TOPIC 6

Production and Construction Issues for Moisture Sensitivity of Hot-Mix Asphalt Pavements

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Today we are demanding more from our pavements than ever before. As we continue our efforts to design and construct hot-mix asphalt (HMA) pavements that perform better and last longer, we must consider all of the factors involved in the ultimate performance of the pavement. Moisture-induced damage within HMA has been described as a national issue leading to the decreased life of our nation's roadways. As we consider the nature of materials and specifications across the country, it is important to understand the impact that both material production and construction can have on the ultimate performance of the HMA pavement in the field.

During the design of most HMA mixtures, tests to evaluate the potential for moisture-induced damage are conducted. For most states in the United States, AASHTO T283, "Resistance of Compacted Bituminous Mixture to Moisture Induced Damage," or a modified version, is used for this purpose. If a designed mix meets the requirements of this test, it is assumed that the mix will perform in the field with respect to resistance to moisture damage. However, if the designed mix is not produced and constructed properly, moisture damage can still occur as a result of construction deficiencies.

There are a number of production- and construction-related issues that can affect the ability of an HMA pavement to resist moisture damage. Factors from the handling of stockpiles through placement and compaction of the HMA on the roadway can affect the potential for moisture damage in the field. In fact, mixes that are marginal with respect to resistance to moisture damage that are well constructed on the roadway may perform better than mixes with a low potential for moisture damage that are poorly constructed. Therefore, the proper production and construction of HMA pavements is vital to providing roadways that will perform up to and beyond their design lives.

CAUSES OF MOISTURE DAMAGE

Before discussing the production and construction factors that can affect the resistance of HMA to moisture damage, the mechanisms that cause moisture damage must first be defined. There are two primary modes of moisture damage: adhesive and cohesive failure. Adhesive failures occur when the asphalt binder separates from the aggregate, typically in the presence of water. Cohesive failures occur because of a weakening within the asphalt binder film coating the aggregate, generally owing to moisture effects. The literature describes five primary mechanisms that lead to either of these failure modes: detachment, displacement, pore pressures, hydraulic scouring, and spontaneous emulsification (*1*, *2*).

Detachment is described by a microscopic separation of the asphalt film from the aggregate by a thin layer of water without any obvious breaks in the film (*2–4*). Detachment is believed to be caused by incomplete drying of the aggregate during plant production. Excessive moisture not removed from the aggregate can later migrate within the interstitial pores of an aggregate and lead to detachment of the asphalt film.

Displacement is described as the preferential removal of the asphalt film from the aggregate surface by water (*1–3*). This occurs when water is absorbed into an aggregate through a break in the asphalt film, owing to incomplete coating of the aggregate, rupture of the asphalt film, or loss of dust coatings around the aggregates. Rupture of the asphalt film can occur as a result of fracturing of the aggregates during field compaction, in-service traffic, or environmental action such as freeze–thaw (*1*). Displacement occurs because the aggregate has a higher affinity for water than for the asphalt binder. Therefore, the water displaces the asphalt binder around the aggregate.

The pore pressure mechanism occurs from the presence of water in the interconnected voids of the HMA (*5*). Densification of the HMA under traffic causes the interconnected voids to become isolated (no longer interconnected), and the water is trapped within these isolated voids. As traffic passes over the HMA, pore pressures increase and then decrease again after the load passes. This continuous increase–decrease of pore pressures can rupture the asphalt film and lead to displacement or hydraulic scour.

Hydraulic scour occurs in surface mixes from the application of vehicle tires on a saturated HMA (*1*, *2*). Water is compressed into the pavement in front of the tire, resulting in a compressive stress within the interconnected void structure. Once the tire passes, a vacuum forms, pulling water back out of the interconnected voids. This compression–tension cycle occurs every time a vehicle passes over the pavement and can lead to moisture damage due to displacement or spontaneous emulsification.

Spontaneous emulsification occurs when an inverted phase emulsion (water suspended within asphalt) forms within the HMA (*1*, *2*). Unlike the previously mentioned mechanisms, which result in adhesive failures, this mechanism leads to cohesive failures. In the field, spontaneous emulsification failures can be difficult to detect because no loss of asphalt coating can be observed.

In describing the production and construction factors that can affect moisture damage, each of the aforementioned mechanisms of failure can occur. It is, however, important to note that for any of the five mechanisms to occur, generally, water must be present either within the aggregate or within the pavement. Sufficient drying of the aggregates and constructing the pavement in such a way that the pavement is impermeable will help ensure that moisture damage will not occur.

For the purposes of this paper, production factors shall include the handling of materials once at the HMA facility through completion of the mixing process within the plant. Construction factors shall include the loading of produced mixture through compaction of the roadway. In addition, we have assumed that a mix has been designed and approved to comply with all applicable specifications.

OBJECTIVE OF THE PAPER

The objective of this paper was to highlight various production and construction issues that can increase the potential for moisture-induced damage in HMA pavements. Also, good production and construction practices are discussed to help decrease the potential for moisture damage in HMA pavements.

