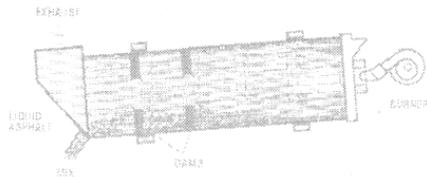
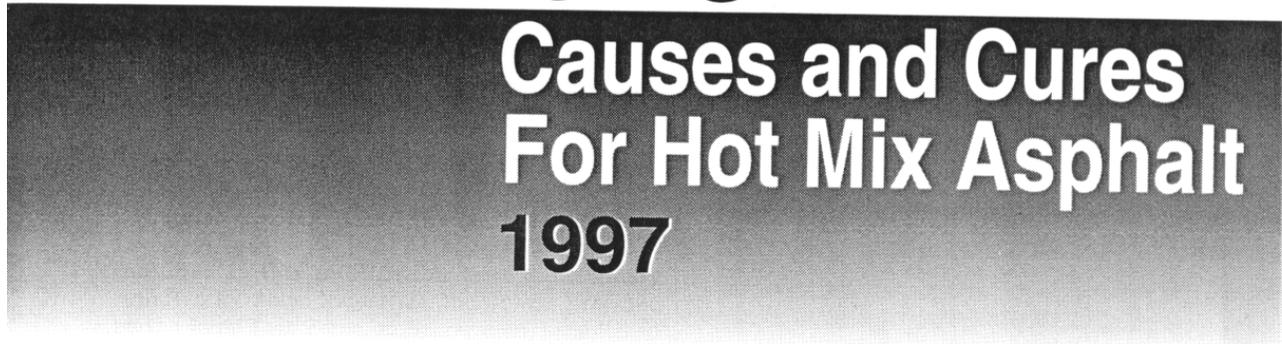
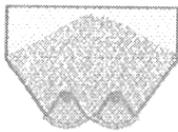


Segregation

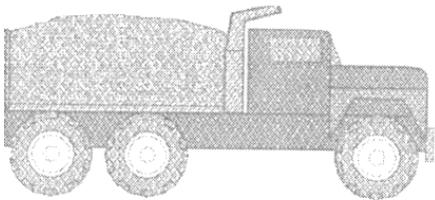
Causes and Cures For Hot Mix Asphalt 1997



Prepared by Joint Task Force on Segregation of
AASHTO Subcommittee on Construction;
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WEIGH BATCHER



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Introduction

Hot Mix Asphalt (HMA) is a mixture of graded aggregate and asphalt cement designed to provide both strength and durability. It is unique in that it is also flexible, making it adaptable over a wide range of climatic conditions.

Considerable effort has been exerted over the last decade to improve the performance of Hot Mix Asphalt through better combinations of grading, the addition of polymers, fibers, and various other products. These products are intended to reduce rutting, add to durability, and lead to a longer life of the pavement. In order to ensure pavement performance, the HMA must be mixed, stored, transported, and placed uniformly and with the same gradation the lab designed. At each point during the manufacturing process from stockpiling, aggregate blending, mixing, conveying, storing, truck loading, and placement at the paver, the mix has an opportunity to segregate, creating non-uniform mixes. A segregated spot may be “the birth of a pothole.”

When segregation is present in a mixture, there is a concentration of coarse materials in some areas of the paved mat, while other areas contain a concentration of finer materials. Segregation creates non-uniform mixes that do not conform to the original job mix formula in gradation or asphalt content. The resulting pavement exhibits poor structural and textural characteristics,

provides poor performance and durability, and has a shorter life expectancy and higher maintenance costs.

Problems associated with segregation are serious. Their elimination is essential to the production of high quality paving mixtures. Elimination of segregation is the responsibility of those who produce and place HMA, organizations who design the mix, owners who inspect the final product, and manufacturers who design and market paving equipment.

There are basically five types of mix segregation that occur on the road. They are as follows:

1. **Truck End Segregation:** Figure 1 shows a roadway with segregated spots, often referred to as wings, occurring longitudinally and on each side of the lane being paved. These wings constitute spots of coarse aggregate separated from the uniform mixture. They are typically much more open graded than designed and, if severe enough, will deteriorate in a short period of time, leading to a pothole in the road. Less severe truck end segregation may not appear until the road has been under traffic for several months. Truck end segregation is usually caused by improper truck loading, silo segregation, improper truck unloading, or running the hopper empty between loads.

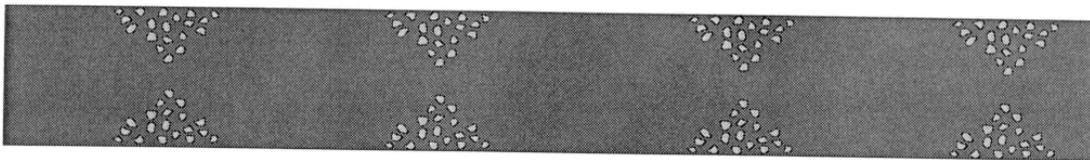


Figure 1. Truck End Segregation.

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2. **Centerline Segregation:** The second most common type of segregation is centerline segregation (shown in Figure 2). This normally occurs in the center of the lane and is primarily attributable to coarse aggregate as it is discharged from the conveyor system into the auger area. It then rolls underneath the auger chain drive or gearbox and concentrates in the center of the mat being laid.
3. **Joint/Edge Segregation:** Figure 3 shows that the next most prevalent type of segregation, which occurs at the outside or the outer edges of the pavement being placed. This commonly occurs from the augers not being run at sufficient speeds on the paver, allowing the coarse aggregate to roll to the outside of the mat.
4. **Truck End Segregation/One Side:** This type of segregation is shown in Figure 4. It is a special case of truck end segregation, but is most commonly caused by improper loading of the batcher on the hot storage bin.
5. **Random Segregation:** Random type segregation is shown in Figure 5. The cause of this type of segregation is the most difficult to find. Generally, this type of segregation occurs when improper mixing is taking place either in the batch plant or drum mixer, but can also occur in other places in the process.

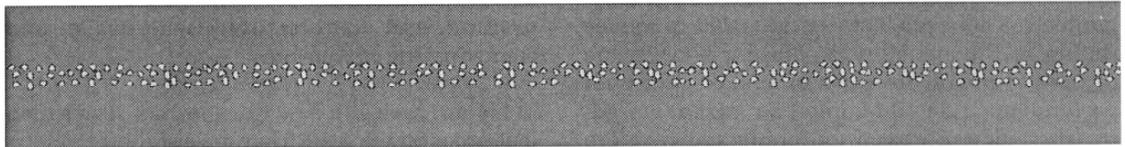


Figure 2. Centerline Segregation.

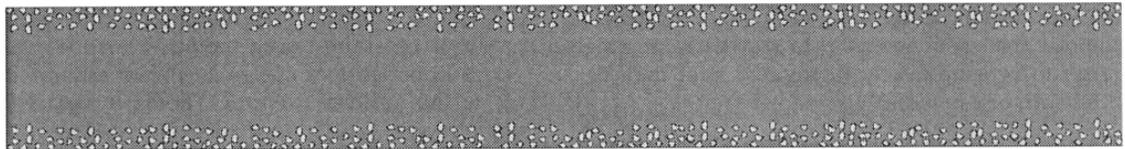


Figure 3. Joint/Edge Segregation.

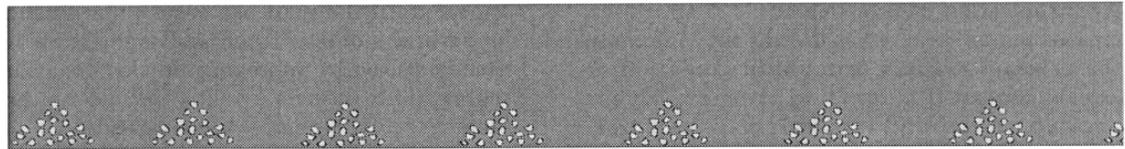


Figure 4. Truck End Segregation/One Side.

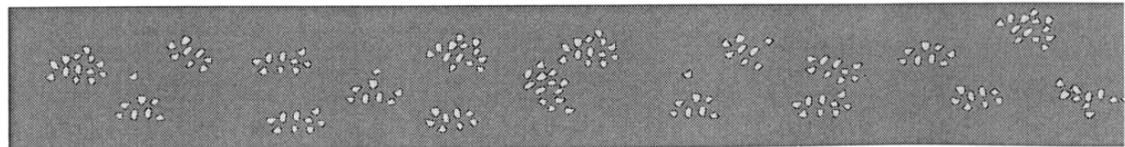


Figure 5. Random Segregation.

