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SEGREGATION OF ASPHALT MIXTURES--CAUSES, IDENTIFICATION AND CURES

by

Thomas W. Kennedy
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Richard J. Holmgreen, Jr.
James N. Anagnos

Research Report Number 366-1F

Segregation in Asphalt Mixtures Produced in Drum Mix Plants

Research Project 3-9-84-366

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Texas
State Department of Highways and Public Transportation

in cooperation with the
U.S. Department of Transportation
Federal Highway Administration

by the

Center for Transportation Research
Bureau of Engineering Research
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November 1986

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

PREFACE

This is the first and final report of a research project concerned with segregation of asphalt mixtures. This report discusses segregation and the effects and remedial measures associated with mixture design, aggregate stockpiling and handling, asphalt mixing plants, and paving.

In addition, the final chapter contains information related to diagnostics, i.e., the identification of the probable cause of various types of observed segregation. Thus the intent of this report is to provide an explanation of segregation, factors producing segregation, procedures and equipment which will minimize or eliminate segregation, and guidelines for determining the probable cause of segregation.

The work required to develop this report involved many people. Special appreciation is extended to Pat Hardeman and Eugene Betts for their assistance with the laboratory testing. Special thanks is given to the District personnel who have shared their problems and experiences. Among these personnel are James Opiela, Waylan Wallis, and James Johnson (Corpus Christi), Bobby Lindley and Walter Plumlee (Abilene), David Bass (Ft. Worth), and David Justice (Yoakum). In addition, the authors would like to express their appreciation to Paul K. Krugler and Billy R. Neeley of the Materials and Test Division (D-9), State Department of Highways and Public Transportation, for their suggestions, encouragement, and assistance in this research effort. The authors extend a special acknowledgment to James Scherocman, Don Brock, Robert McGennis, and Jay Hensley for their help, suggestions, and information. The support of the Federal Highway Administration is also acknowledged.

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LIST OF REPORTS

Report No. 366-1F, "Segregation of Asphalt Mixtures--Causes, Identification and Cures," by Thomas W. Kennedy, Maghsoud Tahmoressi, Richard J. Holmgreen, Jr., and James N. Anagnos, summarizes a study of segregation in asphalt mixture and includes the identification, major causes of segregation, and recommendation to minimize or alleviate segregation.

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ABSTRACT

This report contains a summary of the causes of segregation in asphalt mixtures, methods for reducing segregation, a guide for identifying the causes, and recommendations for eliminating or minimizing the extent and severity of segregation.

The intent of the report is to serve as a field guide for inspectors and engineers for use in understanding and eliminating segregation in asphalt paving mixtures.

KEY WORDS: segregation, asphalt mixtures, mixture design, stockpiling and handling of aggregate, asphalt plants, asphalt paving

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SUMMARY

Segregation of asphalt mixtures is a major paving problem throughout the United States. The intent of this report is to provide information related to segregation, causes, and methods of prevention. Segregation is discussed with respect to the effects of

- mixture design,
- aggregate stockpiling and handling,
- mixing plants, and
- hauling and paving.

In addition, guidelines for recognizing probable causes of segregation and the necessary remedial measures for minimizing or eliminating segregation are provided.

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IMPLEMENTATION STATEMENT

Information and recommendations contained in this report are based on field experience in Texas, supplemented by the experience and findings in other states. The guidelines and recommendations contained in this report represent the current status of knowledge pertaining to segregation of asphalt mixtures and techniques for minimizing segregation. Thus, this report can be provided to field personnel for their use in understanding segregation problems, diagnosing probable causes, and utilizing techniques or remedial measures to minimize or eliminate segregation.

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CHAPTER 1. INTRODUCTION

Segregation in asphalt mixtures is the non-uniform distribution of aggregate with differing sizes and specific gravities. Thus, segregation involves a concentration of coarse materials in a specific area and fines in another area. It is generally the coarse areas that are readily visible, especially under moist conditions or low angle lighting.

Asphalt surfaces which exhibit segregation contain areas which are open textured and generally cannot meet normal density requirements. The open texture and low density allow moisture and air to permeate the mixture, resulting in durability-related damage such as ravelling, cracking, and joint separation. In addition, the mixture may experience stripping or premature aging which in turn leads to premature pavement distress. The overall effect is substantially reduced pavement performance and increased maintenance.

Segregation can occur at various stages of construction, beginning with the design of the mixture itself since segregation is more likely to occur with a gapped or coarse graded aggregate, a large difference between the specific gravities of the aggregate components, low asphalt contents, or a combination of these factors.

This report provides information related to the segregation, construction procedures which can produce segregation, the causes of segregation, identification of possible causes, and measures to minimize or eliminate segregation.

The basic segregation causes and remedial measures are discussed under the following headings in the chapters indicated

- (1) mixture design (Chapter 2),
- (2) stockpiling and handling (Chapter 3),
- (3) asphalt mixing plants and equipment (Chapter 4), and
- (4) paving (Chapter 5).

Many of these causes produce well defined patterns of segregation. Thus, Chapter 6 identifies the basic patterns of segregation and their probable causes and provides suggestions with regard to remedial measures.

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CHAPTER 2. MIXTURE DESIGN

Mixture design is not the primary cause of segregation; however, certain mixtures are more inclined to segregate than others and thus may be a significant contributing factor. The two mixture design factors which significantly affect the tendency for segregation are gradation and asphalt content. In recent years, in an effort to achieve higher stabilities, engineers have reduced the asphalt content of typical mixtures. Lower asphalt contents generally cause reduced cohesion in an asphalt mixture which in turn can contribute to segregation. Low asphalt contents also may cause stripping and poor workability of the mixture. In addition, coarse-graded aggregates (large maximum size) and gap-graded aggregates tend to segregate. Thus, a particular production or paving operation may result in an entirely adequate surface under normal circumstances. However, with an improperly designed mixture these same operations may result in a segregated surface.

The remainder of this chapter discusses segregation as it is affected by mixture design factors.

SEGREGATION MECHANISM

General behavioral characteristics of asphalt mixtures are often difficult to visualize and understand due to the microscopic and seemingly invisible nature of the responses or the complexity of the predictive models often employed. Fortunately, the characteristics of asphalt materials that affect segregation are more finite and easily understood.

The fundamental mechanism that causes segregation can be understood by a simple, visual demonstration. Consider a sample of well graded aggregate cast over a flat surface. It is easy to visualize the coarse particles travelling a farther distance than the finer particles. This demonstration can be extrapolated to an asphalt production and placement operation by understanding that whenever and wherever a mixture is in motion or is disturbed, the coarser and heavier particles will, to some degree, tend to separate from the finer and lighter particles.

AGGREGATE CHARACTERISTICS

The primary aggregate characteristics affecting segregation are specific gravity and gradation including maximum aggregate size.

Specific Gravity Differences

Aggregates with significantly different specific gravities will tend to segregate. In general, use of aggregates with differing specific gravities is often dictated by unavailability of other suitable aggregates. Recognition of the potential problems associated with blending aggregates with widely different specific gravities will help minimize segregation problems. Except in specific cases, however, this is not a major cause of segregation.

Gradation

Of primary importance is the gradation of the aggregate. Aggregate mixtures which have large maximum sizes or are coarse graded have a greater tendency to segregate than do mixtures which are finer graded.

Typically, well graded aggregates are less prone to segregate, while gap graded aggregates are prone to segregation. Figure 2.1 illustrates three possible gradations. On this figure, the sieve sizes are scaled to the 0.45 power, and a straight line drawn from the nominal maximum particle* size to the origin represents the gradation which theoretically will produce maximum packing and minimum voids for that specific aggregate combination (12).

Gradation A is a well graded mixture. It has no deficiency or excess of material within any particular size interval. When a well graded condition occurs, coarse particles tend to be held in place by the next smaller size particles.

Gradation B is a gap graded mixture. This type of gradation is fairly common in Texas. As shown, there is a hump in the curve at about the No. 40 sieve which indicates a deficiency of material of this size. Normally the deficiency of No. 40 size material is attendant with an excess of No. 80 size material. Even though this gap gradation may be entirely within specification limits, it causes the mixture to be sensitive to segregation during the various stages of production and placement.

* The nominal maximum particle size is the largest sieve size upon which any material is retained.

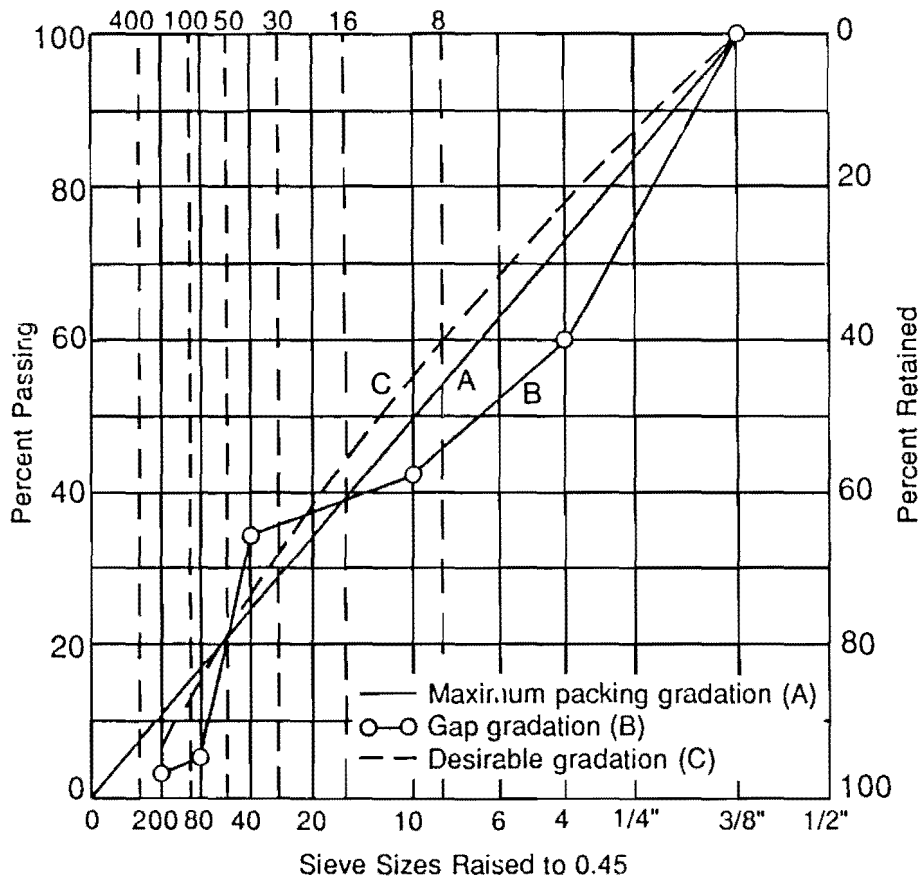


Figure 2.1 Typical aggregate gradations

By more closely approximating the maximum density gradation, the tendency to segregate will be greatly reduced. However, it should be noted that a gradation falling exactly on the maximum density line could also be undesirable since there may not be sufficient room for enough asphalt to develop an adequate asphalt film coating. A plastic mixture could result if slightly overasphalted or a dry, non-durable mixture could result from a slight deficiency of asphalt.

The optimum gradation would be one such as Gradation C which deviates slightly to the fine side above the maximum density gradation or to the coarse side below the maximum density gradation.

ASPHALT CONTENT

Low asphalt content mixtures exhibit less cohesion and are far more prone to segregation than those with higher asphalt contents. This cohesion, especially in a loose state, is developed through the asphalt film coating

with thicker films resulting in increased cohesion. Other mixture properties such as stripping resistance and stability are also affected by film thickness. An asphalt film in the range of 6 to 12 microns has been reported to be satisfactory (1).

The primary contributor to film thickness is asphalt content. Brock (2 and 3) reported that often an increase in asphalt content as small as 0.2 percent was enough to eliminate segregation problems. Absorption of asphalt cement by aggregate also affects film thickness and thus, segregation potential. Although most designers converse in terms of total asphalt content, only the unabsorbed (effective) asphalt contributes to the film coating.

If during the aggregate drying all moisture is not removed, the film thickness can increase since moisture is taking the place of asphalt in the asphalt permeable aggregate pores. Consequently, the segregation potential may be temporarily reduced. However, other problems such as stripping and mixture tenderness may reach critical levels. Although it is conceivable that the lack of asphalt absorption due to moisture might minimize segregation in plant operations, a substantial amount of absorption could occur while the mixture is in surge bins or truck beds as the moisture is removed.

The voids in the mineral aggregate (VMA) can be used to explain much of the mixture behavior in terms of segregation. Figure 2.2 shows a conceptual relationship between VMA and asphalt content. At or near the minimum VMA, the mixture possesses a relatively thick asphalt film which enhances cohesion and minimizes segregation. Asphalt contents which are significantly less than the asphalt content at minimum VMA result in high stability, low cohesion mixtures that are prone to segregate. Asphalt contents on the high side of minimum VMA tend to produce plastic mixtures that are not particularly susceptible to segregation.

Optimizing all factors, the most suitable asphalt content is the one which yields the minimum voids in mineral aggregate (VMA). However, because of inability to determine VMA to high degrees of accuracy and natural variations in construction, it is desirable to select an asphalt content slightly less than the asphalt content for minimum VMA (4).

