fit snugly. Insulated trucks should be used when hauling long distances, typically more than 1 hr, and/or in cold weather, typically less than 50 deg F.

Photo 11. Use of tarp to cover load.

Surface Preparation

SURFACE PREPARATION

Surface preparation for the existing surface will be needed depending on the condition of the surface. If needed, repair work is performed to damaged areas. Milling operations are performed if necessary to create a good textured surface and cracks are sealed. The last step is to evenly apply a tack coat to obtain a good bond between the underlying material and the overlay. The items below need to be checked during surface preparation.

- Repair localized failures
- Ensure milling is smooth
- Seal cracks
- Ensure tack coat properly applied

Repair Localized Failures

Any damage to the existing pavement should be repaired prior to overlaying. The damaged material should be removed a few inches into sound material. All edges should be squared up and tacked with an appropriate amount of tack coat. The repair should then be filled sufficiently thicker than the depth of the patch with asphalt concrete mixture so that, when compacted, the patch is the same elevation as the adjacent surface. When compacted, the dry density should be within specification requirements. The layer thickness should be at least two times the maximum aggregate size but not thinner than 1.5 in. or greater than 3 in.

Ensure Milling is Smooth

Milling is a procedure used to obtain a desired surface elevation and to improve the surface on which the overlay can be applied. During milling, the surface materials are removed to a desired elevation within sound parent material which creates a better bond with the overlay. Milling can also remove paint or excess sealant. One of the problems to look for is scabbing. Scabbing occurs when some of the asphalt mixture is removed down to the interlayer due to lack of bond and some adjacent material is removed down to some point slightly above the interface. In order to prevent this scabbing, the depth of milling might be altered, the machine slowed down, or the milling teeth adjusted.

Photo 12. Scabbing.

Seal Cracks

Large cracks should be sealed to help prevent water from getting into the underlying materials. These larger cracks are generally sealed with a fine sand mix. Medium cracks from a width of approximately 1/2 in. up to 1 in. are sealed with a liquid sealer. Small cracks (less than 1/2 in.) should not generally be sealed since it will be difficult to get sealer into the cracks. These smaller cracks are generally removed when milling is performed.

Photo 13. Excess sealant.

Ensure Tack Coat Properly Applied

The tack coat needs to be applied properly to ensure a good bond between the existing surface and the overlay. The application rate should range from 0.05 gal/sq yd up to 0.10 gal/sq yd. It is applied with an asphalt distributor which should be calibrated. All the nozzles should be clean, the same size, and turned at the same angle. The spray bar height setting needs to be set for a double or triple overlap.

Photo 14. Asphalt distributor with uneven application.

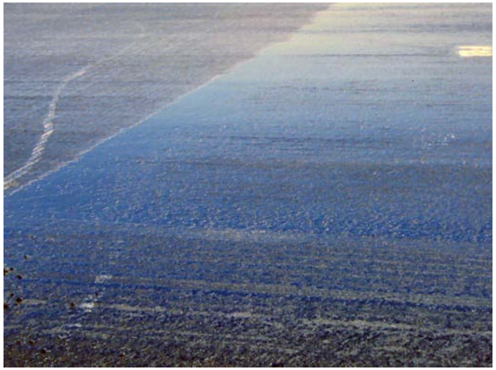

Photo 15. Excessive tack coat.


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PLACEMENT OF HMA

The objective of placing the HMA mixture is to achieve a desired thickness that is uniform and without any segregation while achieving a dense competent mat. There are many factors that affect this goal.

- Underlying layer in good shape
- Proper operation of equipment
- Uniform surface texture behind paver
- Satisfactory yield or thickness
- Minimize handwork

Underlying Layer in Good Shape

The underlying material should have no structurally deficient areas, a smooth surface if milled, and sealed cracks before placement of a new HMA. Once the underlying layer is covered, it is impossible to inspect the pavement and see any problems in the underlying layer. Surface problems can be existing or can be caused by construction equipment so inspection is important immediately prior to placement of the HMA.