Measuring Segregation

Historically, segregation has been measured on a subjective basis with the inspectors making a determination based on visual information only. This becomes very difficult since, in many cases, particularly on surface mix, segregation may not appear for several months after the pavement has been opened to traffic. Visual observation can only identify surface segregation. Thus, segregation below the surface may be undetected.

The agencies that have been most successful in minimizing segregation have been extremely demanding of performance and have not allowed any visible type of segregation to occur. This places a very tough burden on both the inspector and the contractor placing the mix and can lead to disputes. In an effort to develop a non-destructive method of measurement, one state has written a specification using a nuclear gauge to measure density longitudinally along the pavement, looking for variations in density. A variation of more than 5 lb/ft³ (80 kg/m³) (highest to lowest) or 2.5 lb/ft³ (40 kg/m³) (drop from the average to lowest) has been considered to be unsatisfactory. This method has been found to be successful in detecting truck end segregation.

The National Center for Asphalt Technology (NCAT) is presently working with an equipment

manufacturer to try to determine if a more accurate measurement might be the use of the asphalt content, utilizing the longitudinal variation technique noted. At this writing, a fully validated, non-destructive segregation measurement test has not been developed.

Segregation frequently occurs to some degree. The aggregate particle sizes in Hot Mix Asphalt vary substantially in diameter. The large particles are as much as 10,000 to 12,000 times the diameter of the smallest particles. The largest particle can often weigh as much as 1,000,000 times as the smallest particle. To believe that total uniformity can always be achieved would be naive. However, variations of as much as 10% on the #4 (4.75 mm) sieve should be viewed as excessive.

The following sections give a road map to determine where the segregation is occurring and how to prevent it. A diagnostic chart included with this document shows the five different types of segregation. This information will assist in determining the type of segregation occurring and provide help in solving the problem.

Mix Design

Proper mix design is important in the effort to eliminate segregation. Mixes are categorized as dense-graded (uniform aggregate particle size distribution) or gap-graded (a size range in the aggregate grading which contains little or no material). Mixes that are dense-graded may be forgiving by compensating for mistakes in the plant operation or laydown operations without affecting the mix performance significantly.

In order to avoid segregation, gap-graded mixes may require greater attention to detail during placing and handling than dense-graded mixes. If the mix is gap-graded to a sufficient degree and has a low asphalt content, it may be very difficult to produce without segregation, regardless of the techniques used. Extra care and/or the use of mix additives may minimize segregation problems with gap-graded mixes.

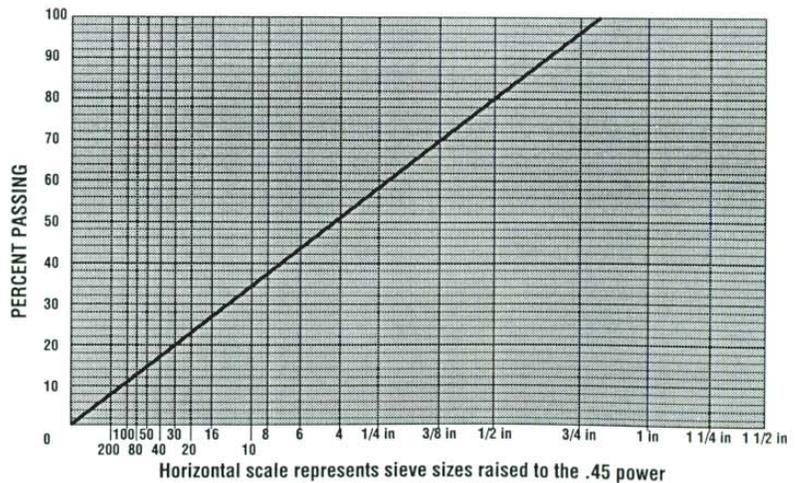
Probably the single most important mix design criterion for segregation susceptibility is asphalt content. Low asphalt content mixes tend to segregate much more than mixes containing high asphalt content, regardless of the gradation.

Gap-graded mixes can be successfully used. However, the mixes may require fibers or polymers, enabling the use of a higher asphalt content that makes the film thicker. In many mixes, a slight increase in asphalt content (often as little as 0.2 percent) will reduce segregation significantly. Increased film thickness dampens particle-to-particle contact and reduces the tendency for mix to separate at transfer points throughout the process.

The maximum density line can be used as a guide to understanding aggregate gradation. The maximum density line represents a gradation in which the aggregate particles fit together in their densest possible arrangement.

To plot the maximum density line, use the FHWA 0.45 Power Gradation Chart as shown in Figure 6. Draw a straight line from the maximum aggregate size through the origin. The maximum aggregate size is defined as one sieve size larger than the nominal maximum size; the nominal maximum size is defined as one sieve size to retain more than 10 percent of the aggregate.

Figure 6.
Maximum Density Line.



Experience dictates that mixes with gradations that fall directly on the maximum density line should **not** be produced. Often there is insufficient room in the mixture for the liquid asphalt, and a plastic type mix results. Another problem arises when the mix design is near the maximum density line. Gradation variations in stockpile materials cause the curve to vary back and forth across the maximum density line, thereby gap-grading the mix. It is suggested that the mix designer select approximately two to four percentage points above the maximum density curve if a fine textured mix is desired. A gradation blend two to four points below the curve should be selected if a coarse textured mix is desired. (See Figure 7). These bowed up and bowed down

curves usually result in a good, forgiving mix. Detailed discussion of mix design is beyond the scope of this publication.

Rarely does a mix that lies on the maximum density line contain sufficient voids in the mineral aggregate (VMA), especially if the design has a relatively high percentage of minus No. 200 (0.075 mm) material. A grading selected on a line approximately parallel to the maximum density line will produce a uniformly graded mix that will have little tendency to segregate. However, the maximum density line should be used only as a guideline for uniform grading. Other criteria such as VMA, air voids, stability, and other specifications must also be met.

Figure 7.
Selecting Mixines.

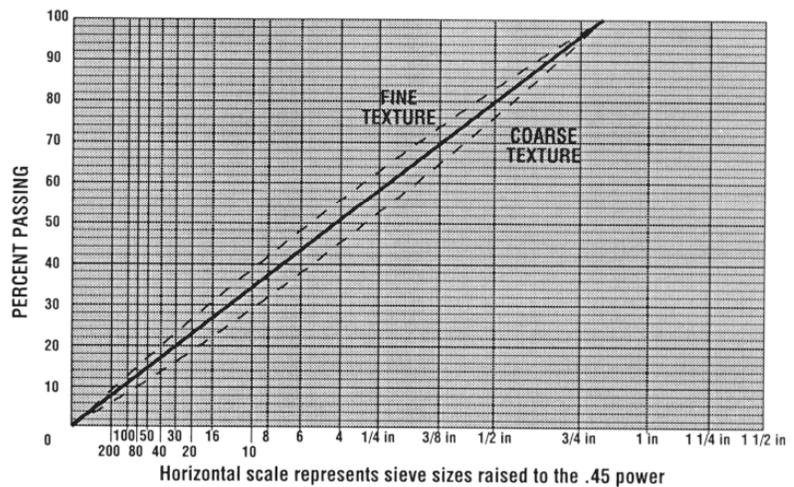
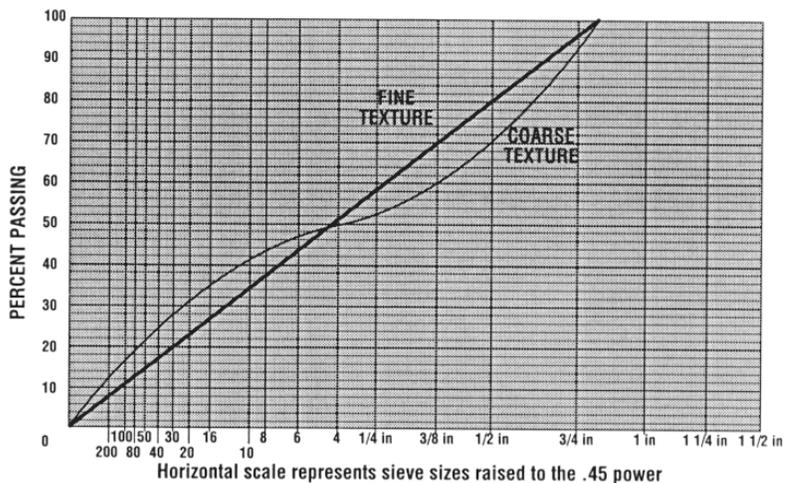


Figure 8.
"S" Curves Tend to Segregate.