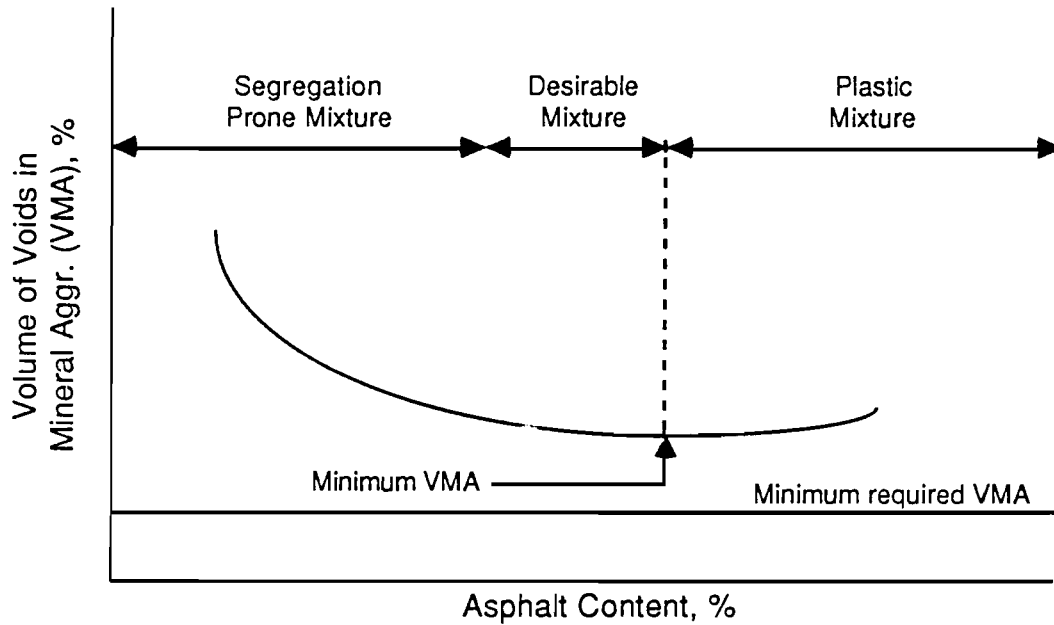


Figure 2.2. Conceptual relationship between asphalt content and VMA (4)

FILLERS

Excessive fines, particularly minus 200 material, can also produce an asphalt mixture which is prone to segregate. These fines which often are not considered during the design of the mixture have large surface areas which must be coated with asphalt thus reducing the film thickness on the coarse aggregate which in turn results in a dryer mixture and the tendency for segregation.

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CHAPTER 3. STOCKPILING AND HANDLING

Aggregate stockpiling and handling can produce significant segregation of the aggregates. The effect is usually more important for drum mix plants than for weigh-batch plants since the hot screens in batch plants provide a means to correct errors and problems. However, it should be noted that weigh-batch plants are not immune to problems resulting from improper stockpiling and handling although such problems generally do not produce segregation type problems.

STOCKPILING

Figure 3.1 shows the actual gradation of an aggregate stockpile in Texas which had a considerable range of material sizes ranging from No. 4 to minus No. 200. Aggregates such as these are quite susceptible to segregated stockpiles.

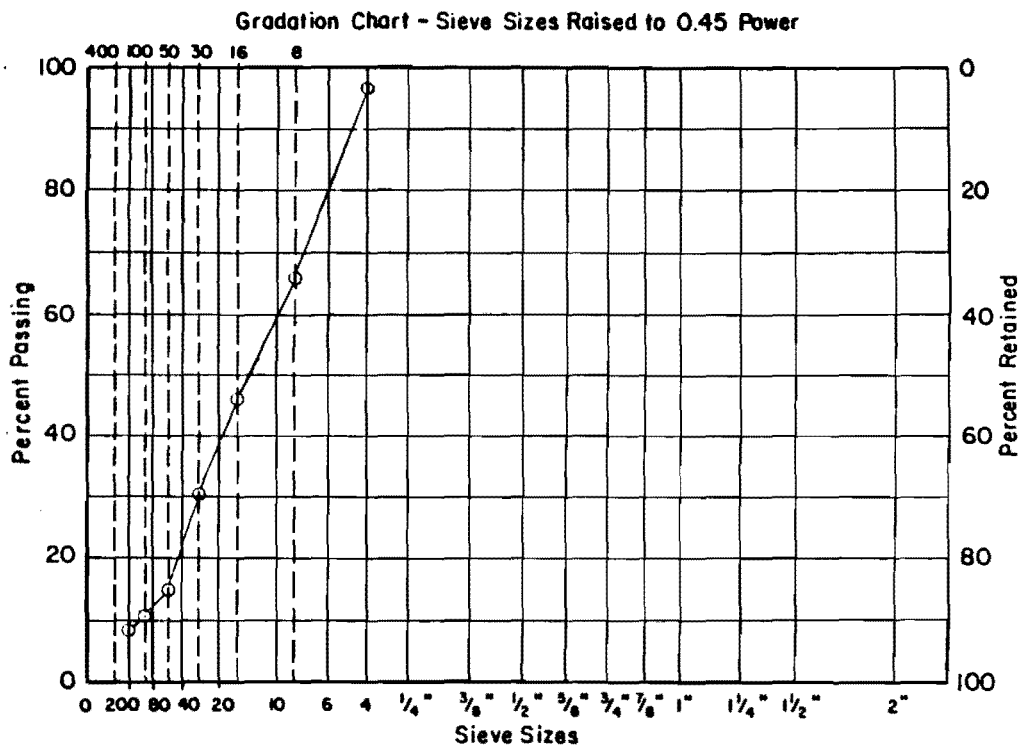


Figure 3.1. Example of stockpile gradation prone to segregation

Thus for an aggregate source that has multiple sizes, large, conical-shaped stockpiles should be avoided. As aggregate is loaded on top of this type of stockpile, there is a tendency for larger particles to roll to the outside and bottom of the stockpile (Fig 3.2). The problem becomes more serious as the stockpile becomes larger and higher and for very dry aggregate since aggregate moisture minimizes segregation.

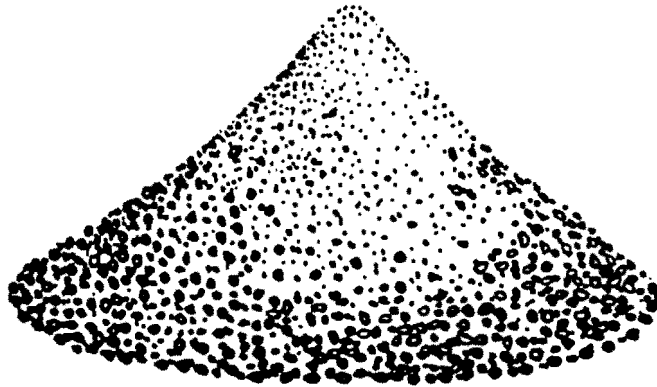


Figure 3.2. Unacceptable stockpiling technique (5)

In the case of a drum mix plant, a segregated stockpile has the potential to cause a segregated type of mixture. Although this problem may resemble and often is categorized as segregation, the underlying problem is that the gradation of the aggregate placed in the cold bins is wrong or at least one that is different from the design. Since there are no screens, such as on a weigh-batch plant, an asphalt mixture with an improper gradation is ultimately produced and placed.

This problem can be minimized by constructing stockpiles which are not cone-shaped and which are constructed in successive layers (Fig 3.3). Using this technique, different aggregate fractions will remain evenly mixed and large aggregates will not tend to roll.

Sometimes, special types of equipment such as radial stackers, overhead belts, or elevating conveyors are used to construct stockpiles. Although such devices tend to produce conical stockpiles, one way to use these types of devices is to control the positioning of the falling materials by using baffles or other devices.

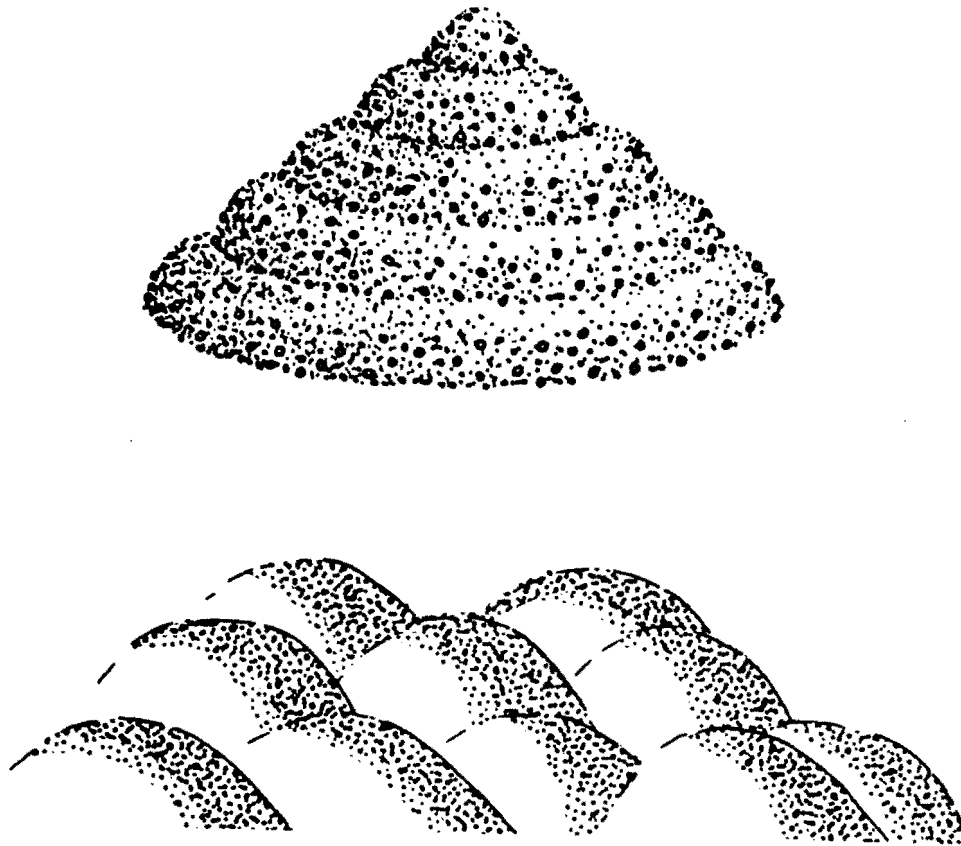


Figure 3.3. Recommended stockpiling techniques (5)

If aggregates are to be stockpiled with a crane and clamshell bucket, loads should be placed adjacent to each other rather than always dumped in the same place. In addition, the material should never be cast or slung from the bucket; rather, it should be dropped vertically and in layers with each layer being completed before the next is begun.

If stockpiles are constructed with a bulldozer or other track or rubber-tired vehicle, manipulation of the aggregate should be kept to a minimum since this promotes segregation. When operating on a particular stockpile the bulldozer should avoid performing movements in the same area every time. This promotes not only segregation but also degradation of the material.

In addition, aggregates should be stockpiled according to their size. In general, a minimum of three stockpiles are required, one each for coarse stone, fine stone, and sand. Additional stockpiles may be required if there is a large variation in the size of the aggregates. Stockpiles should be

placed on a clean, stable surface and should be constructed in a manner to prevent mixing of aggregate from one stockpile with the aggregate from an adjacent stockpile. If adequate space is not available, bulkheads separating adjacent stockpiles may be required.

Perhaps the best way to minimize segregated stockpiles is to use five or even six separate materials, each of which is uniformly sized. Not only does this minimize stockpile segregation, it generally results in a more uniform mixture. The major disadvantage to this technique is the added expense of more highly processed materials and extra cold feed bins.

AGGREGATE HANDLING

Whenever aggregates are moved there is a tendency for segregation to occur. Thus, problems can occur due to conveyance of aggregate from the stockpile to the cold bins, and ultimately into the dryer or drum mixer.

Loading Aggregate from Stockpile

Aggregates are typically loaded out of a stockpile with a front-end type loader and placed in the cold feed bins. The care and skill of the loader operator is critical in producing an acceptable mixture. This is especially true in the case of a drum mix plant.

Since a plant is usually calibrated with respect to the gradation and even the moisture content obtained from a stockpile sample, the loader operator should make every effort to remove material from the stockpile in the vicinity where the sample was taken. If new material arrives during a day's production, this material should be stockpiled so that it will not impede loading operations and should not be used until sampled. While the above is not directly related to segregation, it is important to the production of a quality asphalt mixture.

Rather than scooping up the side of the stockpile, the operator should proceed directly into the stockpile, rotate the bucket, and move directly out. This ensures that any segregation of coarse particles near the outside of the stockpile will not be the only material removed. Large bucket loads with multiple size material should be avoided since coarse particles will tend to roll off.

Cold Bins

When filling the cold feed bins the aggregate should be dumped directly into the center of the bin (Fig 3.4). The loader operator should adjust his speed of operation to maintain a reasonably constant level of material above the feeder gates so that a uniform flow results. If bins are allowed to run too low, a reverse cone or drawdown in the center may result. Bins that are overfilled tend to form a cone which the operator should strike off with the bucket; however, attempts to strike off the cone can result in spillage of the aggregate into the adjacent bin (Fig 3.5). If aggregate spillage is a problem, bulkheads should be installed to separate the cold bins (Fig 3.4).

When a clamshell is used to feed the bins, aggregates should not be removed from the same location successively. If trucks are used to feed the bins, they should deposit their loads directly above the feeder.

The shape and aggregate flow characteristics of the cold bins can also affect segregation. Corners which would collect coarse particles should be avoided. If a visual inspection of a bin reveals any sharp corners which may inhibit steady flow of aggregates, fillets can be welded into these corners.

Cold feed bin opening configuration can contribute to segregation if the material is segregated from the stockpile. In cold feed bins with rectangular openings, bridging of the aggregate can occur (Fig 3.6a). Brock (2) suggests that utilizing a self-relieving configuration as shown in Figure 3.6b will result in more uniform flow of the aggregates through the bin opening.