MATERIAL PRODUCTION ISSUES

For the purposes of this paper, the production of HMA begins with the stockpiling of aggregates on the HMA plant site. Once the stockpiles have been placed, the aggregate must travel through the cold feed system (no matter the plant type) to be heated and combined with the liquid asphalt binder. After the mixing of the aggregates and binder has been completed, the mixture must be loaded for transportation to the roadway. In this paper, material production encompasses all of the activities up to loading of the trucks for transportation. Within this section, the various steps of HMA production and their potential effect on moisture-induced damage are discussed. As will be seen throughout this section, two recurring issues are related to moisture-induced damage: segregation and the moisture content of the aggregates. Segregation prevents the HMA from being produced to meet the job mix formula. If the mix does not meet the job mix formula, then the results of moisture susceptibility testing during mix design are not applicable. Moisture remaining in the aggregate after the asphalt binder has coated the aggregate can lead to detachment of the binder film during service life.

Stockpile Handling

It is well known that the quality control of the HMA product, regardless of plant type, begins with the aggregate stockpiles. This also includes recycled asphalt pavement stockpiles. The goal is to produce a mix that is as close to the mix design target values as possible and to consistently provide that material to the paving train for placement in the field. The equipment used for production purposes can blend the various stockpiles to be used in the HMA consistently, but it cannot control the gradation of the individual stockpiles. Therefore, it is important to provide consistent and uniform aggregates to be blended. That is, even the most accurate production facility, when provided with aggregates that are highly variable in gradation or moisture content, cannot provide a consistent material at the design target values.

The foundation for aggregate stockpiles should be stable, clean, and dry (*6*). Stable foundations are needed so that the construction equipment can efficiently build the stockpiles and remove material from the stockpiles. Clean foundations ensure that foreign materials, such as roots, soil, or grass, are not picked up with the aggregates. Foundations should be constructed such that water does not pond underneath the stockpile, thus increasing the moisture content of the aggregates near the bottom of the stockpile.

Aggregate stockpiles should be built to minimize segregation of the coarser particles. This can be done by using sound stockpile building practices (*7*). It is also important that there is sufficient space between the stockpiles so that cross-contamination between stockpiles does not occur. Stockpiles should also be built to be free draining, to ensure that the moisture content within the stockpile stays as low and consistent as possible. A method of preventing water from infiltrating into the stockpile is to cover the stockpile using some type of a roof structure (Figure 1). Tarps are generally not recommended for covering stockpiles because moisture tends to collect under the tarp.

Proper handling techniques should be used to minimize segregation. Excessive handling of the aggregates can also cause degradation of the aggregates, which causes a change in the gradation of the stockpile.

With regard to the various methods of treatment for moisture sensitivity, the lime slurry marination (LSM) procedure does affect the aggregate stockpiles. Some states require the aggregate stockpiles to be treated with lime slurry and then allowed to marinate for a minimum specified time. Typically, there is a minimum time limit for this procedure and a maximum time limit after which the stockpile is deemed to be unsatisfactory for use in the product. Again, the consistency and uniformity of the stockpiles and their treatment are extremely important factors in the material production process. Possible factors for consideration for the LSM process are as follows:

- Adequate stockpile area for the maximum anticipated production or marination period,
- Overhead protection of stockpiles in case of inclement weather (rain),
- Positive control of water runoff from stockpiles (many states have specific requirements concerning storm water runoff),
- Control and regulation of marinated materials (i.e., first in, first out), and
- Monitoring and control of moisture content of stockpiles.

Again, the material producer should employ the best available practices for its specific conditions and location to control the quality of the aggregates and supply a consistent and uniform material to the production facility.

FIGURE 1 Covered aggregate stockpiles and cold feed bins.

Cold Feed System

The cold feed system includes cold feed bins, collecting conveyor, and charging conveyor. To produce a uniform, high-quality HMA, it is imperative that the entire cold feed system be properly calibrated. Aggregates from the stockpiles are placed in the cold feed bins by front-end loaders. The use of bulkheads with the cold feed bins is generally sound practice to prevent aggregate from overflowing from one bin to another. Commingling of different stockpiles within the cold feed bins can alter the design gradation (*6*). Aggregate is discharged from the bottom of the cold feed bin onto a feeder belt. This belt then takes the aggregate to the collecting conveyor. The aggregates then generally pass through a scalping screen, to remove oversized aggregates or deleterious materials, and fall onto the charging conveyor, which takes the aggregate to the drum for heating.

In a number of states, hydrated lime is required as an antistripping additive; it is added either between the collecting and charging conveyors or on the charging conveyor. In adding hydrated lime, it is important to understand that the purpose of the hydrated lime is to change the chemical charges of the aggregates so that the asphalt binder adheres better to the aggregate. Therefore, the aggregates and hydrated lime must be completely mixed. Hydrated lime may be mixed with the aggregates by falling through the scalping screen; some states require a pug mill between the collecting and charging conveyors. Regardless of the method by which the hydrated lime is introduced, some moisture is required for the chemical reaction to occur. Also, for best results, the hydrated lime needs to be evenly distributed within the aggregate.

Drying and Mixing Process

The goals of the drying and mixing process are the same no matter the plant type used:

1. Completely dry the aggregates.
2. Add the proper proportions of asphalt binder and aggregates.
3. Produce properly coated HMA meeting the job mix formula.