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Some mixes have gradations that make an “S” across the maximum density line, as shown in Figure 8. These mixes tend to have segregation problems.

The slightly bowed curve shown in Figure 9 has resulted in good performance. But the potential benefit that a designer tries to achieve by gap-grading requires special care in handling to avoid segregation problems.

When plotting a mix gradation, plot as many sieve sizes as possible. Figure 10 illustrates how plotting only a few points can result in a misleading graph. When only 4 sieve sizes are plotted as shown in Figure 10 by the thin solid line, the curve may indicate a good mix. But when 7 sieve sizes are plotted, shown in Figure 10 by the dashed line, it is easy to see that the mix is actually gap-graded. Thus, a complete range of sizes should be included in the sieve analysis.

Figure 9.
Slightly Bowed Curves May
Do Well.

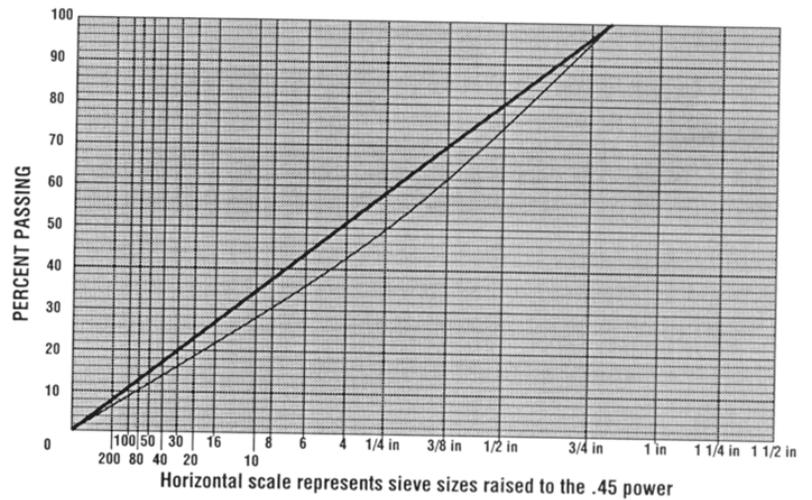
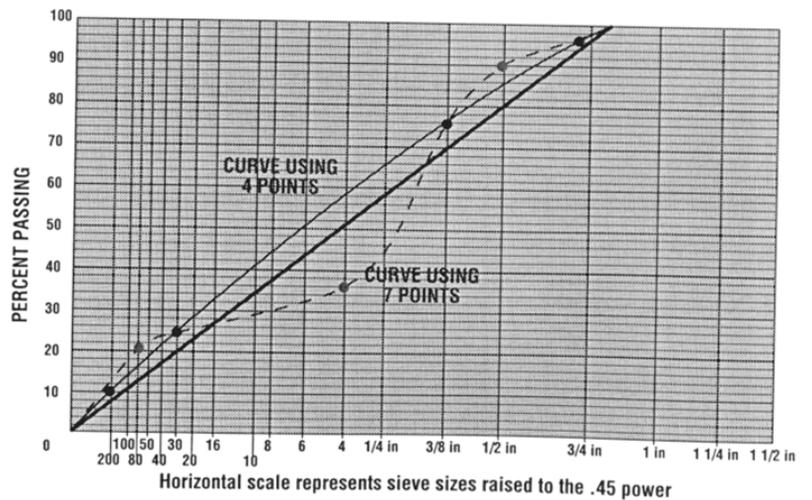


Figure 10.
Same Mix 4 versus 7 Points.



Stockpiling

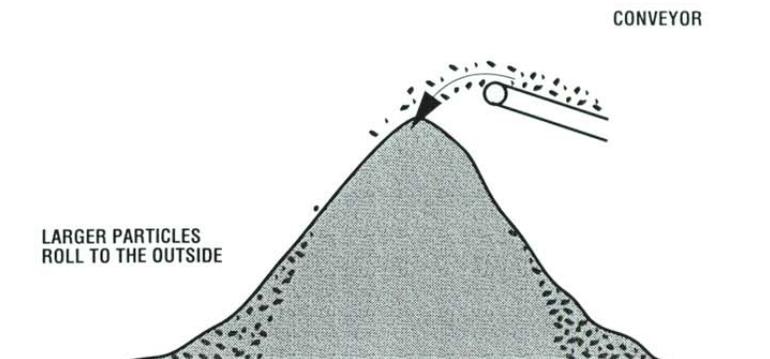
Proper stockpiling techniques are needed to ensure that the material will be uniform when fed to the hot mix plant. High stockpiles are very sensitive to segregation for single aggregate blends. Figure 11 shows a typical example of a single aggregate stockpile. In this example, segregation has occurred because a conveying system was improperly used to form the stockpile. Large particles have rolled to the outside of the pile thereby segregating the material. Fine material coming off the belt tends to fall toward the rear of the stockpile, further compounding the problem. Subsequently, segregated material is fed to the plant. When working with larger size aggregates, it can be beneficial to use two cold feed bins to feed the same material. This practice tends to minimize wide variations by feeding smaller amounts of material from two feed points and by increasing the chance of re-blending the material.

Generally, different sized materials are stockpiled separately for feeding to an asphalt plant. This

makes segregation less likely because the material is evenly sized in each pile. However, segregation can occur in fine-sized aggregates if a wide variation in gradation exists. Stockpile techniques shown in Figures 12 and 13 assure uniformity of material and significantly reduce stockpile segregation. Dozer operation should be monitored to minimize degradation. Monitoring is especially critical when dealing with softer aggregates.

The method used to remove material from the stockpile is as important in minimizing segregation as building the stockpile. The front-end loader at the stockpiles can have a significant impact on aggregate segregation and gradation variations. Aggregate should always be removed in a direction perpendicular to the aggregate flow. The operator should always work the entire face of the stockpile. The operator must take care not to contaminate the stockpiled materials with the materials on which the stockpile is built. These practices, in conjunction with separation of

Figure 11.
Segregation in a Pile.



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Figure 12.
Use Numerous Small Piles.

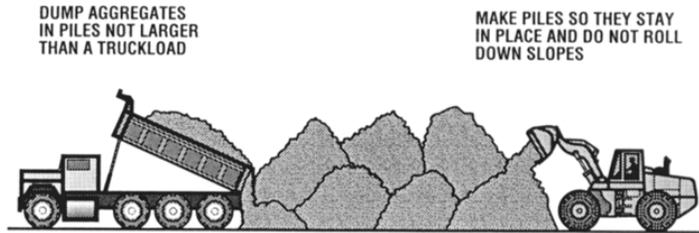
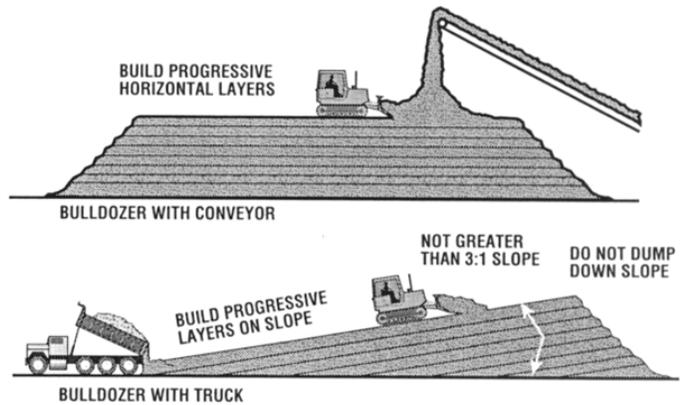


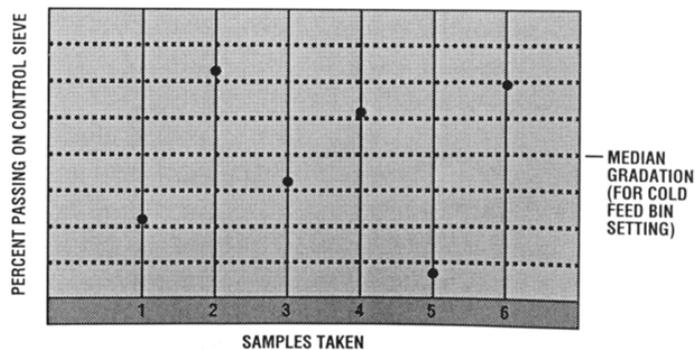
Figure 13.
Build Stockpiles in Layers.



different stockpiles and rotation of materials in the stockpile, should ensure that segregation will not occur in the aggregate as it is removed from the stockpile.