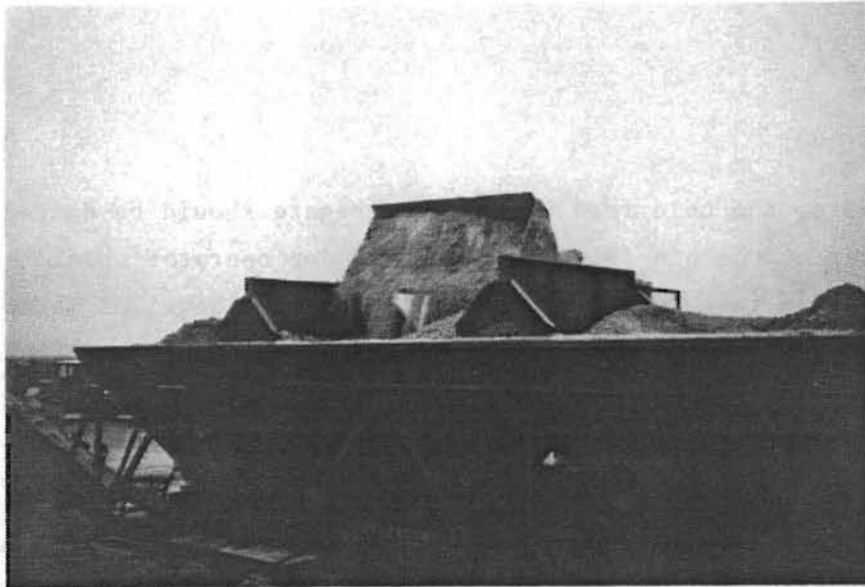


Figure 3.4. Bulkheads on the cold feed bins

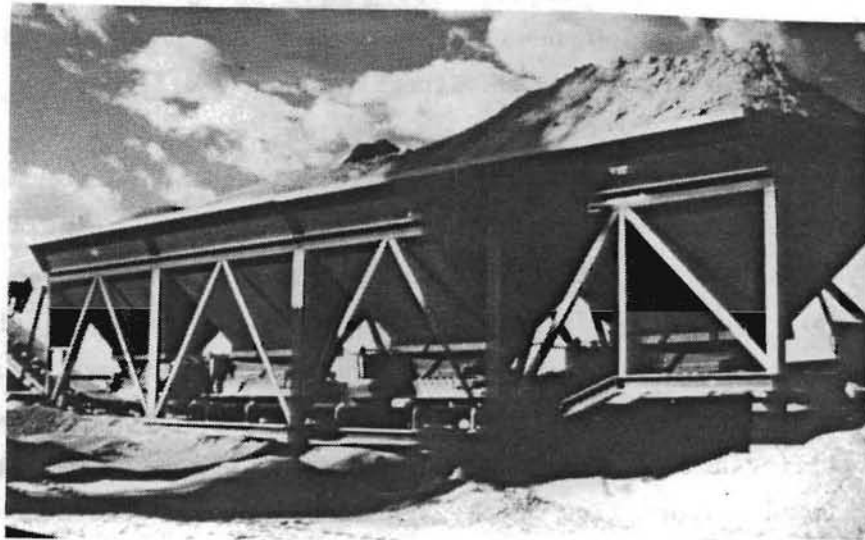
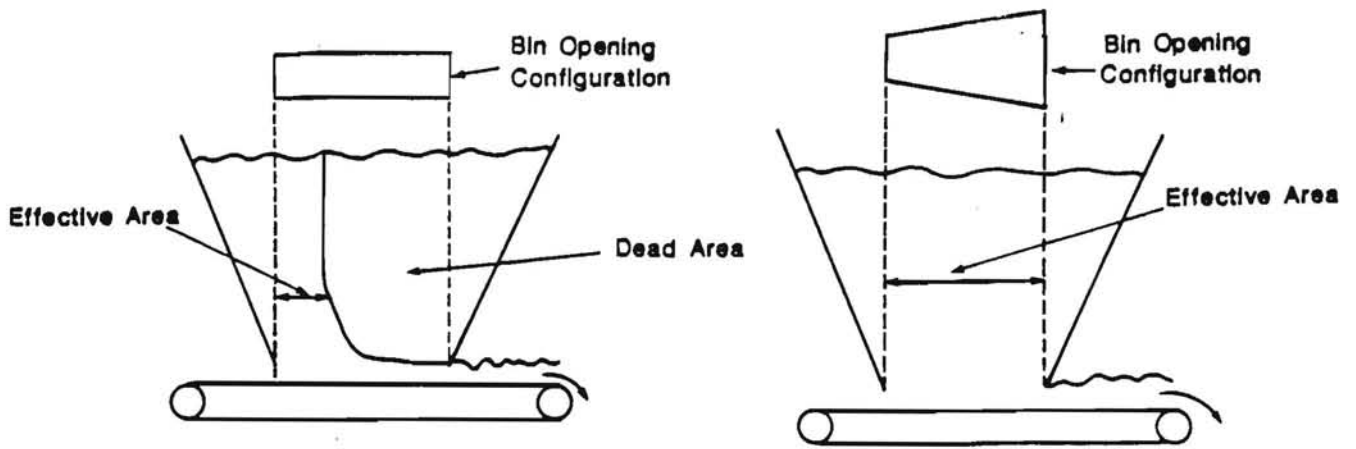


Figure 3.5. An example of overfilling the cold bins



a. Rectangular opening b. Self-relieving configuration

Figure 3.6. Bin opening configurations (2)

CHAPTER 4. ASPHALT MIXING PLANTS AND EQUIPMENT

Although segregation can occur in various locations in a mixing plant, the following are the most critical:

- (1) hot bins on batch plants,
- (2) drum mixers, and
- (3) surge and storage silos.

HOT BINS ON BATCH PLANTS

Segregation occurs to some extent in all screening and hot bin operations (Fig 4.1). The flow of material over the screen deck is such that coarse particles tend to segregate along the bin walls.

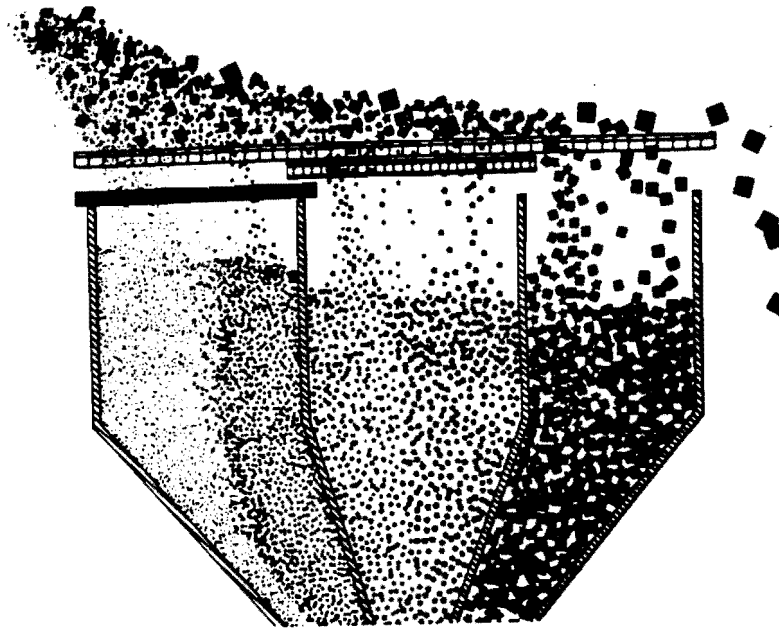


Figure 4.1. Segregation of materials in the hot bins (6)

Since the first bin can contain a wide range of sand size particles, segregation in this bin has the potential to cause problems. Most of these problems involve an accumulation of fine sand material along the outside bin

wall (Figs 4.1 and 4.2). This segregated material can discharge in a single drop into the weigh hopper, resulting in a segregated, fine batch.

To solve this problem, a baffle may be placed in the bin so that the fine material is placed in the center and mixed with coarse material (Fig 4.3). Another possible solution would be to place a baffle so that the coarse material is placed on the sloping bin wall to promote mixing with fine material.

Occasionally, fine material will build up in corners of bins and fail to discharge until a large deposit accumulates. Fillets welded into the corners will help alleviate this problem.

As shown in Figure 4.1, vertical stratification of materials occurs to some extent in all bins. Because of this it is important to use proper sampling techniques to obtain a representative sample.

Another source of segregation in hot bin operations involves improper screening. This could take the form of blinded screens and holes. This situation is analogous to segregated stockpiles on a drum mix plant since the gradation that is produced is different from that planned. Segregation-type problems may also be caused by holes which form in bin walls. Hot bin gradation samples as well as visual inspection of equipment can identify these problems.

DRUM MIXERS

Large particles generally tend to travel through a drum mixer at a faster rate. However, during normal, continuous operations and with well graded aggregates, this potential source of segregation is not particularly significant. During start-up, the feed of coarse materials can be delayed slightly to reduce such segregation. Another method may be to use a diversion chute immediately upstream from the batcher.

If a mixture is gap graded, however, coarse or uncoated particles may tend to segregate throughout the process. This type of segregation can sometimes be minimized by increasing the mixing time by extending the asphalt injection line farther toward the burner end of the drum (Fig 4.4a) to achieve earlier coating of the aggregate, hence improving the cohesion of the mixture, or by installing kickback flights (Fig 4.4a) or dams (Fig 4.4b).

Steep drum slopes can also cause segregation in the mixture since the larger aggregates will flow even faster toward the exit. If a steep drum

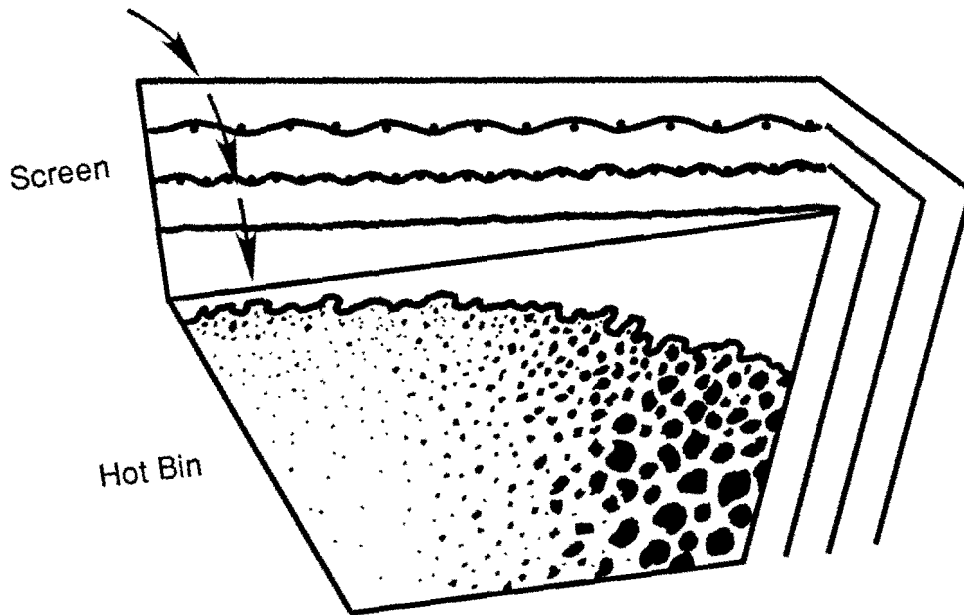


Figure 4.2. Segregation of asphalt mixtures in hot bin No. 1 (7)

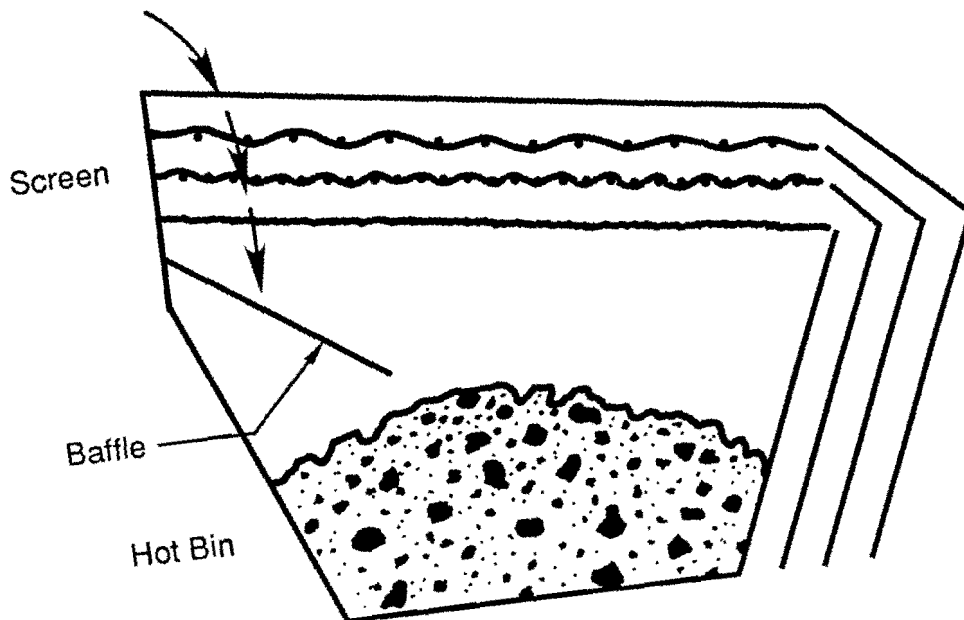
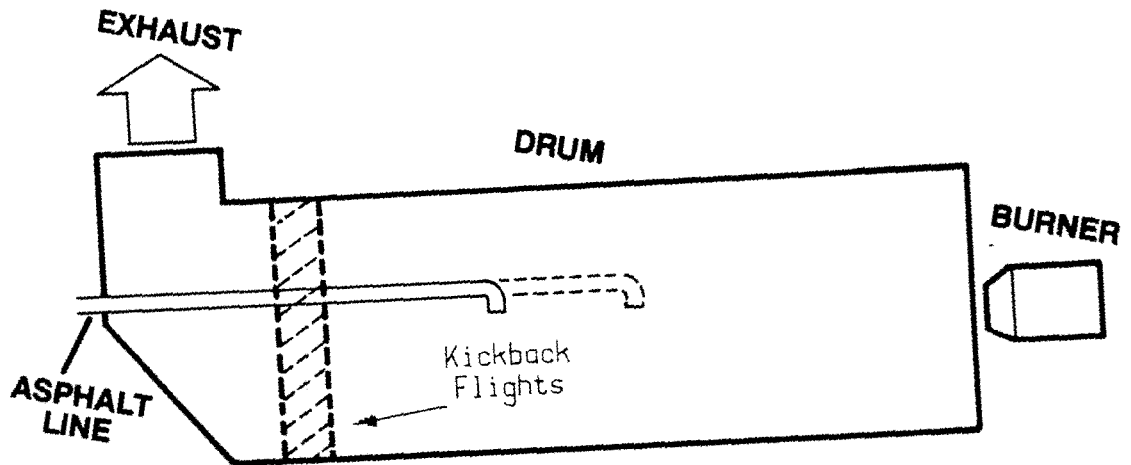
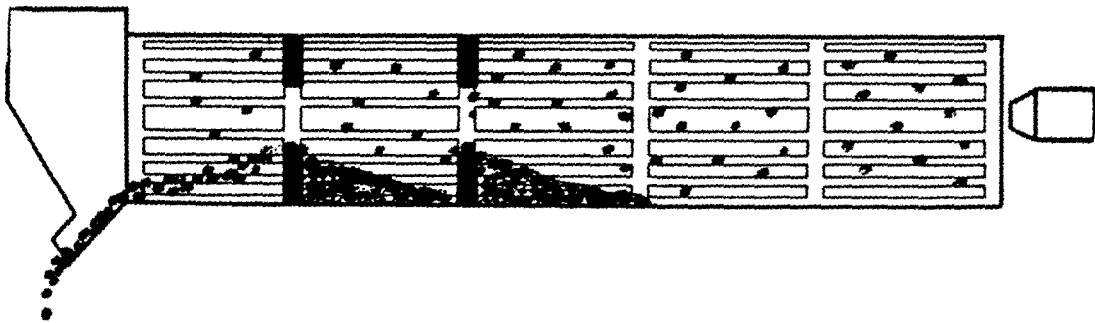