Aggregates not properly coated with asphalt binder lead to a higher potential for moisture damage, owing to displacement. A good, sound quality control/quality assurance program will ensure that the two latter goals are met. However, depending on the gradation and moisture content of the aggregates, the amount of drying within the drying process can change. Aggregate blends that contain a large percentage of coarse aggregates (e.g., coarse-graded Superpave®, stone matrix asphalt) may require more drying time than do blends with a higher fraction of fine aggregates. Regardless, the moisture content of the aggregates should be monitored during production. At least two moisture contents should be obtained per day, and more if the moisture conditions change during the day (e.g., rain) (*6*).

Complete drying of the aggregate can be achieved, no matter the plant type, by maintaining a steady rate of HMA production. The rate of production should match the paving operation on the roadway. If the rate of production is too high, the aggregates are not exposed to the heat within the drum long enough to become dry. Proper maintenance of the flights within the drying drum is also vital to achieving the proper aggregate veil within the drum to ensure drying. In addition, the angle of the drum can be decreased slightly to keep the aggregate in the drying zone longer.

Quality Control and Assurance

Modern HMA production facilities are capable of producing large quantities of materials. To ensure success, the plants should be calibrated frequently to verify that all of the components of the facility are working within acceptable tolerances. Some states have a certification procedure that requires each facility desiring to manufacture material for the agency to verify its operational accuracy, to maintain its certification. If the state or local agency does not have such a requirement, it is highly desirable that the plant operator perform a similar procedure to ensure that the plant is operating within its expected tolerances.

The proper control of each of the mix design components is critical to produce a mix that is as close to the design target values as possible. Some of the issues for consideration during the production process are as follows:

- Control and monitoring of moisture content (particularly with the LSM process; additional moisture content can reduce plant production capacity);
- Control of introduction of antistrip treatment material;
- Adequate mixing of the aggregates with lime (dry or slurry);
- Proper introduction of liquid antistrip into the mix or binder (some agencies allow the addition at the refinery or terminal; others require the addition at the HMA production facility);
- Proper drying of the aggregates;
- Proper handling of baghouse fines; and
- Proper charging of silos.

As in any production process, quality control is an integral and necessary component. The proper control of the various aggregate sizes, their moisture content, the binder, the antistrip treatment material, baghouse fines, mix moisture, mix temperature, and other critical components is very important to the production of a consistent, uniform material meeting the design target values. The continuous testing, monitoring, and adjustment of the plant are vital in supplying a mix to the HMA paving train that meets all of the design requirements.

MATERIAL CONSTRUCTION ISSUES

Once mixture is produced in the HMA facility, it must be loaded into trucks, transported, placed, and compacted to provide the final riding surface. As will be discussed in this section, segregation will again be a major contributor to increase potential for moisture damage. However, unlike the physical segregation within the production process, segregation can also take the form of thermal nonuniformity. Maybe the most important issue related to the construction process is low density. Areas of low pavement density can be permeable to water. If pavements are constructed to be impermeable, then the potential for moisture damage is greatly decreased. The following sections discuss the effect of construction on moisture damage.

Loading of Mixture

During loading of the mix into trucks, the primary mode for increasing the potential for moisture damage is improper charging of the truck bed. Improper charging of the truck bed can lead to segregation on the roadway. Brown et al. (*8*) have shown that segregation can lead to increased permeability within the completed pavement. In turn, greater permeability allows water to more easily penetrate the pavement and bring about moisture damage by any of the five mechanisms of failure.

Transportation of Mixture

The next phase of the construction process is the transportation of the HMA to the project site. An area of concern during transportation is the draindown of asphalt binder from the coarse aggregate. This usually only occurs for mixes having very thick binder films, especially coarse-graded mixes like open-graded friction courses (OGFC) or stone matrix asphalt (SMA). This draining of the asphalt binder from the coarse aggregate structure can be translated to segregation on the roadway. As a result of the draindown, the coarser aggregates are not coated with sufficient asphalt binder, and therefore moisture damage can occur owing to displacement, detachment, or hydraulic scour in the presence of water.

Another potential problem during the transportation of HMA to a job site is excessive cooling of the mix. If the HMA mix has cooled below a certain temperature, which is asphalt binder and mix specific, it will be difficult to achieve proper density on the roadway. Insufficient density allows water to permeate into the pavement.

Paver Operations

Once at the project, the HMA must be loaded into the paver. It is important that there be coordination between the plant and paving train. Enough mixture must be supplied to the paving train to prevent the paver from stopping. However, the supply of mix to the paving train should not be such that there are an excessive number of trucks waiting to empty. As the trucks wait, the mixture cools.