Proper Operation of Equipment

The paver should be in good shape and set up properly. The screed of the paver should be checked to ensure that it is set up with proper crown or no crown. The bottom of the screed should be clean and in good shape. Any screed extensions are heavy duty and are accompanied with a proper extension of auger. The paver needs to constantly move forward to ensure that the placement of asphalt is to the desired thickness and without any segregation. The paver hopper should not run low of material during placement or segregation is likely to occur.

The material transfer vehicle (MTV) has become very popular in the recent years and is required for airfield construction. This self propelled vehicle with a radial arm improves pavement smoothness since trucks don’t come in contact with the paver. The operator must keep the paver moving in a straight line and the MTV helps to support this. The MTV has reduced material and temperature segregation due to the remixing of the material prior to being fed into the paver and it provides a surface with improved smoothness. The rollers should be in good working order with smooth tires/drums and working water distribution systems to ensure the wheels/drums remain clean. The rollers should stay close behind the paver to ensure that the mix is compacted immediately before it cools.

Photo 16. Dumping directly into paver.

Photo 17. Use of material transfer vehicle.

Uniform Surface

The material behind the screed should be placed with no segregation, pulling, or tearing and compacted to some initial density. If the paver moves too fast, the mixture may not be uniformly placed. The contractor should stop the paving operation when the surface is not uniform until the problem has been identified and corrected.

Photo 18. Good surface.

Photo 19. Segregation of asphalt concrete.

Layer Thickness

The asphalt mixture should be placed to the specified thickness. HMA compacts about 20 to 25% so the original thickness has to be about 20 to 25% more than the desired final thickness. For example, a 2-in. compaction layer requires a loose placement at about 2.5 in. Thickness can be monitored by actually checking the layer thickness from cores obtained for measurement of density. Thickness can also be controlled by checking the yield of a number of trucks. Knowing the amount of material placed, the bulk density of the mixture, and the square area that it covers allows one to calculate the layer thickness.

Minimize Handwork

Use of hand tools should be kept to a minimum. Segregation can be caused by broadcasting materials across the surface of the HMA. If there are low spots in the completed surface, skin patching should not be done. The low spot should be left in place or the material should be removed with a milling machine or cut out entirely and replaced with enough asphalt to fix the problem.

Photo 20. Excessive handwork.

Photo 21. Segregation caused by handwork.

Compaction

COMPACTION

Compaction is very important to ensure good performance of the HMA. It is needed to provide good strength, to reduce moisture penetration, to minimize additional compaction under traffic, and to prevent rapid oxidation of the mixture. There are several factors affecting the compaction process including:

- Proper equipment
- Good rolling pattern
- Air/Mix temperature
- Layer thickness
- Longitudinal joint

Proper Equipment

The equipment needs to be inspected to ensure that the rollers are in good shape. A sufficient number of rollers are important when compacting the HMA mixture. If the weather is cooler, the number of rollers may need to be higher in order to compact the asphalt before it cools. It is better to have more rolling equipment than to speed up the rollers. The normal roller speed range is 3 to 5 miles per hour. Speeding up the rollers will reduce the energy that the roller imparts into the AC mat and will not be effective in obtaining adequate density. The rollers should be in good working order with smooth tires/drums and working water distribution systems to ensure the wheels/drums remain clean. The rollers should stay immediately behind the paver to ensure that the mix is compacted prior to cooling. The mix does not cool very quickly when in trucks but as soon as it is placed in thin layers the cooling rate increases quickly.

Good Rolling Pattern

The rollers should move slowly and make gradual turns to ensure that roller marks are not excessive. Rollers should avoid making sudden stops, starts, or turns. Depressions will be created if the rollers stop for a significant amount of time on the hot HMA mat. Contractors generally have rolling patterns that they feel comfortable using and this is a good starting point. However, excessive rolling with steel wheel rollers can cause checking (small cracks) with some mixes. Rubber tire rollers do not cause this type of cracking and are often desired. Rubber tire rollers do, however, tend to pick up the HMA that sticks to the tires.