Figure 4.3. Installation of baffle to minimize segregation in hot bins (7)



a. Kickback flights and extension of asphalt lines (7)



b. Dams

Figure 4.4 Techniques to increase mixing time and improve aggregate coating (7)

slope is suspected as the cause of segregation, it can be corrected by either reducing the slope with adjustable jacklegs or installing additional flights inside the drum to slow the flow rate of the aggregates. When the mixture is discharged from the drum, high lift type discharges are less sensitive to segregation. Gravity type discharges can tend to result in coarse material on one side of the conveyor with fine material on the other (Fig 4.5).

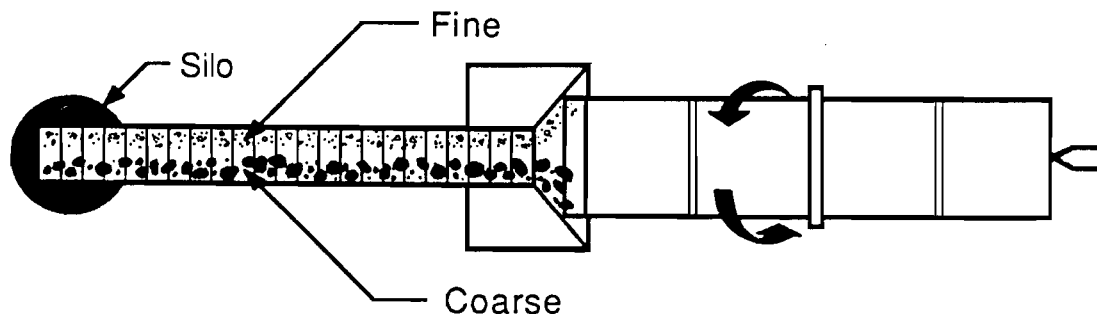


Figure 4.5. Segregation resulting from drum discharge (7)

A fixed plow (Fig 4.6a) that moves the coarse material back toward the fines will reduce this effect (4). Another proposed solution is to restrict the discharge chute enough so that the mixture is deposited primarily in the center of the conveyor.

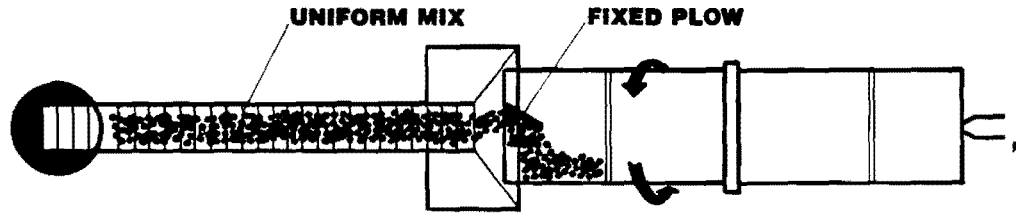
It might be possible with some plant configurations to set the conveyor at a 90 degree angle from the drum (Fig 4.6b). This ensures both coarse and fine material will be deposited uniformly across the conveyor (4).

During start-up periods and any other time when the drag conveyor becomes cold, fine material tends to accumulate on top of the belt near the drag slats (Fig 4.7). When this occurs, coarse materials can spill over the top of the slats, causing segregation. This effect can be minimized by using heated bottoms and/or equipping the conveyor with floating hold-downs.

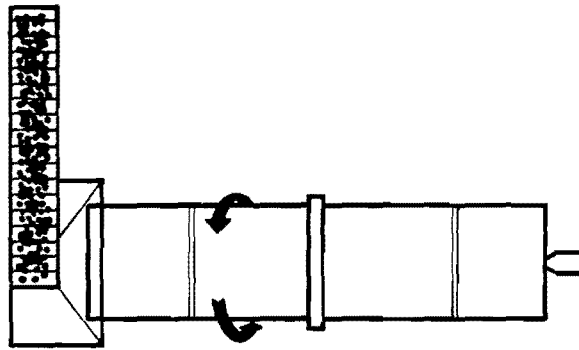
SURGE AND STORAGE BINS

One of the more important causes of segregation and probably the most important is the improper use of surge or storage silos. The nature of drum mix plants, which are continuous production plants, is such that it is desirable to keep the plant operating and avoid repeated start/stop operations during production. Since the demand for the asphalt mixture may not be uniform throughout a period, the mixture must be temporarily stored in surge silos.

Surge bins come in a variety of shapes. The majority of the silos currently employed are circular in cross section. Although silos which are oval, elliptical, rectangular, and even square, are in use. The shape of the



a. Fixed plow



b. Conveyor perpendicular to drum

Figure 4.6. Techniques to minimize segregation produced at drum discharge (7)

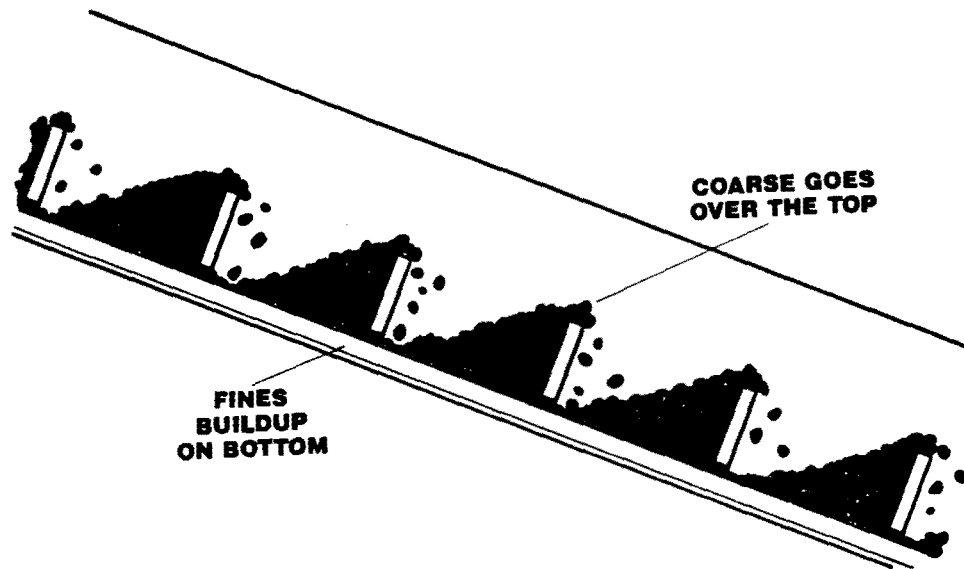


Figure 4.7. Segregation caused by drag conveyor (7)

bin does not seem to have any significant effect on the ability of the silo to deliver mix to the haul truck uniformly. In addition, the size of the bin, either in diameter or in height, in itself does not seem to be a factor in the amount of segregation of an asphalt concrete mix which can occur. However, the manner in which the silo is operated can have a great effect on the uniformity of the mix delivered.

During the early days of drum mix plant usage, silos were a tremendous source of segregation, since the material tended to be cast into the top of the silo with a horizontal trajectory which caused coarse aggregate to roll and collect on one side of the silo (Fig 4.8a). The resulting segregation pattern is similar to that shown in Figure 6.3e, Chapter 6. Fortunately, recent industry efforts have resulted in operating procedures and equipment to minimize segregation associated with silos.

Nevertheless, segregation still occurs in surge and storage silos; however, it is mostly caused by improper use of the specially developed equipment or overall improper plant operations. In addition, there may be some plants still in operation which have not been equipped with the necessary equipment.

Silo Loading Batchers

A variety of conveying devices are used to carry asphalt mixtures from the discharge chute on the drum mixer to the silo. Regardless of the conveying device the mixture should be placed into the silo in a manner which minimizes segregation. Essentially the material should be dropped vertically. Some manufacturers developed a series of baffles to capture and contain the asphalt mixture, dropping it into the center of the silo. Others have used a splitter system to divide the mixture, pushing a portion of the mixture to each section of the silo. In general, the baffle and splitter systems reduced segregation but did not always eliminate it. (13)

Batchers or Gob-hoppers. The most common piece of equipment currently used to reduce segregation is the batcher or gob-hopper (Fig 4.8b). As previously noted, prior to the advent of batchers, material was cast into the bin and a clear pattern of segregation was evident with coarse particles on one side due to the casting action (Fig 4.8a). The function of the batcher is to collect the mixture from the drag conveyor and load it into the bin in a single drop to cause the mixture to splatter uniformly.

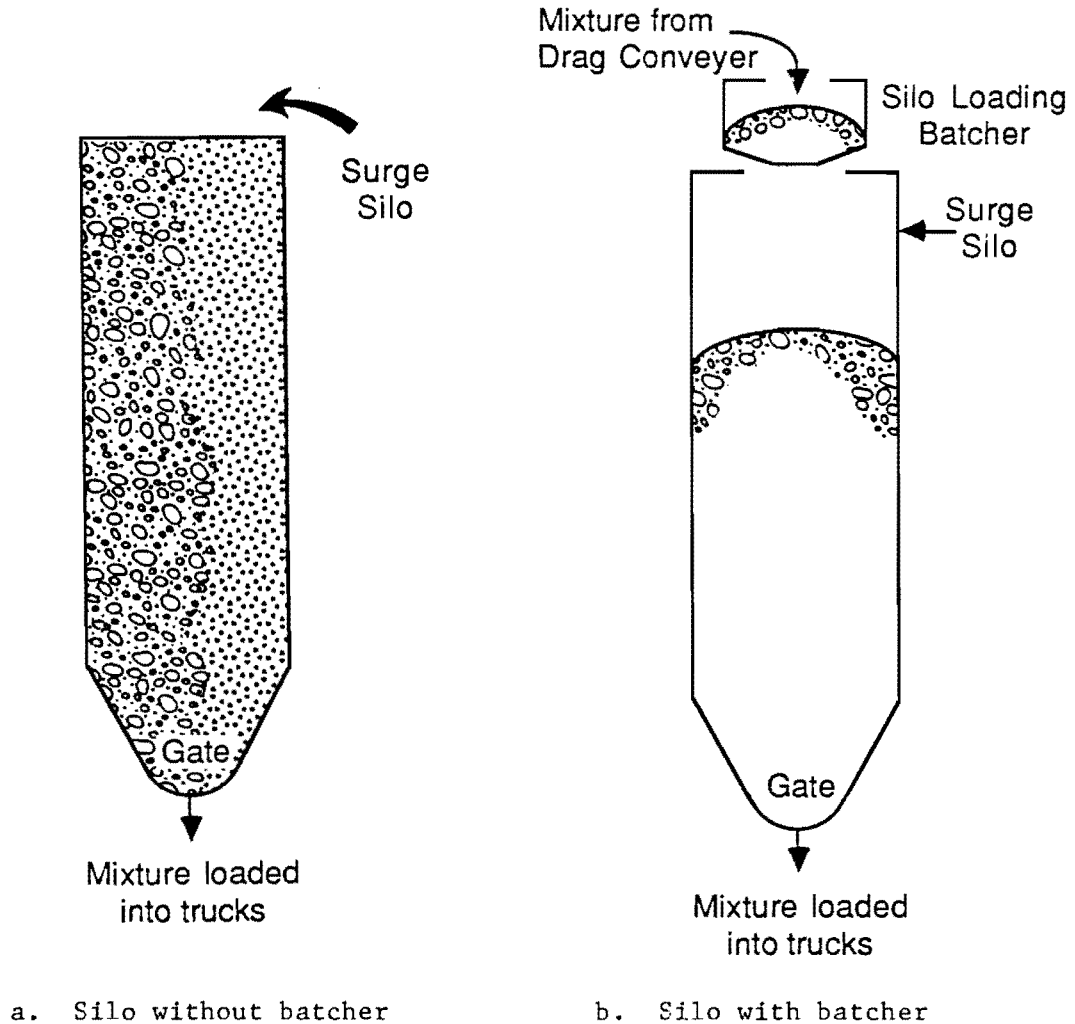


Figure 4.8. Batcher or gob hopper to minimize segregation in storage silos (4)

The manner in which the batcher gate operates can have a significant impact on the effectiveness of the batcher in reducing or eliminating segregation. The gate opening should be sufficiently large to allow a rapid discharge of material. It is advisable to avoid a timed gate opening since it is normally set for only a unique production rate. If the production rate is changed without changing the gate timing the possibility exists for mixture to fall directly through the batcher into the bin. Therefore, the batcher will not be performing its intended function. Also there is a tendency for plant operators to circumvent the use of the batcher altogether by setting a very long gate opening to avoid having to reset the timer for various production rates.