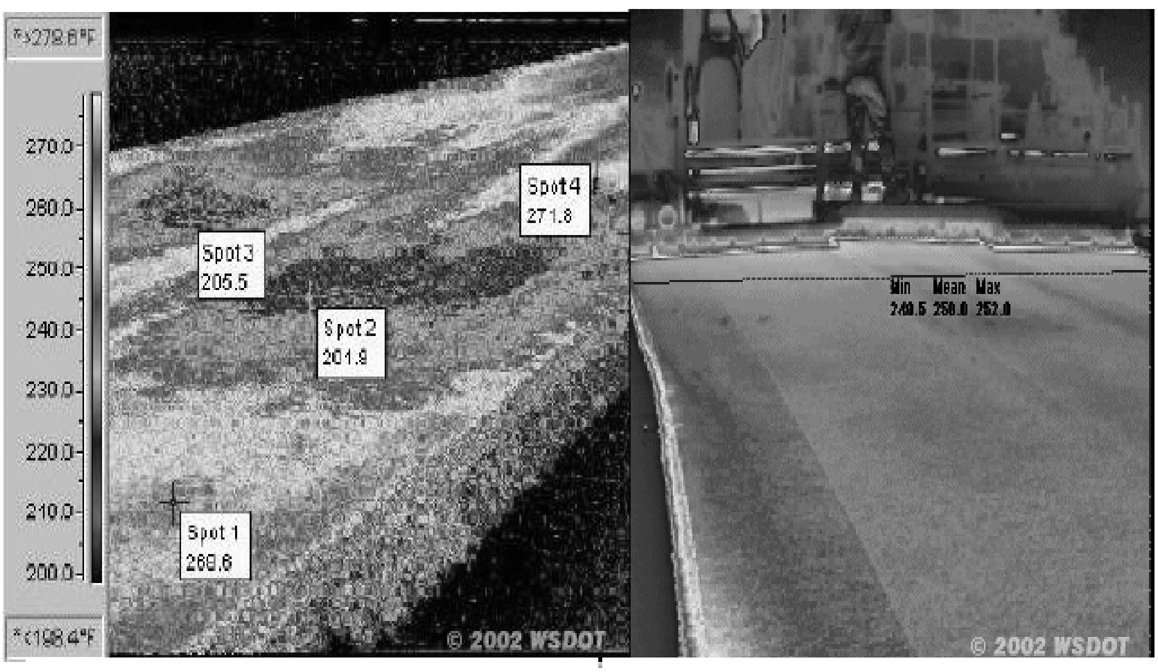
There are numerous methods for loading pavers. Depending on the type of truck transporting the HMA—end dump, bottom dumps, or flow boys—the exact method of charging the paver can be different. The existence of a material transfer vehicle can also affect how HMA is charged to the hopper of a paver. The primary problem related to charging a paver is segregation, whether physical or thermal. As stated previously, physical segregation results in some aggregates not being properly coated with asphalt binder. An example of physical segregation is found in Figure 2. This figure shows a thermal image of a pavement with the telltale signs of end-truck segregation. The segregated areas (lighter color) shown in the figure are more prone to moisture damage as a result of displacement, detachment, or hydraulic scour because this type of segregation leads to thinner asphalt binder films.

Thermal segregation has been around for many years; however, the thermal imaging cameras have only recently identified this potential problem. Thermal segregation occurs during the transportation of mix to a project site. During transportation, the mix cools within the back of trucks, unevenly leaving a crust of cooler mix on top. This crust travels through the paver and leads to cool spots interspersed within warmer spots (see Figure 3*a*). The cooler spots of mix are more difficult to compact under the roller and in some cases will cause the roller to bridge over the warmer mix. This situation will lead to locations with lower density and, thus, potential permeability problems. A possible solution to this thermal segregation is to use a material transfer vehicle, or other suitable device, that remixes the HMA before going into the hopper of the paver. Another option would be to use insulated trucks that help prevent temperature loss. Figure 3*b* shows the thermal properties of a pavement when proper remixing is accomplished.

Compaction of HMA

Once placed on the roadway, the mix is rolled to achieve a desirable in-place density. This step in the construction of a properly designed and produced HMA is likely the most important in obtaining a pavement that will resist moisture damage. For dense-graded mixes, numerous

FIGURE 2 Thermal image of pavement with end-truck segregation.



(a) **(b)**

FIGURE 3 Thermal images of pavement: (*a*) with thermal segregation; (*b*) without thermal segregation.

studies have shown that initial in-place air void content should not be below approximately 3% or above approximately 8%. Low in-place air voids have been shown to result in rutting, bleeding, and shoving, while high air voids lead to permeability problems such as moisture damage or excessive oxidation of the asphalt binder. (It should be noted that some of the "rich bottom" mixes that are being used as fatigue-resistant layers at the bottom of structural sections have very low air voids by design. Because of their location in the designed structure, they are not subject to shoving, rutting, or bleeding.) From a moisture damage standpoint, permeable pavements allow water to infiltrate into the pavement and lead to moisture damage by any of the five mechanisms discussed previously.

The permeability of HMA pavements has become a continuing issue discussed in the HMA community, especially with the introduction of Superpave and SMA mixes in the 1990s. A survey by Brown et al. (*9*) suggested that coarse-graded Superpave mixes seem to be more permeable than conventional dense-graded mixes (Marshall or Hveem designed) at similar in-place air void contents. Work by Westerman (*10*) and Choubane et al. (*11*) using a laboratory permeability device showed that coarse-graded Superpave mixes became permeable when in-place air void contents were more than 6%. The National Center for Asphalt Technology has several reports on the effect of in-place air voids on permeability (*12–14*).