Air/Mix Temperature

The air temperature needs to be monitored to ensure the HMA is compacted prior to cooling of the mat. The lower the air temperature the more difficult the HMA is to compact. In cooler weather, more rollers need to be added since the mixture cools faster.

The asphalt mix should be placed at a temperature that allows the mix to be rolled immediately. The temperature for most mixes is approximately 300 deg F or a little less when compaction begins. The minimum temperature depends on the grade of asphalt and layer thickness but it must be high enough to provide enough time to be placed and adequately compacted prior to the mix cooling excessively. For most mixes the placement temperature should be at least 275 deg F but this will vary considerably between mixes. The maximum limit that the mixture is allowed to be heated to is 350 deg F. If the temperature is increased to or above this limit, damage is done to the asphalt binder resulting in loss of pavement life and the rollers will have to wait for the mix to cool prior to rolling the mix which is also undesirable.

Layer Thickness

Thicker sections are easier to compact than thinner sections. It is more difficult to maintain good smoothness for thicker sections. The minimum layer thickness should be at least two times the maximum aggregate size or three times the nominal maximum aggregate size. Generally 1.5 in. is about the minimum compacted thickness that one would want to place in one lift and around 3 in. is about the maximum compacted lift thickness. Thinner sections tend to cool quickly and the coarse aggregate tends to bridge preventing good compaction. Thicker sections are easier to compact but more difficult to obtain good smoothness.

Longitudinal Joint

Poor longitudinal joints are one of the biggest problems with HMA construction. The best way to compact cold joints is to use a cutting wheel to cut back the edge of the paving lanes that have become cooled. Tack should be sprayed or applied in a way that provides an even coating without material being spread on areas other than the vertical edge. The joint should be rolled first since it is the most difficult portion of the mixture to be compacted. It is generally accepted that a rubber tire roller can help compact the joint better than when using steel wheel rollers only. Be sure that there is no excessive pick up of the mixture on the rubber tires. Several methods have been used for minimizing pick up including: ensuring the tires are hot when rolling and use of some type of release agent (no diesel fuel) on rubber tires. The ultimate proof of good density in the joint is test results from cores taken directly in the joint.

Photo 22. Rolling longitudinal joint.

Quality Control

QUALITY CONTROL

It is very important that the compacted HMA mat be inspected and tested for quality control. The following section details typical quality control activities:

- Quality control plan
- Test results
- Control charts plotted
- Deficiencies and corrective action
- Smoothness and grade testing
- Density testing

Quality Control Plan

The contractor is required to provide a quality control plan to show the government that a plan is in place to ensure control of the constructed product. It is important that this plan be reviewed regularly and changes made if necessary.

A Typical Quality Control Plan answers the following:

- Provide a clear description of what will be done to control quality?
- How will the aggregate and mixture volumetrics be controlled?
- When will QC reports be provided to the government?
- What to do if material does not meet the specification requirements?
- Who will determine and how will core locations be determined?
- When will cores be taken?
- Who will cut cores?
- Who is point of contact for the contractor about quality issues?

Test Results

Quality control test results should be provided to the government within 24 to 48 hours of testing. The tests should include: aggregate gradation, asphalt content, air voids, voids in mineral aggregate, stability, flow, in-place density in the joint and mat, smoothness and grade. The report should include inspection observations, laboratory test results, identify results outside the specification requirements, and provide a plan for what actions will need to be taken as a result of tests results and inspections.

Control Charts Plotted

Plotting control charts allow data to be summarized graphically. The plots help show trends in data and identify cause and effect when there is a mixture problem.

Deficiencies and Corrective Action

The quality control report should identify all deficiencies and describe what action will be taken to solve deficiencies.