A better system involves use of a batcher full indicator. This ensures the batcher will have a sufficiently large slug of material to drop. Normally, two indicators are used, one to dump the gates and the other as a back-up.

Storage silos should generally be kept at least one-third full to keep the mix hot and to avoid segregation. When a batcher is used it is desirable to keep the silo less than one-half full. This will ensure proper momentum in the batch as it falls down and causes it to spread adequately and to not form a cone (Fig 4.9). Silos are normally equipped with high and low level indicators. The high level indicator warns the plant operator when the silo is being over-filled. The low level indicator, which is located just above the cone section, ensures that the operator does not load the trucks below the cone section where segregation in gap graded mix can occur.

The relationship between height and diameter of the silo could affect the segregation characteristics. With large diameter silos, the reverse cone effect may take place if the mixture is pulled out of the center of the silo. The reverse cone effect may be prevented by addition of a small gob hopper inside the lower portion of the silo.

When loading from the drag conveyor into the batcher it is best to load directly into the center in a downward drop (Fig 4.10a). If the mixture has a horizontal trajectory component, segregation will occur in the batcher itself (Fig 4.10b). Coarse particles tend to be slung to the far side of the batcher. The resulting pattern of segregation appears as a coarse line of segregation on one side of the mat (Fig 4.11 and Fig 6.3e in Chapter 6). Improper speed of the hot elevator could cause segregation in the mixture deposited in the batcher. A small amount of mixture on a fast moving conveyor will cause the coarser aggregates to be slung to the far side of the batcher. To avoid segregation, the conveyor speed should be balanced with the output tonnage of the plant.

In order to diagnose improper silo or batching loading, trucks can be loaded in the opposite direction of travel. If the coarse line of segregation still exists but is on the opposite side of the mat, the cause is probably in the upper part of the silo and probably involves loading the silo or batcher with excessive horizontal trajectory.

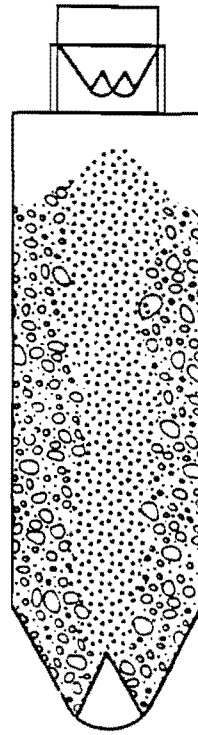
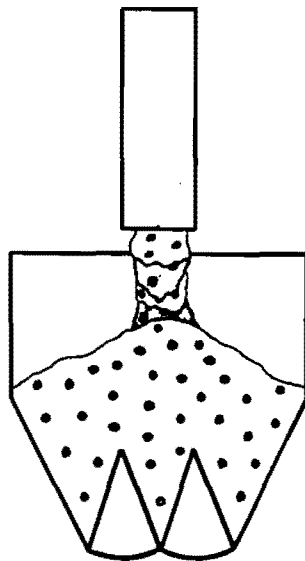
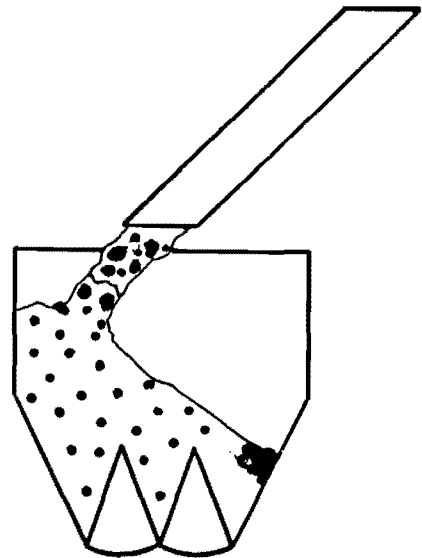


Figure 4.9. Formation of cone inside the silo



a. Correct



b. Incorrect

Figure 4.10. Batchers loading

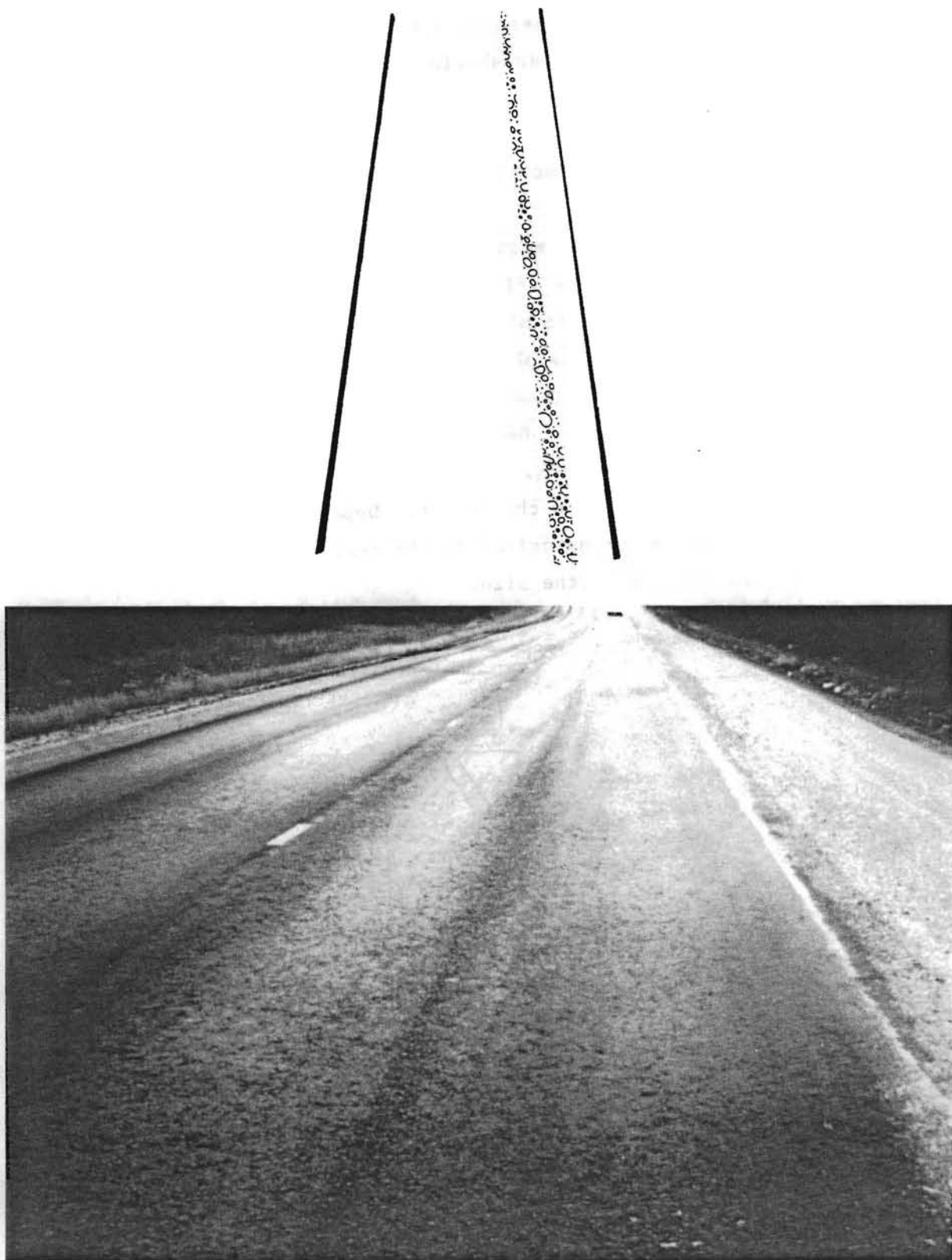


Figure 4.11. Edge segregation resulting from silo segregation

Optimum usage of the batcher requires the batcher to be full prior to gate opening. Ideally, a batcher should hold at least 4,000 pounds and have a relatively large diameter gate (2). However, the batcher should never be completely emptied. Small amounts of mix should be retained in the batcher to provide a cushion for the incoming materials.

Rotating Chutes. Another means of introducing the mix into the silo is with a rotating spreader chute (Fig 4.11). This device turns around at the top of the silo, depositing the mix in a circle around the circumference of the silo. The flow of the asphalt concrete is continuous, but the development of conical piles of mix is minimized by spreading the material out over a wider surface area. Because the chute on the rotary spreader is subject to abrasion from the mix, it must be checked periodically to assure that no holes have developed in the device. Depending on the location of the hole, mix can either be all deposited in the center of the silo or all around the outside circumference of the silo.

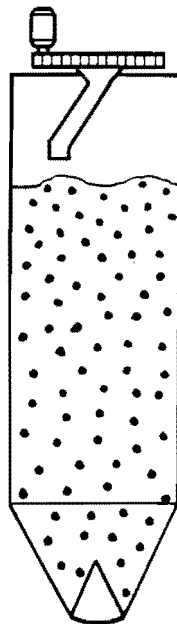


Figure 4.12. Rotating chute (7)

Cone

The bottom of the surge bin is shaped like a funnel. This section, or cone, is used to deliver the mix to the hauling vehicle. The angle of the cone varies between the different manufacturers, but usually is between 55° and 70°. This slope assures that the mix is deposited in a mass into the truck. The angle needs to be steep enough to assure that the larger aggregate particles do not roll into the center of the cone as the mix is drawn down, causing segregation.

The vast majority of the surge silos have low bin indicator systems which warn the plant operator when the level of mix in the bin approaches the top of the cone. By keeping the volume of mix in the silo above this minimum height, the development of segregation will be minimized. As very coarse mixes or gap graded mixes are pulled below the top of the cone, there can be a tendency for the largest aggregate particles to roll into the center of the crater.

Silo Discharging

Periodically the inner walls of the silo should be inspected to check for a possible accumulation of fine material adhering to the sides. This accumulation of fines causes additional sticking which promotes segregation. Such areas should be cleaned of material. If a petroleum based solvent such as diesel fuel is used, the solvent residue should be removed.

Discharge gates are available in a variety of configurations and sizes. Most modern varieties are not particularly sensitive to segregation. Large, elongated gates are the most desirable since they tend to drop a large amount of material which minimizes coning in the truck bed.

Silos which are equipped with weigh batchers will batch the mixture directly into the truck. The weigh batcher is similar to the batcher on top of the silo and will greatly reduce the segregation potential of sensitive mixes (Fig 4.13). The weigh batch can be installed perpendicular to the normal discharge gates which will tend to remix a possibly segregated mixture.

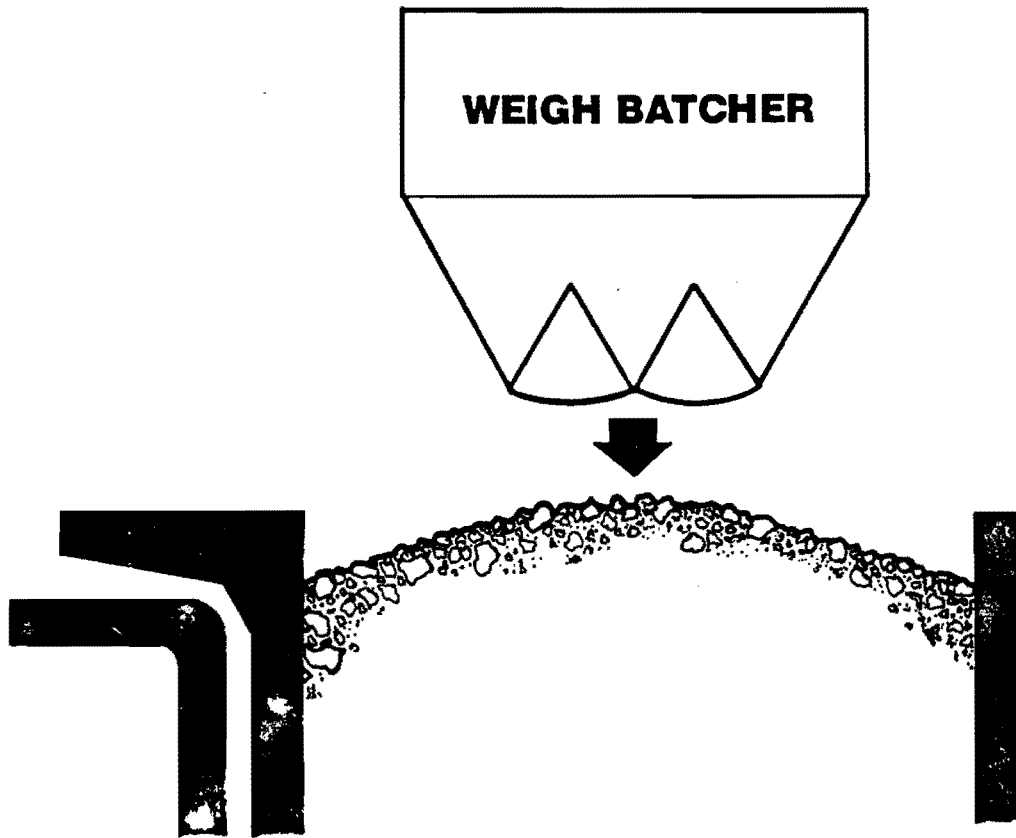


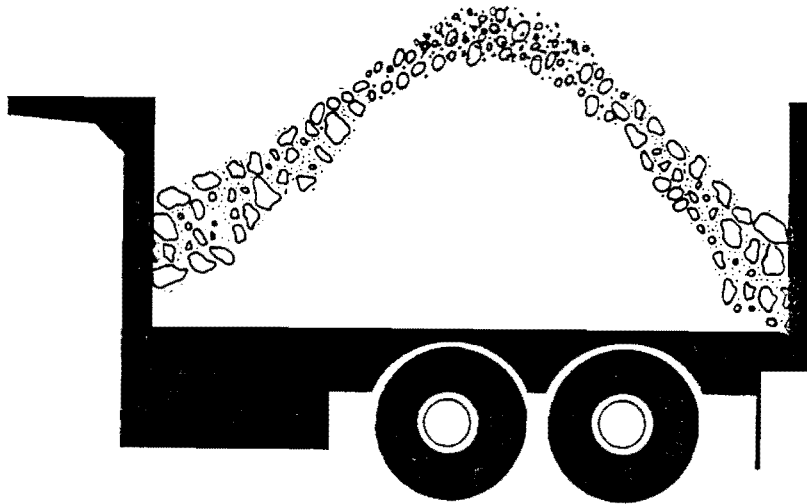
Figure 4.13. Weight batcher on bottom of silo (7)