When sampling stockpile material to set up cold feed bin ratios, it is important to take several samples. In addition, the median result (as shown in Figure 14) should be used to obtain test results that truly represent the grading of the stockpile.

Figure 14.
Stockpile Sampling.



Asphalt Plants

Segregation can occur at numerous points in a Hot Mix Asphalt plant. Where segregation occurs in drum mix plants will differ from where it occurs in batch plants. On a batch plant, the points of most concern are cold feed bins and hot bins. On drum mix plant, surge bins and storage bins are the points of most concern.

Cold Feed Bins

Segregation in the cold feed is usually not a problem unless the aggregate material consists of several sizes. Segregation should not occur when a single size of aggregate is placed in each feeder bin. However, if bridging of material occurs in the hopper (see Figure 15), non-uniform feeding takes place, resulting in a segregated mix.

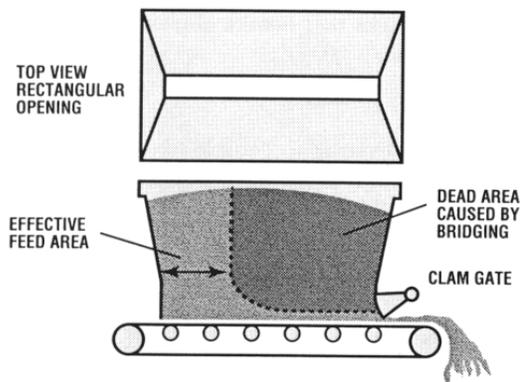


Figure 15. Feeder Bin with Rectangular Opening.

By utilizing a self-relieving bottom as shown in Figure 16, uniform feeding will occur all along the opening of the cold feed bin, eliminating bridging as a source of segregation.

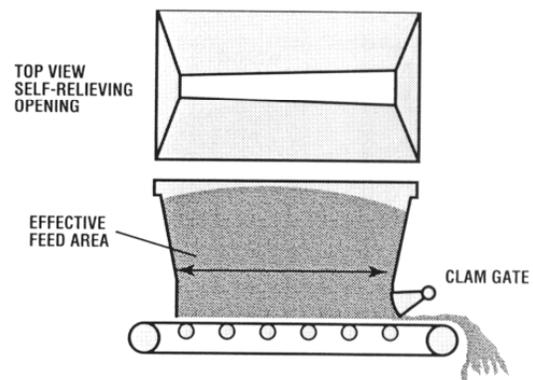


Figure 16. Self-Relieving Feeder Bin.

Hot Bins On A Batch Plant

As mentioned, segregation can occur with all sizes of material. Segregation often occurs in the No. 1 hot bin due to the size and shape of the large bin and the wide size range of materials in that bin. The size variation in material in Bin 1 is potentially greater than any other part of the asphalt plant because its material size varies from as large as 3/16-inch (5 mm) all the way down to one micron.

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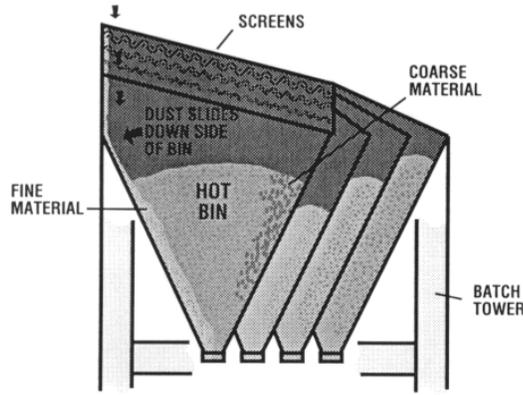


Figure 17. Hot Bin Segregation.

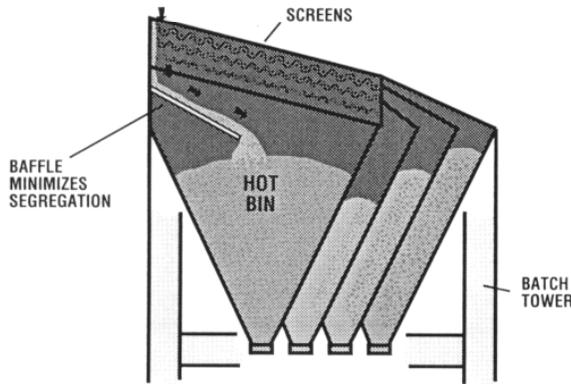


Figure 18. Hot Bin with Baffle.

In recent years, some have voiced concern about uniform dust return from baghouses to batch plants. Generally, material is uniformly collected in baghouses and is uniformly returned. But the material may actually become segregated in Bin 1. The ultra-fine material discharged from the bucket elevator may fall directly through the screen and lay on a sloping bin wall (Figure 17). This ultra fine material may lay there until the bin is almost empty. Then a large slug of the dust may break loose and feed into the weigh hopper, producing an ultra-fine batch that is segregated, and uncoated.

In many cases, suspected non-uniform feed from the baghouse was incorrectly thought to be the cause of segregation in the hot bin and in some cases may have resulted in the addition of expensive and unnecessary equipment. With proper analysis of the problem, a solution could be to install a baffle as shown in Figure 18. The baffle causes the dust to slide to the center of the bin where it is uniformly mixed with the coarse materials.

The same results can be achieved by using a baffle to force the coarse material back to the sloping bin wall. There, it can be intermixed with the fine material. The method used depends on the head room and space available in the hot bins.

Utilizing a dust blower at the baghouse and a cyclone type dust receiver properly located in Bin 1 has also proved effective in eliminating segregation in this area. However, many prefer to use baffles because of relatively high maintenance costs for airlocks that handle abrasive materials such as granite.

Drum Mixer

Due to the differences in particle size, segregation can occur in any type drum mixer. Recognizing this, equipment manufacturers have designed material handling systems to ensure materials are properly mixed. Large particles will generally flow through a drum mixer at a slightly faster rate than the small particles during initial start up and at plant shut down. Negative effects associated with this characteristic can be eliminated by adjusting the start/stop time intervals between the cold feed bins. Due to the continuous flow

process that occurs after start-up, this characteristic does not produce segregation. The potential to segregate is also of little significance unless the material is gap-graded.

When gap-graded mixes are processed in a drum mixer, it becomes more difficult to achieve a thorough coating with a uniform thickness. The uncoated or thinly coated coarser materials are more likely to segregate. Such segregation can be reduced or eliminated through better coating. This can be accomplished by increasing the mixing time by extending the asphalt line farther up into the drum mixer as shown in Figure 19. For hard-to-coat materials, kickback flights can be used, or the addition of a dam (donut) can be installed in the drum to increase the mixing time (Figure 20).

An alternate method is to decrease the drum slope, which increases the dwell time and provides additional mixing. Increased dwell time, whether due to the addition of dams or due to decreasing the drum slope, increases the drum load. This may reduce the production rate if the drum drive motor is a limiting factor.

An often overlooked factor which can significantly affect coating quality and film thickness is the amount of minus No. 200 (0.075 mm) material in the mix. Coating quality will be adversely affected if the amount of minus No. 200 (0.075 mm) material exceeds specifications or even if it is within specifications, but on the high side of the tolerance allowed. Because of the large amount of surface area present in fine material and because of its affinity for the liquid asphalt,

Figure 19. Increasing Mixing Time in a Drum Mixer.