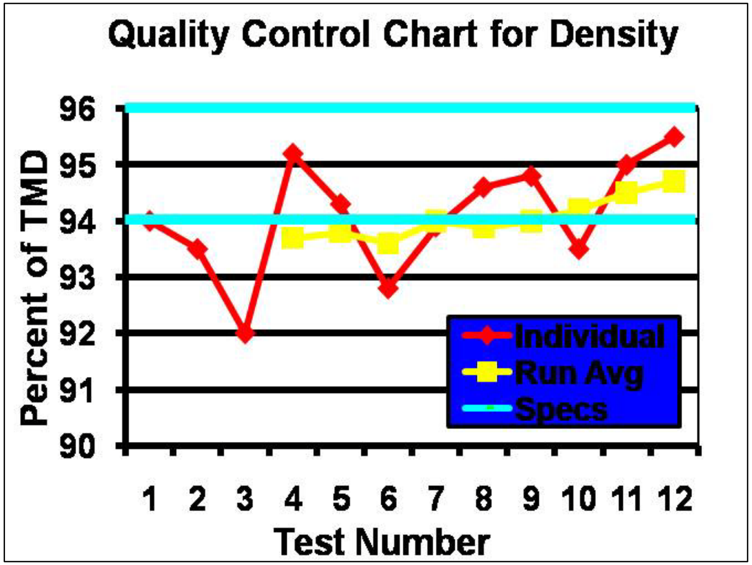

Figure 1. Quality control chart.

Smoothness/Grade Testing

A 12-ft straightedge is used to measure smoothness on airfields and it is typically required that no more than 1/8- to 1/4-in. deviation between the pavement surface and straightedge be measured depending on the location on the airfield. It is required to take measurements in between two points where the straightedge is touching the pavement surface. This test generally looks for bumps and dips in the pavement. One method used to control the grade is the use of stringlines set at the designed grade. The posts should be set up 25 ft apart and the stringlines should not sag between the posts.

Photo 23. Paver with skis.

Photo 24. Use of stringline to control grade.

<u>Density Testing</u>

Mat density should be measured by taking cores from the in-place pavement. This should be done by using random sampling instead of sampling based on visual condition of the pavement. The cores are required to be 4 or 6 in. in diameter. Typically for an airfield, four cores in the mat and four cores in the joints are taken each day of work. Additional cores can be taken in areas that look to be low but the testing in these areas is only representative of the immediate area in question and this is only done as needed.

Joint density should be measured by taking cores directly from the joint. The core size should be 4 to 6 in. in diameter.

Mat thickness should also be measured from the core samples.

Generally the density requirements for the mat and joint for airfields are:

- Mat: 94 to 96% of theoretical maximum density (ASTM D 2041)
- Joint: 92 to 96% of theoretical maximum density

Performance Problems

PERFORMANCE PROBLEMS

Various problems can occur with asphalt pavements. Most problems are a result of design or construction deficiencies and can be prevented if the right procedures are used during the construction process. Typical problems include:

- Rutting
- Bleeding
- Surface distortion
- Cracking

Rutting

Rutting occurs when traffic passes over the pavement a number of times causing a depression. The problems can be structural inadequacy or a mix problem. A structural problem is caused by error in design, failure to meet material quality requirements, deficiency in thickness, lack of compaction, or more traffic applied than considered during design. Of the structural problems, the material quality and compaction can be closely monitored during the construction process. An asphalt mix problem can be caused by use of rounded gravels not crushed very well, use of too much natural sand, and excessive asphalt content. The material quality should be verified by performing laboratory testing to determine the crushed faces of the coarse aggregate and the gradation to monitor the natural sand content. The asphalt content and air voids in lab compacted samples should also be verified at or near 4% to ensure that there is not too much asphalt in the mixture.

Photo 25. Rutting caused by asphalt mixture problem.