There are several factors influencing the interconnectivity of the air voids, and hence permeability, in compacted HMA pavements. Work by Mallick et al. (*15*) and Cooley et al. (*14*) showed that nominal maximum aggregate size (NMAS) (Superpave definition) has a great influence on the permeability characteristics of a pavement, at a given in-place void content (see Figure 4). By an increase in the NMAS, the size of the individual air voids increases, which results in a higher potential for interconnected air voids. Hainin and Cooley (*16*) have investigated the effect of lift thickness on permeability (see Figure 5). The results suggested that as lift thickness increases, permeability decreases for a given mix and in-place air void content. A thicker lift reduces the chance of interconnected voids.

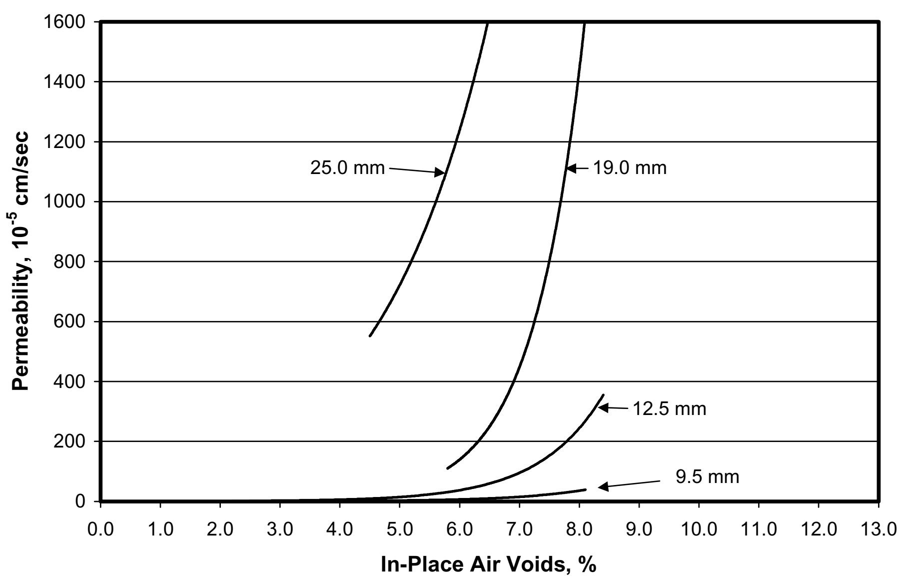


FIGURE 4 Impact of nominal maximum aggregate size on permeability (*15*).

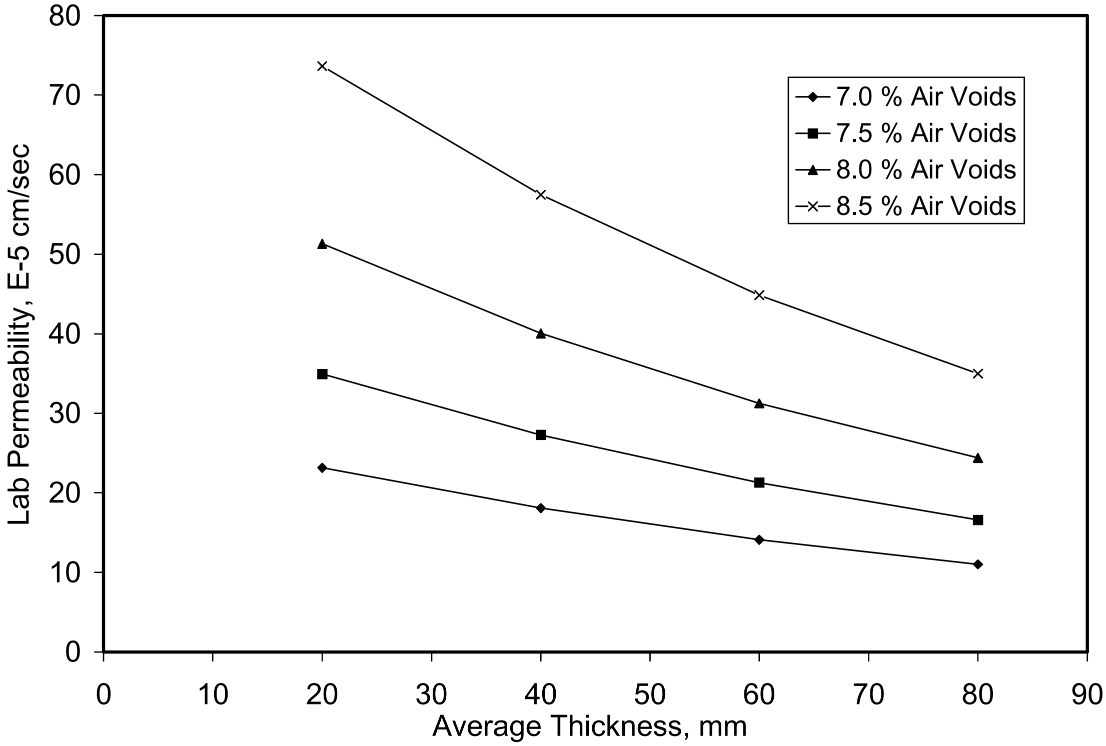


FIGURE 5 Effect of lift thickness on permeability (*16*).