Truck Loading

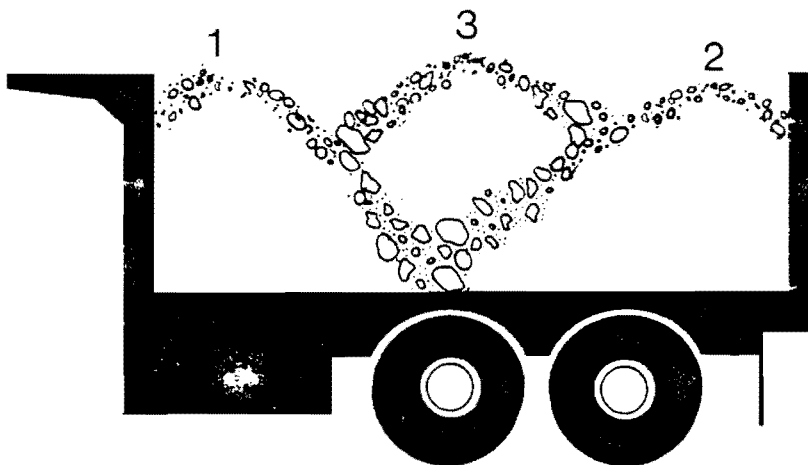
Discharge gates are available in a variety of configurations and sizes. Large, elongated gates are the most desirable since they tend to drop a large amount of mixture which minimizes coning in the truck bed. The least desirable situation is to have a small stream of material slowly deposited in the truck. This enhances rolling of coarse aggregate to the outside of the truck bed. The mixture should be dropped in a large mass.

When loading trucks there is a tendency for material to be deposited in a single pile (Fig 4.14a). When a large truck is loaded in a single drop, coarse material will accumulate in the front, back, and to a lesser extent, the sides of the truck. When this truck load is deposited in the paver, the coarse material is the first and last to be deposited in the paver. The mixture near the sides of the truck bed becomes deposited in the paver hopper wings. This segregated material subsequently appears as coarse spots in the finished surface between each truckload of material.

Trucks with sufficiently large capacity should be loaded in three drops (Fig 4.14b). The sequence of drops is front, back, and middle (2). This sequence tends to force coarse aggregate to remix with unsegregated material as it achieves an equilibrium level in the truck bed. In addition, the first and second drop should be made as close as practical to the front and rear of the truck to minimize the roll of coarse aggregate to the front and back of the truck.



a. Incorrect



b. Correct

Figure 4.14. Truck loading (7)

SUMMARY OF MIXING PLANTS AND EQUIPMENT

In the preceding section, various equipment and techniques were described that help reduce segregation. It should be noted that equipment and techniques which are discussed will help eliminate segregation only if they are operated properly and are adjusted for the particular plant production needs.

It should also be emphasized that changes in production rate and/or mixture design potentially have a drastic effect on the effectiveness of the techniques and equipment. In fact, some mixtures are designed so poorly that even with the best operation, segregation problems may be experienced.

Further, elimination of segregation due to one cause may well expose another cause. For example, an improperly operated batcher could be adjusted to eliminate segregation; however, improper truck loading may still cause problems. Therefore, when attempting to eliminate segregation problems it is best to examine all possible causes at the earliest possible opportunity. There is no use in frequent start-ups and shut-downs each time a segregation pattern occurs.

CHAPTER 5. PAVERS

Even the most careful plant operations resulting in a uniform mixture are often circumvented by improper paver operations and paving techniques. The primary causes of segregation during the laydown process are discussed in this chapter.

TRUCK UNLOADING

As discussed in Chapter 4 on truck loading, there is a tendency for mixtures to segregate in the truck beds. Although the best method of eliminating this source of segregation is in the loading operation, there are several procedures which can be used to minimize the effect.

The best truck unloading operation can be described as flooding the hopper. Normally when the truck is immediately adjacent to the paver the tailgate is released and coarse particles trickle into the hopper. To eliminate this effect, the bed of the truck should be raised slightly to surge the tailgate prior to opening the gate. Thus when the gate is opened a surge of mixture floods the hopper. Not only does this technique prevent a small discharge of primarily coarse material from being deposited in the hopper, the coarse material will be remixed in the turbulent flooding operation.

Bumps in the road between each truck load can be produced if the truck bumps into the paver or if the driver rides the brakes when the truck is being pushed by the paver.

HOPPER OPERATIONS

When the truck empties into the paver hopper, the coarser material on the sides of the truck bed will roll directly into the wings of the hopper (Fig 5.1). Therefore, if the hopper wings are dumped after each truck load, the coarser material in the wings will produce a distinct pattern of segregation. This type of segregation will appear as systematic coarse spots between each truck load or whenever the wings are emptied (Fig 5.2 and Fig 6.3b, Chapter 6). Such patterns can occur as two spots on either side of the mat (Fig 5.3) or can extend entirely across the mat (Fig 5.4). This problem

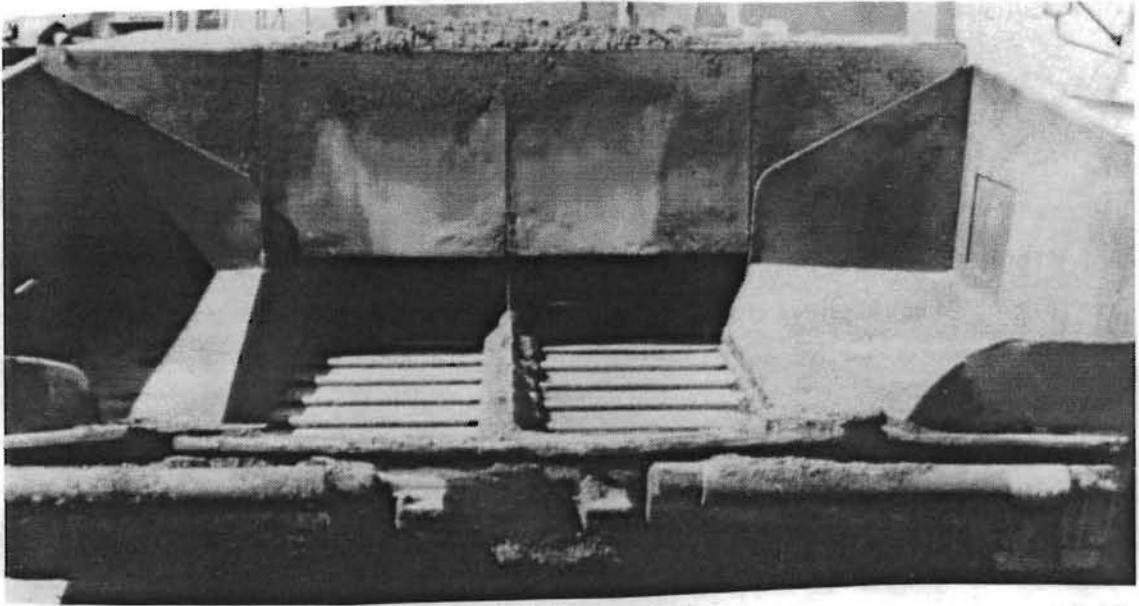


Figure 5.1. Paver hopper

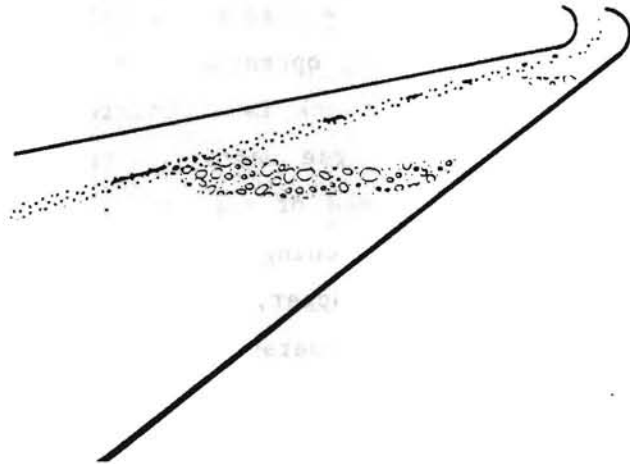


Figure 5.2. Systematic spot segregation between truckloads

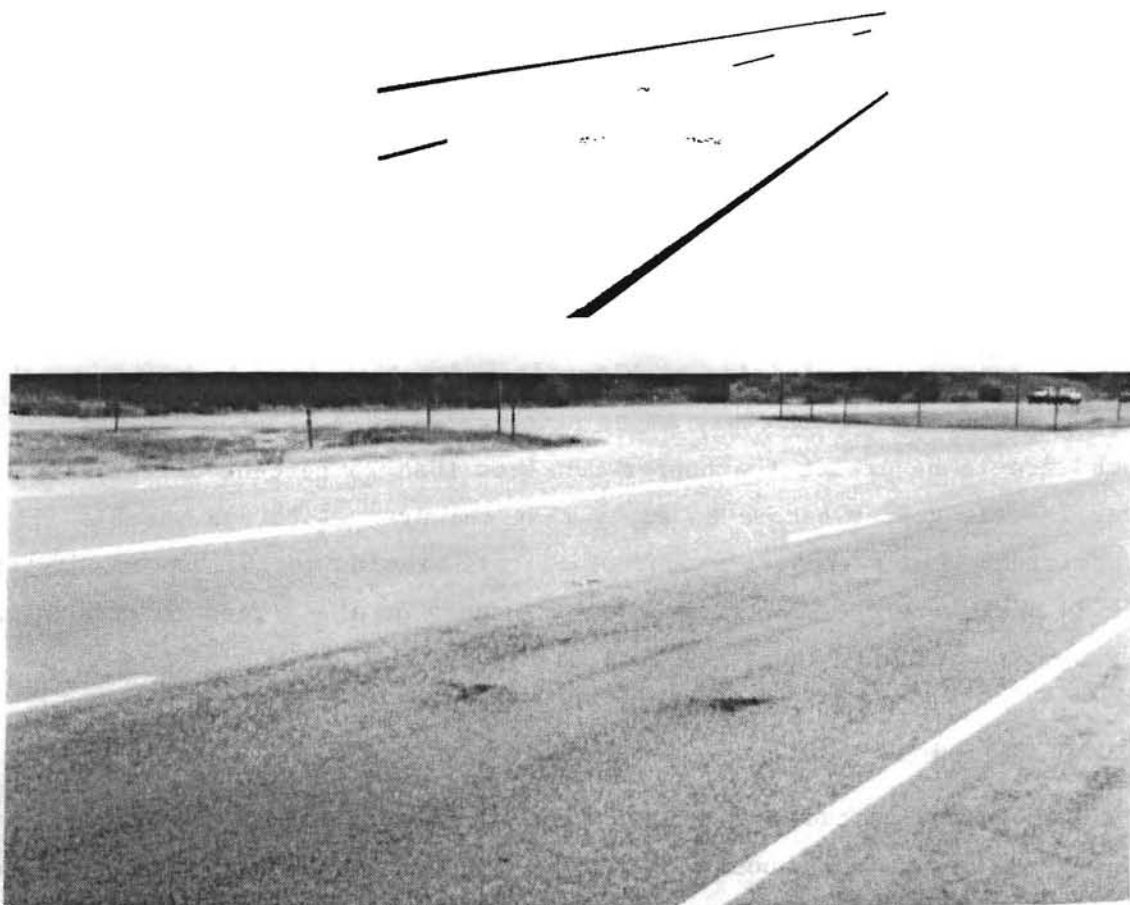


Figure 5.3. Spot segregation due to emptying hopper wings

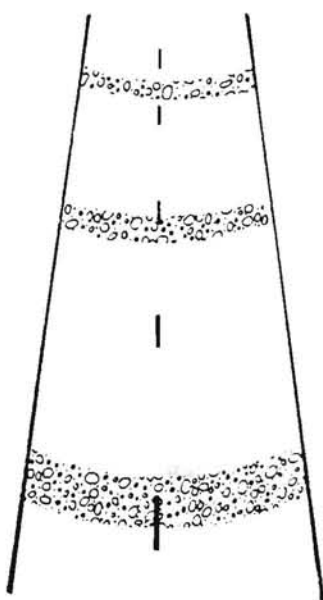


Figure 5.4. Spot segregation extended across the mat

has been worsened in recent years by the use of pavers with very large hoppers. Thus, wings should only be dumped a minimum number of times.