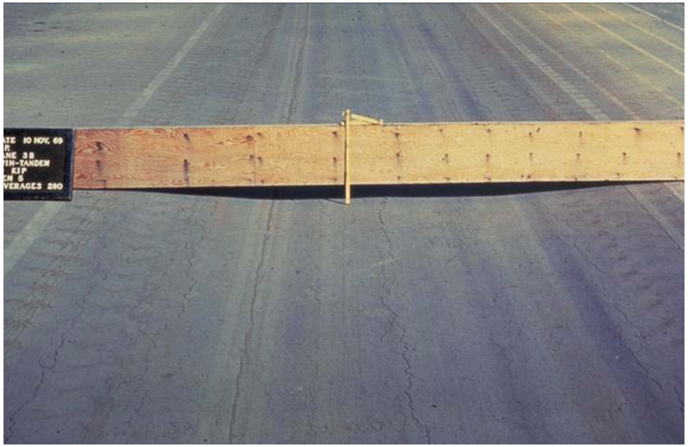

Photo 26. Rutting caused by problems underneath asphalt mixture.

Bleeding

Bleeding occurs when excess asphalt binder migrates to the surface under traffic. Bleeding occurs when the asphalt cement in the mixture is too high and the in-place air voids are too low. This generally happens in high traffic areas such as roadways or taxiways where channelized traffic occurs. The amount of asphalt cement can be monitored at the plant by sampling and conducting solvent extraction or ignition test on the asphalt mixture and after placement by coring and performing laboratory solvent extraction or ignition test on the core sample.

Photo 27. Bleeding of asphalt mixture.

Surface Distortion

Surface distortion can occur immediately after construction when the asphalt mixture is in its most tender condition. This problem can be magnified when sealers are used since they will slow down oxidation of the surface binder and will actually add additional asphalt to the surface. As time passes, the asphalt mixture stiffens due to the oxidation of the binder near the surface which helps to reduce the potential for this problem.

Cracking

Reflective Cracking

Reflective cracking is caused when an asphalt overlay is placed over an asphalt or concrete pavement that has active moving cracks. The cracks in the surface mix are caused by the movement of the cracks in the underlying layers. The procedure that works best for preventing these cracks over concrete pavements is to rubblize the underlying concrete prior to placing the overlay.

Photo 28. Reflective cracking.

Photo 29. Reflective cracking.

Thermal Cracking

Thermal cracking is caused by the shrinkage of asphalt pavement caused by low temperatures. Thermal cracking looks very similar to reflective cracking except that the cracks generally start at the top of the pavement and propagate downward. This type of cracking is minimized by selecting the correct grade of asphalt cement to use, ensuring the mix is not overheated during construction, and obtaining compaction that meets the specification requirements.

Longitudinal Joint Cracking

Joint cracking is caused by lack of adequate density in the joints and usually occurs during cold weather. This type of cracking can be prevented if good compaction is achieved during construction. Sealing the cracks can help improve the life of the pavement by reducing the amount of water that seeps into the pavement and by reducing the potential for raveling and FOD.

Photo 30. Cracking in joint.

Checking

Checking can possibly occur during compaction. This type of cracking occurs when the mixture moves laterally while being rolled with steel wheel rollers. This often results in a loss of bond to the underlying layer. If the cracking is minimal and only occurs in a few localized areas, the fine cracks are not a significant problem. These cracks generally only penetrate about ¼ inch. Checking is minimized by using a rubber tire roller.

Photo 31. Checking under steel wheel rollers.

Slippage Cracks

Slippage cracks occur when the top layer slips over the underlying layer. The cause of slippage cracks is typically associated with inadequate tack coat and/or inadequate cleaning of existing surface before an overlay is applied.

Photo 32. Slippage of asphalt mixture over underlying layer.

Alligator Cracking

Alligator cracking occurs when the pavement structure is not sufficient to support the traffic. The pavement generally ruts first and then fatigue cracks appear along the length of the ruts. As traffic continues, lateral cracks will connect the longitudinal cracks and become increasingly worse with applied traffic. Several things could cause this type of cracking such as access to free moisture, lack of thickness of underlying layers, or insufficient material quality.

Photo 33. Alligator cracking.

Photo 34. Alligator cracking.

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Brown, Ray. (2011). “Inspector’s Manual for Hot-Mixed Asphalt and Portland Cement Concrete Pavement Construction.” United Facilities Criteria UFC 3-250-XX, U.S. Army Engineer Research and Development Center, Vicksburg, MS.