In a recent study at the National Center for Asphalt Technology (*16*), 42 ongoing HMA construction projects were investigated with respect to permeability. A total of 354 cores were obtained from the 42 different Superpave projects. Of the 42 projects, 13 projects used a 9.5-mm NMAS gradation, 26 projects used a 12.5-mm NMAS gradation, and 3 projects used a 19.0-mm NMAS gradation. Laboratory permeability tests were conducted on each core in accordance with ASTM PS 129-01, Standard Provisional Test Method for Measurement of Permeability of Bituminous Paving Mixtures Using a Flexible Wall Permeameter. This method uses a falling head approach in measuring permeability.

The results indicated that in-place void content was the most significant factor affecting the permeability of Superpave pavements (see Figure 6). Other factors having a significant impact on permeability were percent coarse aggregate in blend (i.e., fine- or coarse-graded), percent passing 12.5-mm sieve (defining NMAS in data set), percent passing 1.18-mm sieve, design compactive effort (N_{des}), and lift thickness. As the values of percent coarse aggregate in the blend, percent passing 12.5- and 1.18-mm sieves, and N_{des} increased, permeability increased. For coarse-graded Superpave designed mixes, as the coarse aggregate ratio (ratio of coarse aggregate to fine aggregate as defined by the 4.75-mm sieve) approached 1.0 or higher, permeability increased significantly. Also, permeability decreased as lift thickness increased.

From a moisture damage standpoint, it is obvious that a permeable pavement increases the potential for stripping (unless the pavement is designed to be permeable like OGFC). A pavement that is permeable allows the water to penetrate into the pavement. Once the water

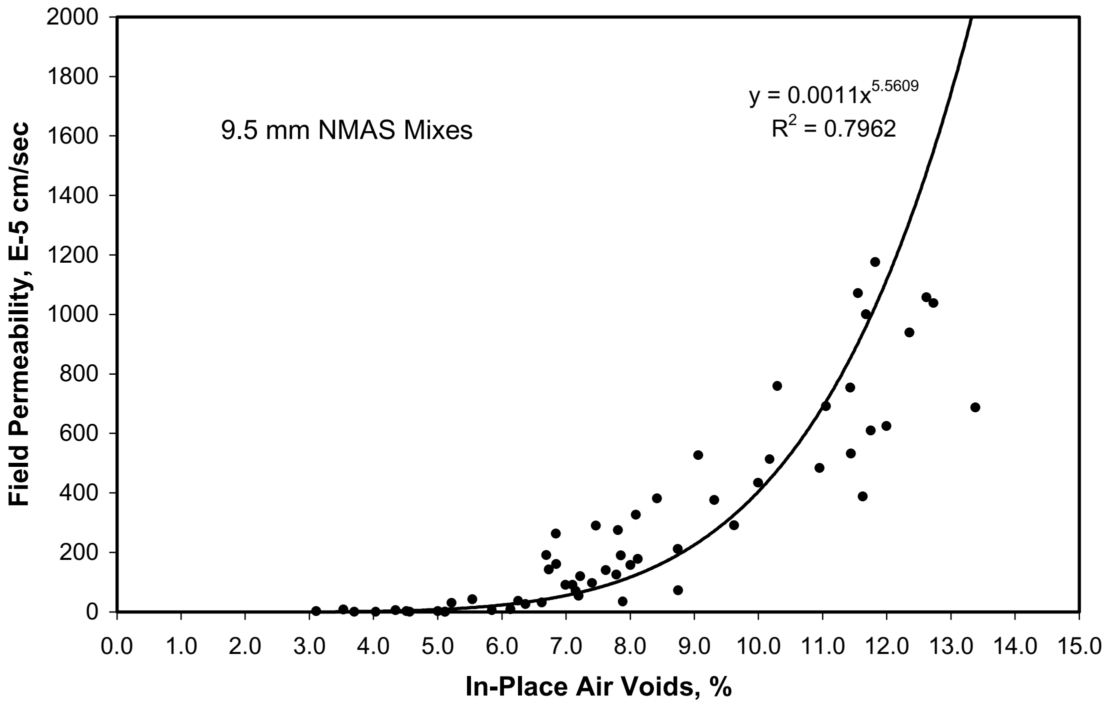


FIGURE 6 Relationship between permeability and in-place air voids (*14*).

penetrates into the pavement, moisture damage can occur from any of the five mechanisms of failure.

The area of the pavement that is likely the most susceptible to allowing water into the pavement structure is a longitudinal joint. Allowing water to penetrate into the pavement can prematurely distress the pavement at longitudinal joints (see Figure 7). Some unpublished work conducted at the Virginia Transportation Research Council used a field permeability device to track the changes in permeability across the joint. Field permeability tests were conducted 18 in. on either side of the joint, 6 in. on either side of the joint, and over the longitudinal joint. Figure 8 illustrates how permeability changed across the joint. Typically, longitudinal joints are constructed to a lower density than is the mainline pavement. This lower density at the joints is a result of compacting unconfined edges, not properly pinching the joint with the roller, and so forth. Figure 8 clearly illustrates that the mainline roadway (18 in. on either side of joint) had much lower permeability—hence, higher density—than at the joint. At 6 in. on either side of the longitudinal joint, the permeability is also higher than within the mainline. This region of low density near the joint is the primary area where water can infiltrate into a pavement.

Another factor related to moisture damage when compacting HMA is excessive rolling or the use of rollers that are too heavy. Either factor may cause fracturing of the aggregate. Again, in the presence of water, the fractured aggregate can absorb water and lead to displacement of the asphalt film.