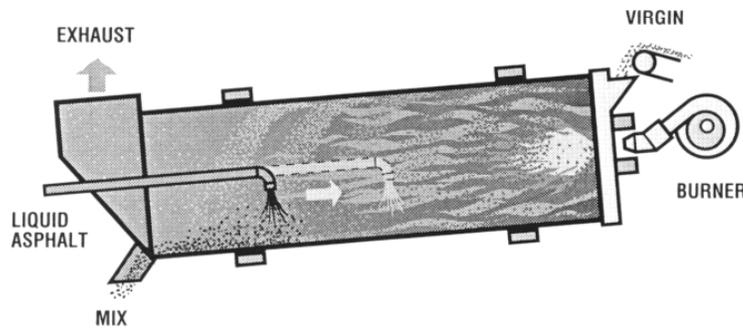
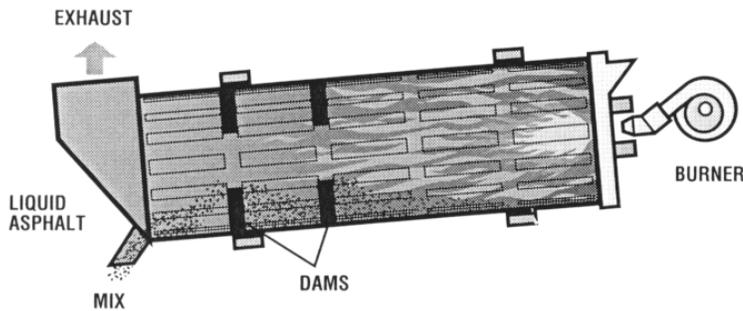


Figure 20. Drum Mixer Dams Retards Flow.



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coarser material in the mix will have a reduced film thickness even though it may appear to be fully coated. Reduced film thickness changes the dynamic characteristics of the coarse material and increases its tendency to segregate. Reducing the amount of minus No. 200 (0.075 mm) material to the low side of the allowable tolerance will usually correct this problem. Moreover, it will be easier to produce a uniform mix and easier to handle the mix throughout the trucking and laydown operations. Mix design changes, however, must be verified through appropriate mix property testing.

The coating of large stones can also be affected by internal moisture and absorption. When internal moisture is present in large aggregate, its temperature tends to be cooler than finer material. Cooler stones will not coat readily until they have given up their moisture and reached a uniform elevated temperature comparable to the temperature of the rest of the mixture. Internal moisture can be eliminated by increasing drying and mixing times using the methods described above.

Asphalt absorption problems are related to internal moisture problems. This is because the same pores that contained the moisture in the stone will absorb a portion of the available

asphalt. This absorption reduces the actual film thickness on the outside surfaces. If absorption is suspected, break open several larger stones and examine them under a magnifying glass. A dark band ranging from a few thousandths of an inch to 1/32-inch (0.1 to 0.8 mm) wide from the surface inward indicates that absorption is occurring. An ultraviolet light can also be used to identify asphalt absorption. The solution to attaining the film thickness originally desired is to increase the asphalt content to make up for the portion being absorbed.

Mix discharged from drums by gravity is more prone to segregation than mix discharged from drums with a high lift where the material is required to make a 90-degree turn prior to discharge. With gravity discharge, coarse material often discharges on one side and fine material on the other. The segregated material drops directly onto a drag conveyor and continues to segregate right on through the batcher and bin as shown in Figure 21. The problem can be improved by restricting the discharge chute from the drum to a smaller opening, forcing the mix into the center of the drag conveyor. Adding deflector plates or straightening vanes is also an effective way to make sure the drag conveyor is properly loaded from a gravity type discharge (see Figure 22).

Figure 21.
Drum Discharge Segregation.

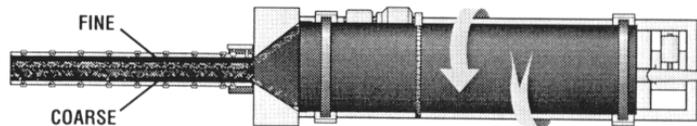
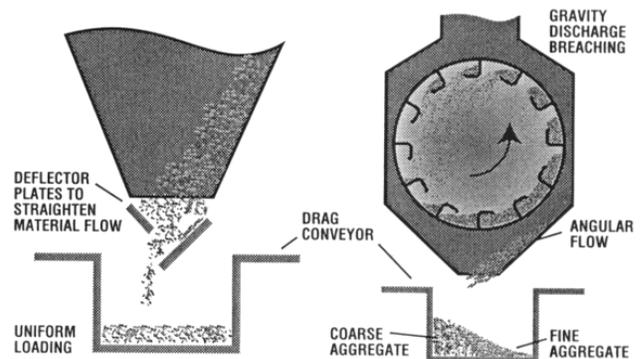


Figure 22.
Gravity Discharge.



Another solution is to install a plow or single discharge point in the drum as shown in Figure 23, forcing all mix to come out at one point. However, experience shows it is difficult to design and install an effective plow on most drum mixers. When possible, it is best to set the drag conveyor at a 90-degree angle to the drum discharge to create a right angle change in material flow. This setting reduces or eliminates drum discharge segregation.

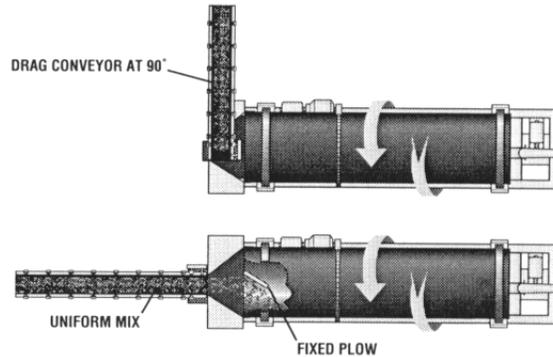


Figure 23. Drum Discharge Plow.

Counter-flow Drum Mixer

In the last decade, two additional types of continuous mix plants have been introduced called counter-flow drum mixers. Figure 24 shows a counter-flow drum mixer which consists of a counter-flow dryer with a drum type mixer surrounding the burner tube. Many of the same problems that occur with a drum mixer can occur with this type of plant depending on the type of discharge from the plant. Typically, these plants have a high lift type discharge resulting in discharging of the mix at 90 degrees to the drum. This 90 degree turn helps to correct segregation occurring within the drum. Counter-flow plants do not expose the liquid asphalt or Reclaimed Asphalt Pavement (RAP) to the gas stream, eliminating the emissions of light ends from the plant and from the liquid asphalt itself. This may lead to a somewhat better coating than on the drum mixers and aids in eliminating segregation.

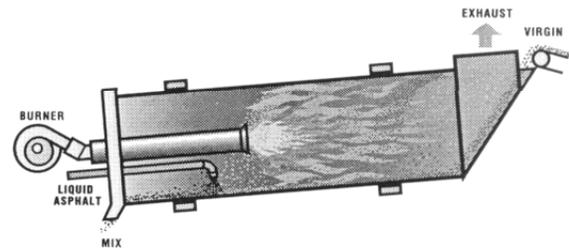


Figure 24. Counter-Flow Drum Mixer.

Some counter-flow drum mixers (as shown in Figure 24) may have relatively short mixing times and can result in uncoated particles at the discharge leading to segregation. When this occurs, plows as shown in Figure 23, dams or other retarding devices may serve to control segregation.

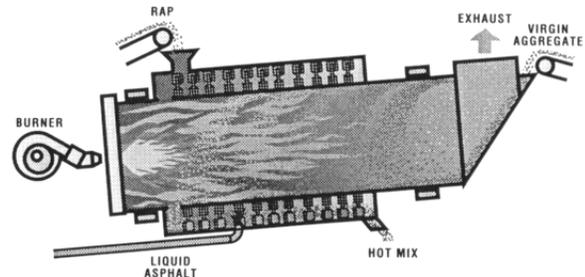


Figure 25. Unitized Counter-Flow Drum Mixer.

Figure 25 shows the unitized counter-flow drum mixer, which is a counter-flow drum with a very large mixer surrounding the discharge end of the

drum. With this device, the dryer-drum acts as a shaft of a very large mixer. The dried and heated aggregate drops from the interior drum into the outer mixing shell. Asphalt binder and RAP are added and mixed in the outer shell. Due to the relatively long mixing time, good coating occurs with this type of plant, reducing segregation problems. Also, due to the long mixing time, the fine dust can be injected into the mixing section upstream or after the liquid asphalt is injected. This procedure allows the liquid asphalt to coat the larger aggregate prior to the fine dust being re-added into the mix. The dust then becomes part of the asphalt film. In cases where segregation is occurring, adding the dust after the asphalt may eliminate the segregation problems on counter-flow drum mixers.

Surge and Storage Bins

Drag Conveyors—Segregation will usually not occur in a drag conveyor unless it is “hydroplaning.” Hydroplaning occurs as a result of a material build-up in the bottom of the drag conveyor. Cold conveyors that do not have floating hold-downs are prone to build up on the bottom liners. The build-up may create a high friction drag surface that results in material spilling backwards over the drag flights as shown in Figure 26, even at very low production rates. This condition is easily observed. Material falls backwards down the drag conveyor instead of moving uniformly in one mass with full material from flight-to-flight.