Certain hopper modifications have been found to also reduce segregation caused by dumping of the wings (3). One modification is to weld a bevelled bottom on the wings. This promotes a more continuous flow of material from the wing area onto the drag slats. Another modification is to place fillets in the corners of the wings to keep coarse material from collecting in these areas.

The best way to minimize problems from dumping wings is to insure that the hopper is never completely empty prior to dumping. Two useful "rules of thumb" are to never let the hopper run less than 25 percent of capacity or never let the hopper become so empty that the drag slots are visible (11). In addition, when a greater amount of mixture remains in the hopper, it tends to hold heat longer, which reduces the tendency of the screed to ride up and over cooler material, causing a hump in the mat surface.

AUGER OPERATION

On most pavers the hopper gate opening is adjustable to allow the paver and augers to run continuously even with varying production rates. These gates should be opened wide enough to deliver a continuous and adequate amount of mixture to the augers. The speed of the augers should be adjusted to provide a continuous slow flow of material.

If an inadequate amount of material is delivered to the augers, the fine material will tend to drop out of the mixture and only the coarse material will be moved laterally. Thus, if the augers are continuously starved for mixture, the coarser material will be deposited at the edges of the mat producing a continuous segregation pattern (Fig 5.5 and Fig 6d, Chapter 6).

Similarly, if the augers are running too slow there will be a lack of mixture delivered to the outer edge causing a coarse strip at the edge of the mat. Periodic edge segregation can also occur if the augers are periodically starved or run too slow (Figs 6a and 6b).

In contrast, if the augers are running too fast there will be a tendency to have a lack of material at the center of the paver, causing a possible continuous coarse segregation pattern in the center of the mat (Fig 6f, Chapter 6). A periodic pattern can also develop if the augers are momentarily run at too high a speed.

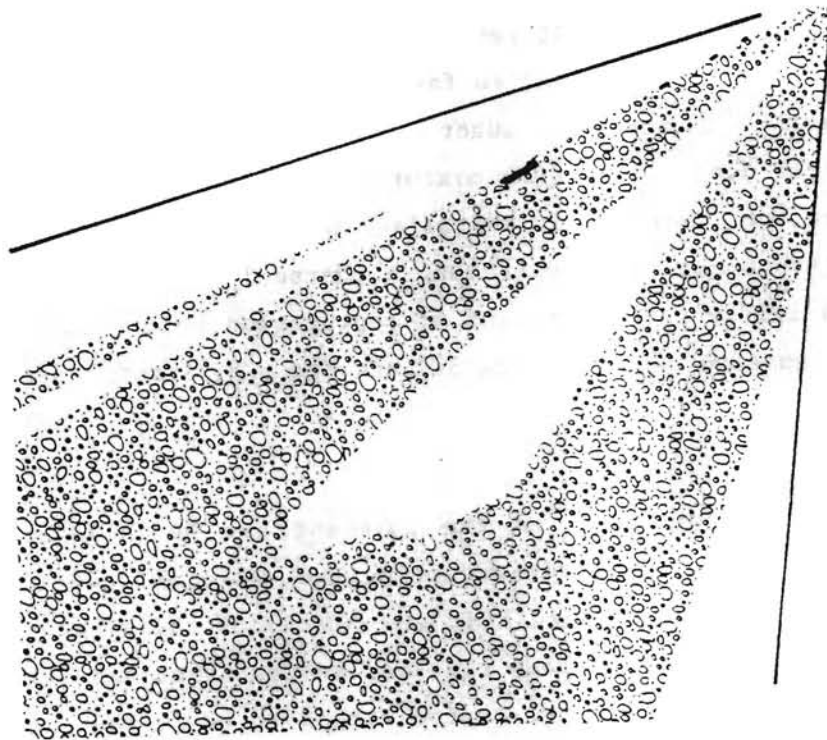


Figure 5.5. Severe segregation resulting from starving of augers, visible as coarse areas near edge of mat

Augers should be monitored to make sure they are operated fast enough to satisfy auger demand but not so fast that they tend to sling the mixture.

On either side of the auger gear box are reverse augers or "kicker screws" (Fig 5.6), which tuck mixture under the gear box. If these reverse augers are worn, improperly installed, or for any other reason not tucking enough mixture under the gear box, a coarse line of segregation will form. This is a fairly common pattern of segregation which appears like a joint down the center of the mat (Fig 5.2 and Fig 6.3, Chapter 6).

SCREED

The degree of crown on the pavement can be adjusted by screed adjustments. In addition to adjusting the whole screed, the crown on the leading edge (front) and trailing edge (back) of the screed can be separately adjusted. Lack of lead crown can lead to center streak (Fig 6.3f, Chapter 6), and excess lead crown can cause streak to be formed on both sides (Fig 6.3d, Chapter 6). For most mixes the lead crown should be set slightly greater than the trailing crown.

JOINTS AND JOINT RAKING

Longitudinal Joints

Another common form of segregation can be caused by improper longitudinal joint raking. Some rakers tend to scatter the overlapped mixture (Fig 5.7 foreground), sometimes as far as half way across the mat which produces apparent segregation. More critical, however, is the fact that less material is available to pinch into the joint, which results in a substantially reduced joint density.

A better procedure (Fig 5.7 background) involves carefully "bumping" or "crowding" the excess mixture such that it remains very close to and over the joint. Not only does this eliminate segregation; it also provides a greater bulk of material to pinch into the joint, which results in a higher joint density.

Although bumping the joint is best, some rakers prefer to pull coarse particles away from the joint, leaving only fine material in the vicinity of the joint. Unfortunately, the remaining coarse particles are often cast across the new surface. If this procedure is followed, the coarse particles

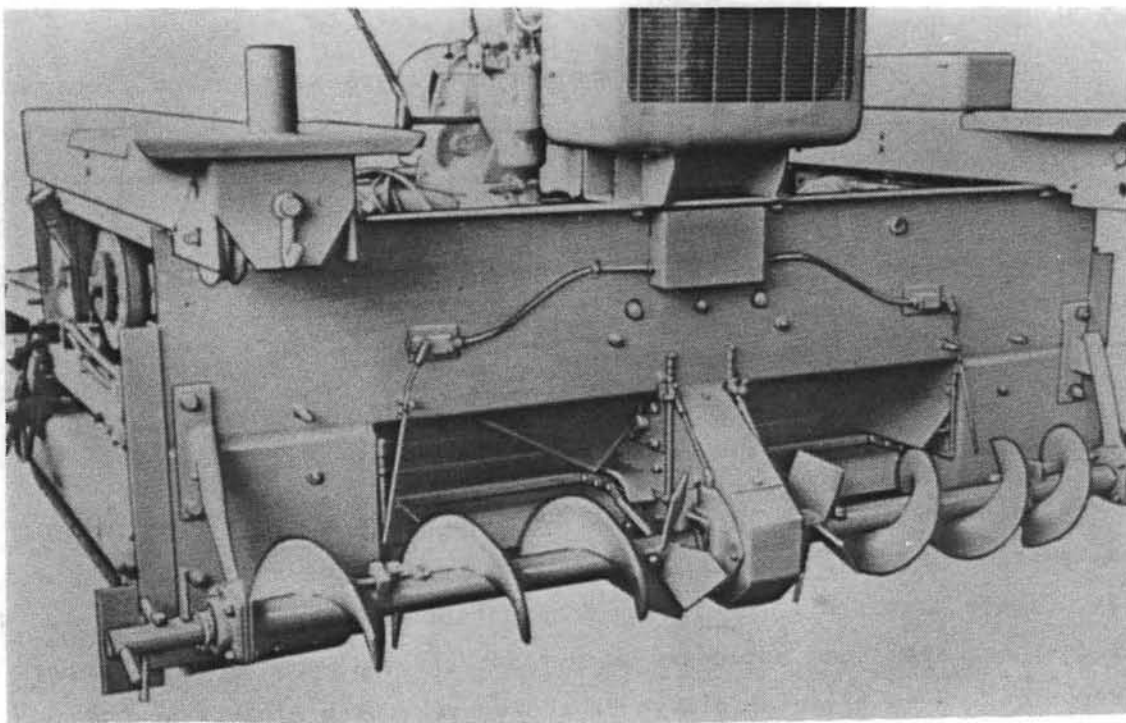


Figure 5.6. Kicker screws



Figure 5.7. Examples of racking the joints

should be wasted and not scattered across the surface or certainly not placed back in the hopper.

There are possibly other techniques to reduce segregation from hand work. However, the most basic rule is that less hand work and related activity results in less segregation. Paving operations which consist of a flurry of raking, shovelling, and other activities behind the paver are often those which result in a substantial amount of segregation. Paving operations which have minimal activity behind the paver are not only less prone to segregation but also result in smoother, higher quality surfaces.

Transverse Joints

Segregation in the vicinity of transverse joints is also common. Usually transverse joints occur at production stoppages such as at the end of a day. There is often a considerable amount of manually placed mixture (Fig 5.8) in these areas and attendant with this hand work are varying amounts of segregation. Even mixtures placed in these areas with a paver are subject to segregation since the paver is not in its normal steady state.

Although not a direct cause of segregation, paving operations are often performed such that many trucks congregate in front of the paver during daily start-up operations. In this situation, workers who are attempting to carefully construct a proper transverse joint (using whatever technique) are under considerable pressure to hurry so that the remaining trucks can be unloaded and discharged for another load. One way to eliminate this situation is to delay or space trucks. This ensures that there will be sufficient time for workers to be mindful of segregation and smoothness without having undue pressure placed on them to perform their duties in a quick but haphazard manner.

Although a certain degree of segregation at transverse joints is always evident, there are a few procedures that can be followed which will reduce the effect. One procedure would be to remove a portion of the mat from the previous day's production so that segregated areas are simply discarded.

Another technique involves manually separating the coarse particles from the mixture in the vicinity of the joint and wasting them. As before, rakers sometimes perform this technique but instead of wasting the excess coarse aggregate, scatter it across the new surface.



Figure 5.8. Manual placement of hot mix

SUMMARY OF PAVING OPERATIONS

When considering the effect of paving operations on segregation, it is apparent that maintaining a uniform operation with a constant level of material above the auger is important. In addition, pavers which are in poor operating condition may cause segregation if they have worn screed plates, extensions, etc. Also, if the mixture and/or screed become too cold, segregation occurs from coarse aggregate being dragged.

A worthwhile although sometimes detrimental goal is to lay the largest amount of mixture possible in the least amount of time. Excessively rapid paving, however, is not absolutely necessary to achieve high production. It is recognized that in urban areas, traffic congestion and other factors often make it difficult to achieve a steady operation. However, it is best to make every effort to keep the paver moving with as few starts and stops as possible. This not only tends to reduce segregation but also results in a smoother surface and a more uniform mat density.

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CHAPTER 6. DIAGNOSING PROBABLE CAUSES OF SEGREGATION

As identified in Chapters 2 through 5, a considerable number of production and placement operations can cause segregation. Further, two or more causes can act in conjunction with each other. Segregation experience in Texas as well as in other states indicates that a major problem was the difficulty of relating a type of segregation to its probable cause. Thus, this chapter attempts to provide guidelines as to the more probable causes of segregation.

PRELIMINARY DIAGNOSIS

A preliminary diagnostic tool developed by Bryant (8) in the mid-1960s, and subsequently used and reported by Hensley (9) and Brock (3), uses the results of extraction tests normally conducted for job control. The technique has been successfully used on several projects in Texas to assist in diagnosing the cause as well as the existence of segregation (4 and 10). In fact, Brock (3) also reports successful use of this technique for a substantial number of other production-related problems.

The Bryant technique involves summarizing the extraction test results by plotting the relationship between asphalt content and the percent passing a particular sieve. Normally, the sieve chosen as an indicator is that which separates coarse from fine aggregate. Most agency specifications use either the No. 10 (2.00 mm) or No. 8 (2.36 mm). In production operations the aim is to get all of the data points in a tight cluster about the unique point defined by the job-mix formula.

In terms of diagnosing the existence and cause of segregation, patterns developed by the scatter in the Bryant plot are indicative. First, if the data plots roughly in a straight line, upward and to the right, such a pattern indicates a uniform asphalt film thickness. This condition indicates segregation is occurring after mixing takes place from some deficiency in handling.

Figure 6.1 is a Bryant plot for data obtained from an airfield paving project in Texas (10). A very definite straight line pattern is exhibited. Observation of the actual surface along with this plot indicated that segregation was present and that the source was improper mixture handling probably during paver operations.