FIGURE 7 Distressed longitudinal joint.

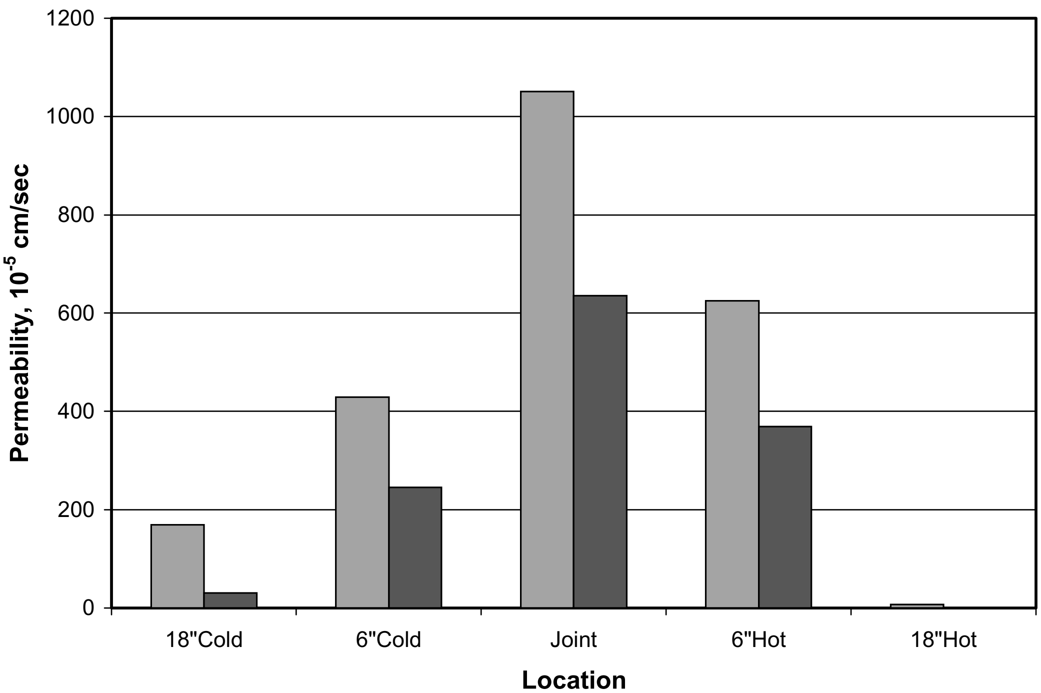


FIGURE 8 Change in permeability across a longitudinal joint.

Other Construction Issues

Several other construction issues warrant discussion. With regard to paving conditions, factors such as ambient and base temperature should be monitored. If either is too low, obtaining the proper density may be difficult.

Pavements should always be constructed on stable bases. A stable platform is needed so that the compaction energy provided by rollers is provided to the HMA layer being compacted.

Next, pavements should maintain a sufficient cross slope to ensure that water does not pond on the surface. If water does not flow off the pavement, there is a greater potential for the water to infiltrate the pavement, increasing the potential for moisture damage.

SUMMARY

The construction and production processes for HMA can have a profound effect on how a pavement will perform with respect to moisture damage. During production, a number of issues should be carefully controlled to help ensure an HMA that is resistant to moisture damage. Aggregate stockpiles must be properly built and maintained to prevent segregation. The plant operator must account for the moisture content of the aggregate stockpiles. If the moisture content is too high, then the production process should be slowed to allow for complete drying of the aggregates. Moisture left in the interstitial pores of the aggregates creates a potential for detachment of the asphalt binder film. Also during production, close control of the materials should be conducted. It is also important during the production process to ensure that all aggregate particles are properly coated with asphalt binder. Aggregates not properly coated can absorb water and thus lead to an increased potential for moisture damage. As always, good production practices with a good quality control program should always be used to ensure that a high-quality HMA reaches the roadway.

From a construction standpoint, there are two primary issues that must be closely controlled. First, segregation of the mix should be minimized. This includes both physical and thermal segregation. Numerous studies have shown that segregation can reduce the anticipated life of a pavement. The use of equipment that remixes the HMA before charging the paver hopper helps to minimize both physical and thermal segregation. The second construction issue is the proper compaction of the mix on the roadway. Compaction should be conducted in such a way that the mixture reaches the desired density and the aggregates within the mix are not excessively fractured. Longitudinal joints must be closely monitored to ensure that they are compacted properly.

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Questions and Answers

L. ALLEN COOLEY, JR.
National Center for Asphalt Technology, Speaker

Q1—Steve Healow, Federal Highway Administration, California Division
I have a question on your infrared images. They look like they were from Washington State and I find them compelling. I wonder if you can elaborate on the first slide and the third slide. The first slide was where you had the heterogeneous mat; there was thermal segregation all over the place, whereas on the third slide, there was no thermal segregation. It looked pretty homogeneous for the entire mat. What was different about those two processes? Was it the same contractor and was his level of effort different between those two images? What was the contractor doing in the first image to maximize his thermal segregation and what was done in the third image to minimize thermal segregation?