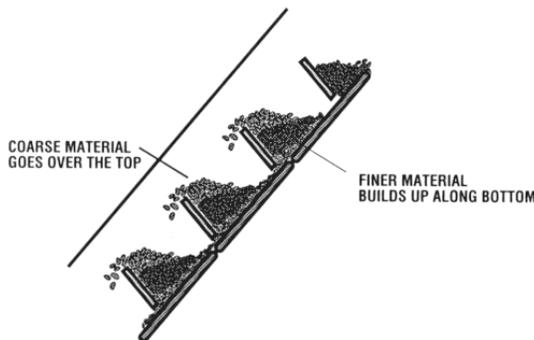


Figure 26. Hydroplaning in a Drag Conveyor.

When the drag conveyor is hydroplaning, considerable segregation can occur, especially at the beginning and end of each run. Hydroplaning is more prevalent on batch plants where the segregation can be carried from batch to batch. Drag conveyors should be equipped with floating hold-downs and heated bottoms for cold start-ups.

Segregation is minimized when the drag conveyor is as full as possible. When the slats are only partially filled, the larger aggregate is apt to roll to each side within the drag conveyor. So, it's better to run at higher production rates to keep the drag conveyor full. If the production rate is higher than the rate used by paving operations, store the extra mix and shut down production earlier than usual.

Storage Bins—The most sensitive area for segregation on a hot mix plant is in surge and storage bins. The large sizes of the bins contribute to segregation problems. Since the first surge and storage bins were developed many years ago, considerable improvement has been made on bin equipment to prevent segregation. One of the most detailed and complete studies of hot mix surge and storage segregation was conducted by the University of Texas in the early '70s. From their investigation, various techniques were devised for eliminating segregation.

The result of the study revealed two good devices for eliminating segregation in surge and storage bins. One was a bin loading batcher at the top of the bin as shown in Figure 27. The other was a rotating type chute in the top of the bin. Both devices provide uniform loading of the mix. However, the bin loading batcher proved to be the most economical and is the device used on all surge and storage bins today.

The study also addressed various gate openings and showed that some gate configurations worked better than others. But, the study confirmed that if the bin was properly loaded with uniform mix, the gate configuration was not of significant importance. However, batchers are not an absolute “cure-all.” They can create problems of their own and it's best to understand how and why.



Figure 27. Bin Loading Batcher.

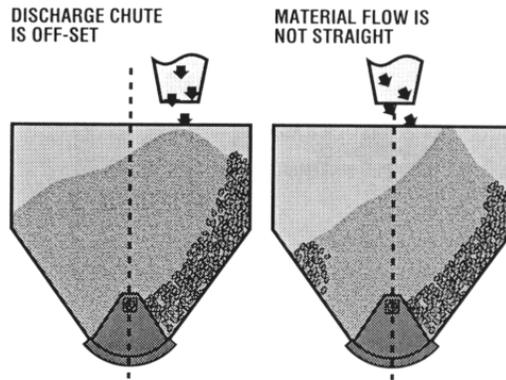


Figure 28. Chutes that Cause Unsatisfactory Material Flow.

Bin Loading Batcher—The most popular device for eliminating segregation on surge or storage bins is the bin loading batcher. The following observations and practices should be followed when using a batcher:

- a. The batcher should hold at least 5,000 pounds (2,000 kg) and have a relatively large diameter gate opening to ensure rapid discharge of material into the storage bin.
- b. The batcher must be loaded directly in the center and the material from the chute loading the batcher should have no horizontal trajectory (see Figures 28 and 29). Also, whenever mix is discharged through a chute, a small chute opening minimizes segregation (see Figure 30). Remember, if the material segregates in the batcher, it will segregate throughout the bin.
- c. The batcher should be filled completely before each drop. Normally two high bin indicators are utilized. One dumps the gates and the other ensures the gates will dump if the first indicator fails. When the batcher gates fail to open, mix backs up in the drag

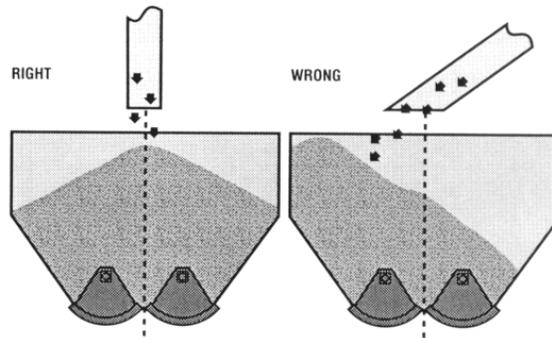


Figure 29. Batcher Loading.

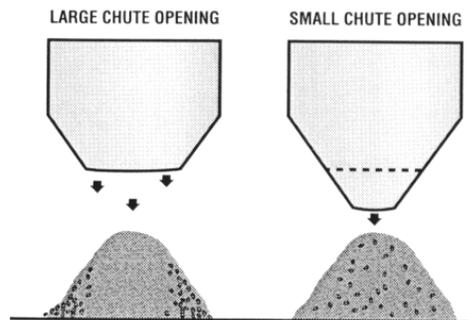


Figure 30. Less Segregation with Smaller Chute Opening.

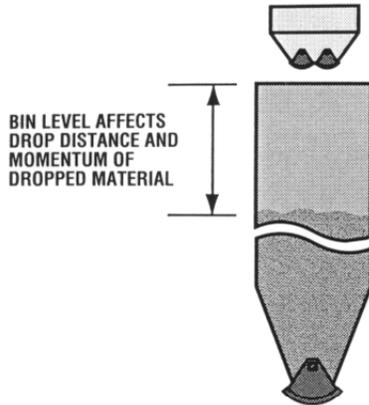


Figure 31. Bin Batcher Drop Distance.

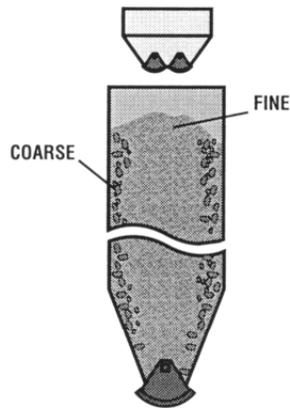


Figure 32. Bin Kept Too Full.

conveyor all the way into the drum. This possibility makes operators want to leave the gates open, totally defeating the batcher's purpose. Timers should not be used on batchers except to control the gate open time. The production rate of plants will vary and different times are required to fill the batcher. Remember, it is essential that the batcher be totally filled each time so that an adequate slug or a single mass drops into the bin.

d. The batcher should never be completely emptied. The gate open time should be adjusted so that a small amount of material (approximately 6 inches (150 mm)) remains in the batcher after the discharge cycle is completed. If the gate remains open too long, new material falls straight through the batcher and goes directly into the bin, resulting in random segregation.

e. When utilizing a bin loading batcher, the emptier the bin, the farther the fall of the material and the more likely a level, uniform bin loading will occur (see Figure 31). The worst situation when operating a bin loading batcher is to have the bin material level consistently near the top (see Figure 32). The mix drop then has insufficient momentum and results in peaks of material instead of splattering the material to form a level surface. The rules for correct batcher operation are summarized in Figure 33.

Loadout from Surge or Storage Bins—Uniform filling of the surge or storage bin can minimize concerns of segregation. Pulling material below the cone is not as sensitive as with the old type center-loaded bins. This is due in part to improved bin loading with batchers and rotating chutes, but results primarily from utilizing a steep cone angle that produces a mass flow of material from the bin. With most non-gap-graded materials, the bin can be emptied with minimal concern of segregation. However, with gap-graded material, the bin level should still not be allowed to drop below the cone.

Rapid discharge from the silo gate helps eliminate segregation in trucks. This reduces the chance of segregation in the truck bed by minimizing the rolling action of the mix as it is flowing into the truck bed.

In cold weather, bins should be insulated, at least on the cone. Cold surfaces can cause the mix to stick to the cone and under these conditions the material can restrict the flow instead of discharging in a uniform mass flow.

-
1. Batch size should be at least 5,000 lbs (2,500 kg).
 2. Batcher should be loaded in the center.
 3. Material should flow straight down into the batcher.
(no horizontal trajectory)
 4. Batcher gate timers should be adjusted so that gates shut with 6-8 inches (150-200 mm) of material left in the batcher. Do not allow any free flow through the batcher.
 5. Batcher should be maintained so that the mix drops out rapidly as a slug.
 6. Do not keep material level consistently near the top.
-

Figure 33. Batch Rules.

Truck Loading and Unloading

Due to rapid truck loading underneath surge or storage bins, truck drivers often tend to pull the truck under the bin and not move it while loading. If the mix is sensitive to segregation, larger stones will roll to the front of the truck, to the rear, and to the side, resulting in the coarse material being the first and last material to be discharged from the truck bed. The coarse material on each side will then be trapped in the wings of the paver hopper and can be discharged between truck loads. This discharging results in coarse areas of pavement between each truck load. This type of loading is shown in Figure 34.

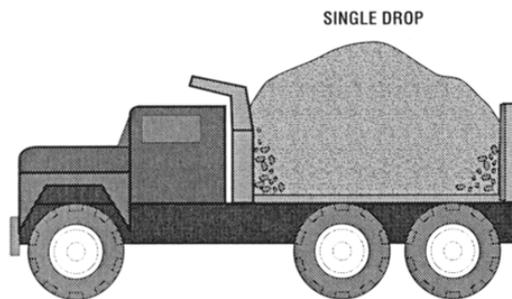


Figure 34. Improper Truck Loading.

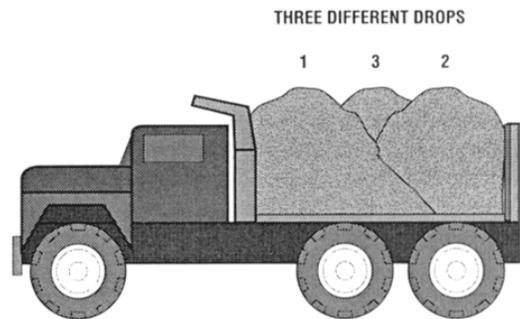


Figure 35. Proper Truck Loading.

By loading the truck in three different drops, with the first drop being near the front of the truck bed, the second drop near to the tail gate, and the third drop in the center, coarse material will be forced to roll to the middle of the truck and then be covered as shown in Figure 35. This ensures that the first material to be dumped from the truck will be good material with the coarse material intermixed in the middle.

Bins equipped with weigh batchers as shown in Figure 36 tend to batch material directly into the trucks in a manner similar to the bin loading batcher. The weigh batcher, if designed properly, greatly ensures uniform loading of the truck and improves the chance of avoiding segregation with a sensitive mix.

When unloading a truck into a paver hopper, it is important to discharge the material as a mass, instead of dribbling the material into a paver. To do this, the bottom of the truck bed needs to be in good condition and lubricated so that the entire load will slide rearward. To further assure that the material is discharged as a mass before the tailgate is opened, elevate the truck bed just enough to “break” the load while remaining at a safe angle (see Figure 37).

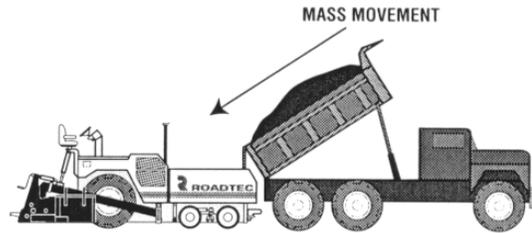


Figure 37. Larger Dumping Angle Ensures Mass Discharge.

Discharging from the truck in a mass floods the paver hopper and minimizes the break and run of material that may occur between the tailgate and the paver hopper. A mass discharge prevents an accumulation of coarse material at the outside portion of the paver hopper.

With sensitive mixes, it is often necessary to modify the forward portion of the truck bed to eliminate undesirable effects caused by the hydraulic cylinder enclosure. If the mix has a tendency to segregate, a pocket of coarse mix can occur as the mix slides away from the cylinder enclosure. As the load moves rearward, the mix caves in, forcing large stones to accumulate in the center of the bed at the front of the truck. Then, as the load moves into the paver, truck end segregation occurs (see Figure 38). Adding a plywood or light gauge metal cover across the entire front of the bed from side-to-side will usually eliminate this problem. NAPA’s video *Hauling Hot Mix Asphalt (TAS-19)*, provides detailed information on proper truck techniques.

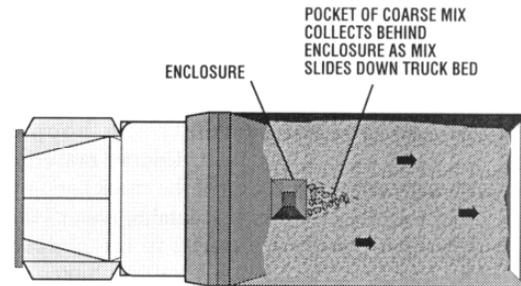


Figure 38. Cylinder Enclosure Causes Truck End Segregation.

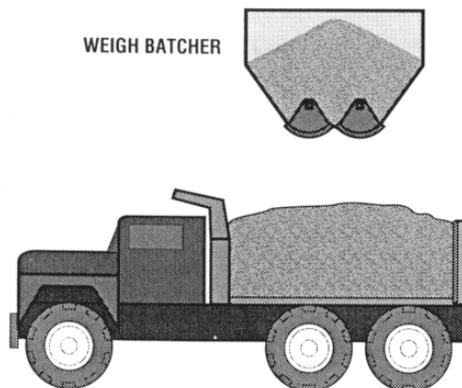


Figure 36. Bin with Weigh Batcher.

Paver

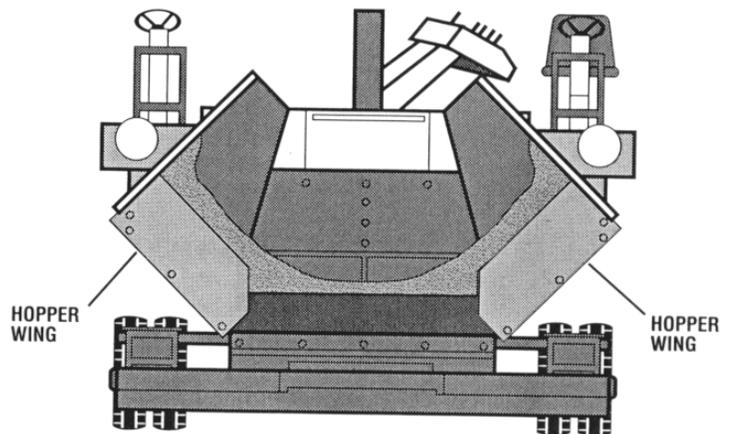
Even though material has been successfully processed through the cold feed bin, through the plant, through the surge or storage bin, and then uniformly loaded on the truck, segregation can still occur in the paver. Improper operation of a paver can cause segregation in varying degrees. Here are suggestions that should be considered when segregation occurs at the paver:

a. Do not completely empty the hopper between each truck load. Coarse material tends to roll to each side of the truck bed and thus roll directly into the outside area of the hopper. By leaving material in the hopper, the coarse material has a better chance of being mixed with finer material before being placed on the road.

b. Fold hopper wings only as required to level the material load in the hopper. Folding eliminates the valleys in the material bed, thereby minimizing rolling that occurs when unloading. It allows the truck tailgate to swing open fully to flood the hopper with mix (see Figure 39). (It is noted that in some states, contractors have blocked out the corners of the hopper wings and never fold them. The wings are cleaned out at the end of each day.)

c. Dump the truck so as to flood the hopper. With the hopper as full as possible, material tends to be conveyed from the bottom of the dumped and minimizes the tendency to roll as it is dumped into the hopper.

Figure 39.
Paver Hopper Wings.



- d. Hopper gates should be opened high enough to supply needed material to the paver. Do not run the gates too low and starve the augers for mix, because fine material may drop directly on the ground, leaving the coarse material deposited on each side by the auger (see Figure 40).

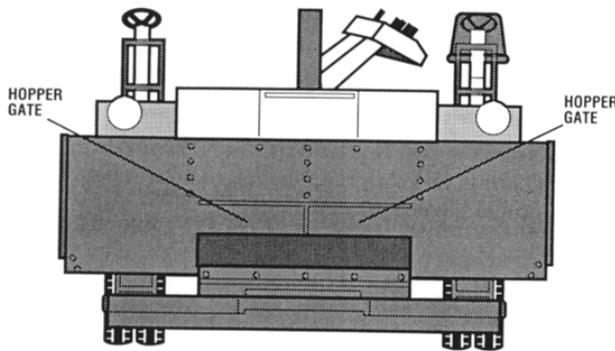


Figure 40. Paver Hopper Gates.