A—Allen Cooley
I don't know a good answer. Those slides were from a NAPA training presentation. My guess, knowing a little bit about what's going on with the thermal imaging, is that the first slide was a worst-case scenario, long haul distance, no material transfer vehicle, and so forth—all those types of things. And the last slide was probably where the material transfer vehicle that remixed the mix was used. That way you are getting a more uniform temperature within the mat.

Q2—Carl Monismith, University of California, Berkeley
Allen, I noted that neither John D'Angelo's presentation nor yours included anything about the actual mixing process, the mix production. It seems to me that this could be a problem also. Again, I'll show my age. I grew up in an era when batch plants were generally the way to produce hot mixes; moisture content in batch mixes was controlled to less than ½%. I am wondering if part of our problem, at times, comes about because there may be less control of the moisture in the aggregate at the time of production in the widely used drum plants. This certainly could lead to moisture sensitivity problems. Thus, I would hope that people might discuss this in the breakout session concerned with production.

A—Allen Cooley
I agree 100% and that's a little bit my fault, because when I saw the title of John's presentation, I thought he was going to cover it, and he probably thought I was going to cover it. In our paper, we do discuss moisture contents of the aggregates. We know if you leave the moisture in the aggregate, there is a higher potential for the displacement of the film, which can lead to moisture damage. That is contained in our paper.

Q3—Dave Newcomb, National Asphalt Pavement Association
On your distribution of air voids on projects, it is really like you said, disheartening to see such low densities, and low density is a precursor to distresses. Has anybody followed up to actually quantify how many of those pavements or what the condition of those pavements actually are?

A—Allen Cooley
We are in the process of doing that. As part of NCHRP 9-9 (1), which is the research study to evaluate the design gyration levels within Superpave, we are actually going back and coring each one of the 40 projects. Obviously, we got density at the time of construction, but we are also obtaining cores after 3 months, 6 months, 12 months, and 24 months. At 24 months, we are doing a performance evaluation. There's talk with the project panel that we may also obtain 4-year cores to take a look at densification, which is what we need for the design gyration level stuff. But at that time period, if it's extended to the fourth year as well, we will do another performance evaluation and have that type of information.

Q4—Roger Smith, Consultant
We often hear the term "first line of defense" applied to density and achieving density in our mat. I think that maybe that's the second line of defense once you're out there paving. One thing I've seen from my experience, especially in private work and especially at city/county level, is overlay work done without regard to reestablishing cross slope on the surface of the pavement so the water drains off the pavement. I think it's very important for the agencies, whether it be the state or the local agencies, as part of their overlay design and project, to really ensure that they are taking that opportunity of the overlay to reestablish cross slope.

A—Allen Cooley
That's a very good comment, thank you. Any more questions?

Q5—Gerry Huber, Heritage Research Group
A couple of comments, Allen. The one thought that went through my mind when you showed the tapered longitudinal joint, I thought right back to your comments about permeability. I know one of the concerns of some of the folks who are using those is getting density into them and that you end up with a 12-inch-wide strip that's very low on density. Just a comment.

A—Allen Cooley
I wasn't pushing that particular method. What I was doing was saying there's new technology. I think you're absolutely right. There is some low-density stuff. Besides the notched wedge, there are different materials that you can put on the joint to try and limit some of the permeability issues and stuff like that. I was solely saying there are some new technologies but we need to go farther as well.

Q6—Gerry Huber, Heritage Research Group
That's pretty much what I thought you were saying. I just thought I'd raise it as a point for the audience. Then the last thing is dealing with the pictures of the thermal segregation. One of the things I've trained myself to do whenever I see those pictures is immediately look at the scale on the side of the picture, because the tighter the range on the scale, the more blotchy it ends up looking. The botchy slide has a bottom end of 200 degrees and the other slide has a bottom end of 80 degrees. That may be the reason why the second and third slides may have ended up disguising some of the blotchiness, or the first one enhanced it either way.

A—Allen Cooley
May have.

Q7—Mansour Solaimanian, Pennsylvania State University
Good presentation, Allen. I think what you talked about in terms of permeability is very important. What you mentioned was that you could have basically the same air void and different nominal maximum sizes and get different permeabilities. I think that is probably one of the reasons why we cannot find a good match between our laboratory results and pavement performance. We always emphasize that you must get your air void level within the given range in the laboratory and conduct your partial vacuum saturation and you get 50% to 60% or whatever saturation level for the same air void level for two different mixes. We then conduct the test and we come up with either pass or fail. Now we put those mixes in the field and we see totally different behavior even at the same level of voids, because they have different void sizes and permeabilities. So I think any test method that works with the laboratory air voids in terms of establishing criteria should really look at permeability as one of the factors that contributes. That is one of the things that we are going to look at in Phase 2 of NCHRP 9-34. Rather than just emphasizing that you should get a specific air void level and do your test, maybe we should say because of different void structures, you should look at the permeability and go from there.

A—Allen Cooley
I agree wholeheartedly. Just as another comment on that, Kevin Hall had a paper a couple of years ago. He came up with a test to evaluate the air void pathway within samples. If I remember right, when he looked at lab samples, basically what he found is all of the flow is coming out the side of the sample. When you looked at field samples, all the flow was going through the samples. What we’re seeing is the density gradient within the lab-compacted samples. That’s another piece of the puzzle along with the permeability. We need to take a look at both of them at the same time when we look at a laboratory moisture damage test.