- e. Run the paver as continuously as possible. Use rapid start and stops only as necessary. Adjust the paver speed to balance paver production with plant production as well as rolling capacity. NAPA Publication IS-120, *Balancing Production Rates* provides a method to determine the paver speed.
- f. Run augers continuously. Auger speed should be adjusted so that a continuous flow of material occurs. Augers that run at high speeds are cycling on and off continuously and could result in segregation at the paver.
- g. If material level in augers is allowed to run low, the center of the mat will be deficient of material and this will generally result in a coarse strip. Baffle plates, as shown in Figure 41, may prevent coarse materials from rolling in front of the auger gear box and causing centerline segregation. With the

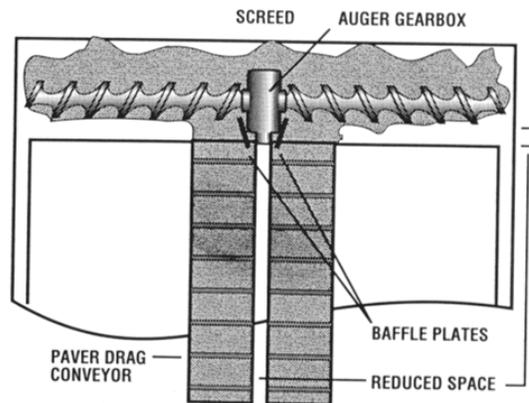


Figure 41. Gearbox Baffle Plates.

22 Segregation — Causes and Cures

installation of the baffles, the augers then divert material uniformly to the center. Two important changes made on some pavers to minimize segregation and eliminate the need for baffles are:

1. With the raiseable augers, the augers have a separate gearbox, flight chain drives are on the outside, and the chains now have less space between them at the center of the hopper. This prevents the pocket for mix to roll into.
 2. Head sprockets of the flight chains are now closer to the auger.
- h. If the outer edges of the paver auger are deficient of material, coarse strips along the outsides can occur as the coarse aggregate

rolls to the outsides. Sonic or similar feed controls may eliminate this by keeping a constant head on the screed.

- i. If possible, adjust paver extensions so that the paver pulls the same amount of material from each side of the hopper. If one side is pulling more material, a valley will form in that side of the paver hopper, causing segregation to occur in sensitive mixes. If correction cannot be made by adjusting the extension, offset the truck slightly towards the side requiring more material to even out the material bed in the hopper.

NAPA's publication, *Paver Operations for Quality*, IS-125, provides detailed information on proper paver operations.

Material Transfer Vehicle

The difficulty of dumping mix from the truck into the paver while keeping the paver moving continuously should be apparent from the earlier discussion. Figure 42 shows two material transfer vehicles (MTVs) which are designed to eliminate this difficulty. The MTVs allow the haul truck to stop at a suitable distance ahead of the paver, then dump its entire load without moving. (See Figure 43.) The MTV carries 25 to 30 tons (22.5 to 27.2 metric tons) of mix.

The MTVs are designed to ensure that segregation does not occur from the truck to the hopper and to eliminate any segregation that may have occurred from the time of mixing. The MTVs cannot correct faulty mix designs.

To work with the MTV, a holding hopper is installed on the paver, allowing storage of approximately 20 tons (18 metric tons) of material. A swivel conveyor from the MTV fills the hopper.

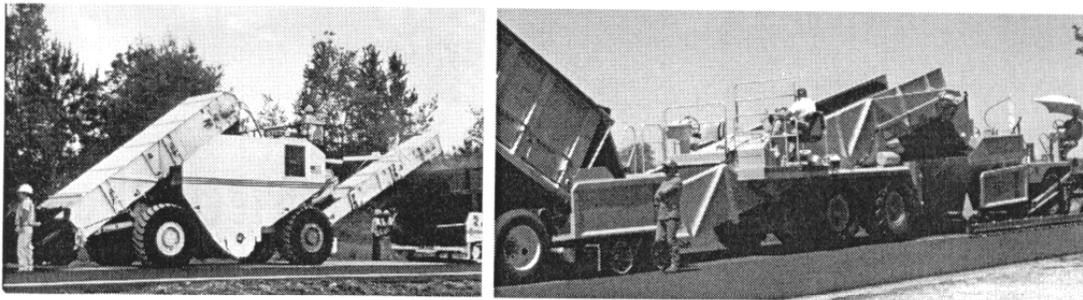


Figure 42. Material Transfer Vehicles.

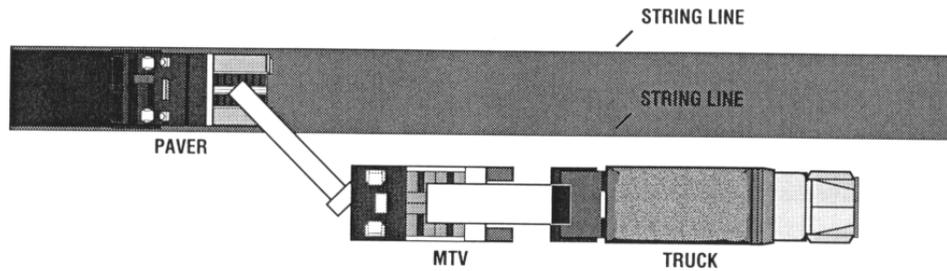


Figure 43. MTV Operating in Adjacent Lane.

from the top. The swivel conveyor allows the MTV to charge the paver from an adjacent lane. This concept allows continuous operation of the paver, re-blends the material, and allows the use of large, horizontal discharge trailers.

Moreover, the holding hopper on the paver eliminates the accumulation of coarse material in the wings. Accumulation of coarse material and dumping of the wings is a major cause of truck end segregation.

An MTV can be effective in eliminating truck end and random segregation due to the unit's ability to reblend the mix with augers (see Figure 44). The resulting pavement smoothness has been shown to be very good. It is noted that other good paving techniques and well maintained equipment can be used to accomplish the same results.

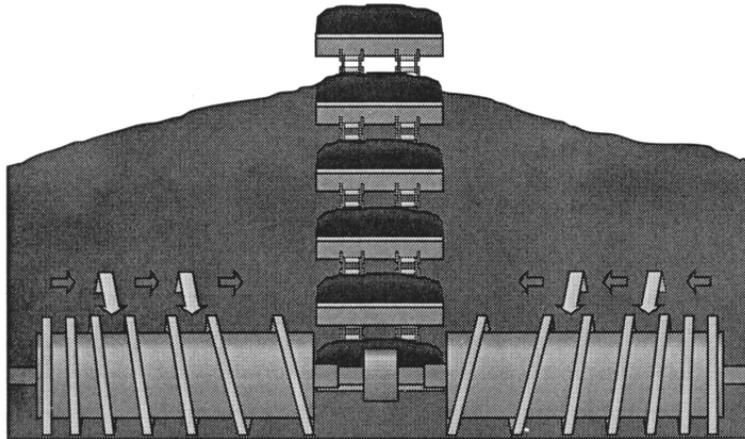


Figure 44. MTV Mixing Augers.

Diagnostic System

The Segregation Diagnostic Chart accompanying this technical paper shows five different kinds of segregation. It provides a diagnostic system for analyzing the potential causes of segregation based on these types of segregation as they occur on the road. Thus, the most likely causes of segregation can be quickly identified in the chart. This paper can then be consulted for more detailed information regarding causes and remedies.

Testing

Segregation and asphalt content go hand-in-hand. If mix is uniformly produced and uniformly coated and the material segregates after mixing, a sample of coarse material will reveal low asphalt content while a sample of fine material will show high asphalt content. NAPA Publication QIP-109, *Asphalt Cement Content Diagnostic Approach for HMA Facilities*, shows methods of analyzing asphalt content and extraction problems. Refer to this publication if segregation is occurring in the sampling or in the splitting of the material prior to running extraction tests.

Summary

In summation, segregation in Hot Mix Asphalt mixtures is a common and persistent problem. However, the problem can be controlled and even eliminated through proper mix design and through proper maintenance and operation of plants, trucks, and paving equipment. It is hoped this publication will assist in analyzing the problems and will be helpful in the selection of an effective cure.