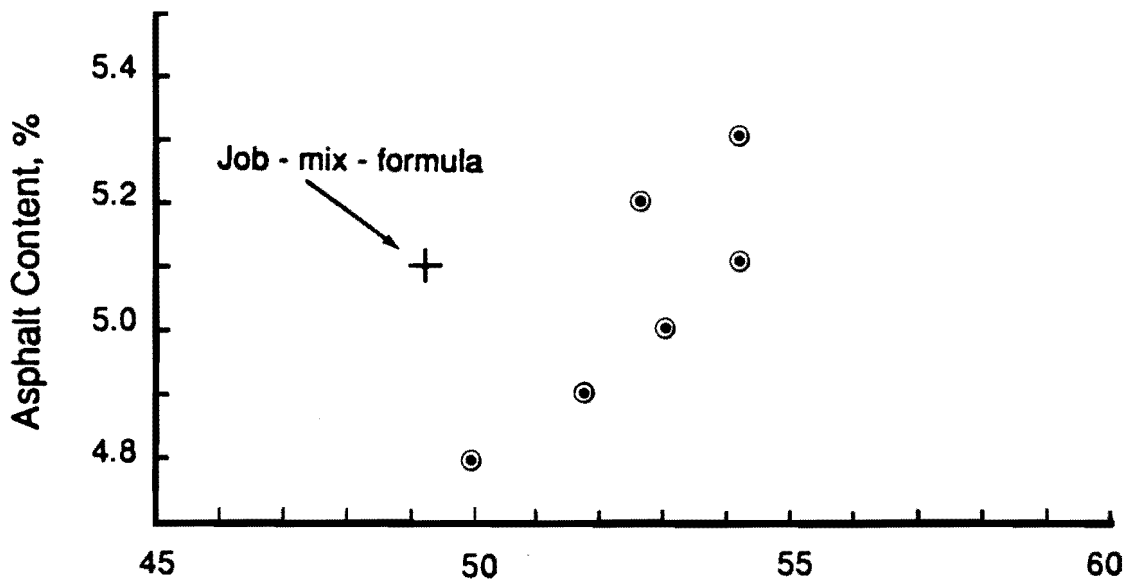


Figure 6.1. Bryant plot for project with segregation after mixing (Ref 10)

Although a straight line pattern is indicative of the category of segregation considered in this report, other patterns exist which indicate other problems. For example, Figure 6.2 is a Bryant plot for a highway paving project in Texas. With the exception of one point, the asphalt content is fairly constant but the percent passing the indicator sieve is somewhat variable. This indicates a non-uniform asphalt film thickness which indicates that the probable cause was with stockpiling or handling of aggregates prior to mixing or perhaps a problem with mixing itself.

It should be noted that the veracity of this approach in diagnosing segregation depends on collecting a representative sample and properly performing the extraction test. In addition, since the extraction only reflects mixture properties at the point of sampling, the Bryant analysis

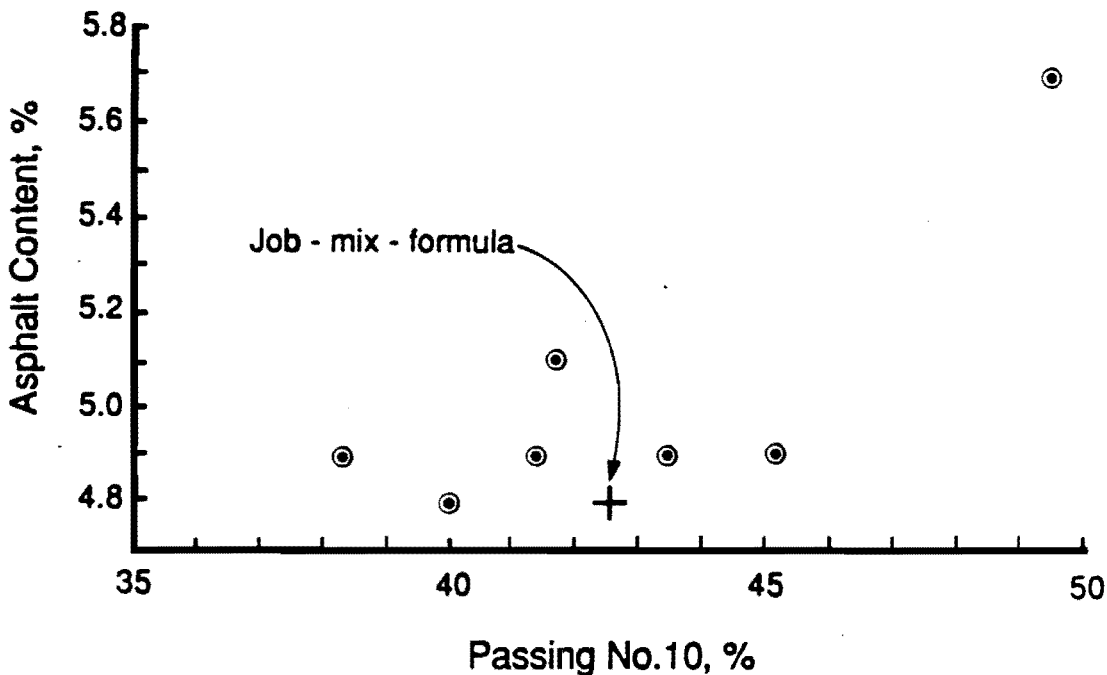


Figure 6.2. Bryant plot for project with segregation prior to or during mixing (Ref 10)

will only diagnose the existence of segregation at this point. In several extreme cases, it was found necessary to take extraction test samples at various points in the production and placement operation in order to determine the exact cause of segregation.

It must also be remembered that it is entirely possible to detect segregation by a straight line pattern only to discover that the sample was segregated during or after collection. In addition, if the extraction test is performed so that undue operator variation is evident in the data, the Bryant approach is useless as a diagnostic tool. For example, Brock (2) reports that a pattern of data points forming a vertical line over a wide range of asphalt contents may indicate an error in the extraction test procedure.

SAMPLING MATERIALS

In sampling aggregates and asphalt mixtures a sample that is representative of the materials being used must be obtained. While sampling is not a cause of segregation, poor sampling techniques can provide erroneous

information which will adversely influence the final mixture and will not provide meaningful information to assist in diagnosing segregation or other types of mixture problems.

Aggregate Sampling

When sampling a stockpile, the same rules apply to the technician and his equipment as applied to the loader operator (Chapter 3). As previously mentioned, the sample taker should coordinate efforts with the loader operator to make sure that the aggregate used is the same as that sampled. Also, the person who collects the sample should not scoop up the side of the stockpile with the sampling device.

Samples should be collected high enough above the base of the stockpile to minimize sampling only coarse aggregates. Some technicians prefer to drive a board into the stockpile above the sampling location in order to prevent roll-down of coarse particles into the sampling area.

Large, heaping samples should be avoided so that coarse particles do not roll off. Square-nosed shovels should not be used since they promote segregation. Special, scoop-like sampling shovels should be employed to minimize this effect.

Although the minimum required sample sizes generally are defined in departmental Construction Manuals, a good rule to follow is "the larger the sample, the more representative it will be." Representative test specimens can be derived from large samples by use of quartering cloths or mechanical sample splitters. Quartering is the best method for coarse or high moisture content samples. Mechanical splitting is best with finer and low moisture content (dry) samples.

The minimum frequency of sampling is also defined by the Construction Manual; however, greater sampling frequency provides a more accurate estimate of the aggregate characteristics during the construction period.

Mixture Sampling

When sampling asphalt mixtures, the same precautions need to be taken to ensure that the sample itself is not segregated. One of the overall problems with inspecting segregated mixtures is that often, the segregation is not immediately recognizable. Therefore, it is important that a representative sample be collected so that problems can be identified in a timely manner.

Another consideration when sampling mixtures is the sample location. The best sampling location from the standpoint of identifying segregation without regard to cause is directly behind the paver before rolling. A sample taken at this point is representative of all the construction operations which might produce segregation.

Samples can also be taken from the truck and at the plant to help determine the operation which is causing the segregation. For example, if the mixture sample is taken from the truck at the plant, segregation caused by paving operations would not be detectable from the sample. Thus, if segregation is identified, then the cause is not due to paving. On the other hand, if segregation is not present then the segregation is occurring in the trucking, truck unloading, or paving operation. Similarly, samples can be taken at the plant to reveal whether segregation occurred during or prior to the mixing operations.

TYPICAL SEGREGATION PATTERNS

Many of the causes of segregation tend to produce specific patterns of coarse material. By recognizing these patterns it is often possible to isolate and identify the possible cause or causes. Brock (7) developed a flow chart which addresses some of the more common causes.

Typical mat segregation patterns are:

- (1) random segregation (Fig 6.3a),
- (2) systematic spot segregation each side (Fig 6.3b),
- (3) systematic spot segregation one side (Fig 6.3c),
- (4) continuous segregation both sides (Fig 6.3d),
- (5) continuous segregation one side (Fig 6.3e), and
- (6) continuous segregation center of mat (Fig 6.3f).

Tables 6.1 to 6.6 identify possible sources and treatments of these segregation patterns. Only a minimal explanation is given in the table although page numbers from Chapters 3, 4, and 5 are provided as reference.

It should be noted that mixture design is not included in the diagnostic tables. As previously stated, this factor should always be considered when a segregation pattern is encountered. Of particular interest are mixtures which are gap graded and/or low in asphalt content. In many cases, adjustment in either or both of these parameters will reduce or eliminate segregation altogether.

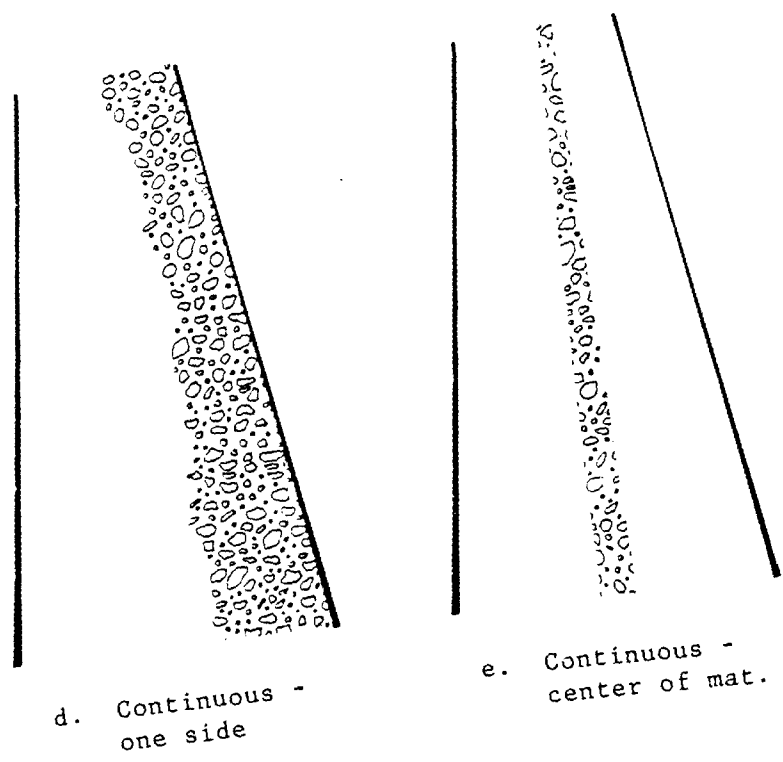
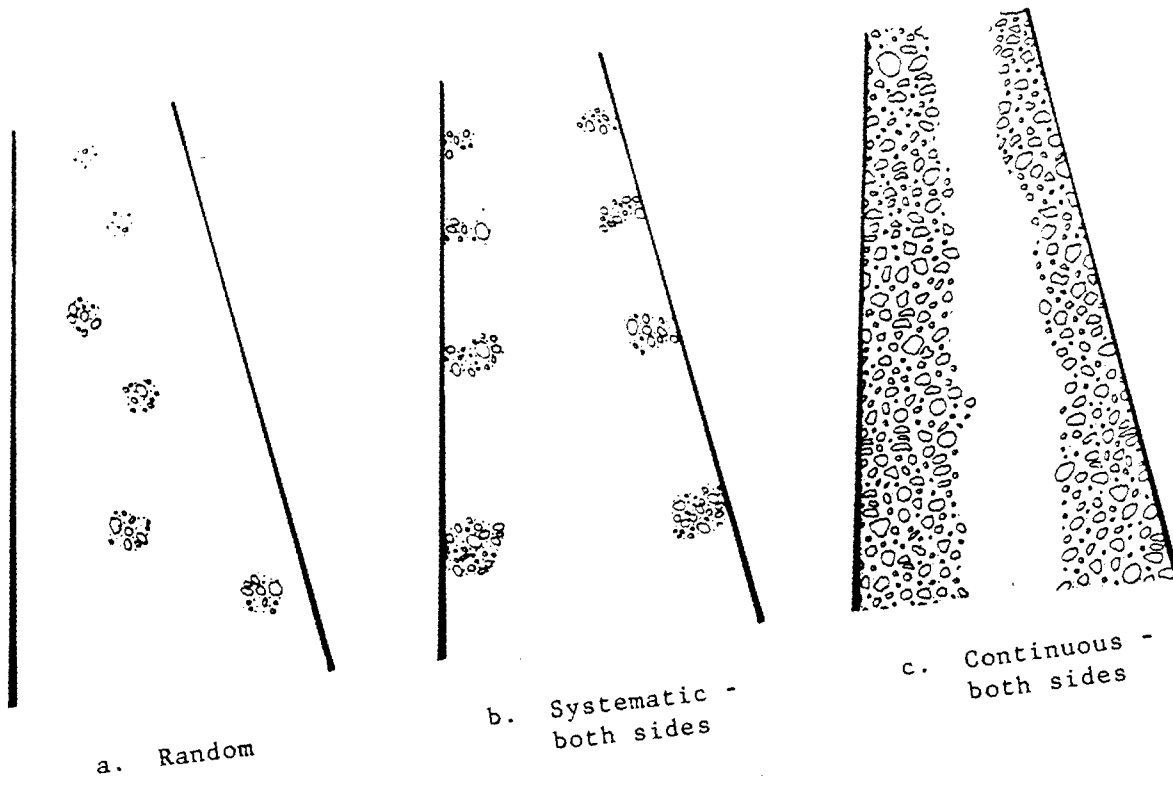


Figure 6.3. Typical segregation patterns

As previously mentioned, one of the most troublesome aspects of segregation is recognizing segregation during construction. Although severely segregated areas are visible during construction, it is more often difficult to identify segregated areas in a fresh mat. One of the ways to identify a potential segregation problem is by using the special diagnostic charts discussed in Chapter 3.

Unfortunately, it is entirely possible that segregated areas, particularly those which occur from the paver, might not be detectable solely from normal extractions. Otherwise there are two pavement conditions which are conducive to recognizing segregation.

First, the best way to identify segregated areas is to observe the surface in a wet condition. Certainly inspection personnel cannot be expected to accept work only after rainfall. In addition, it is not the intent of this report to recommend wetting all surfaces to determine acceptance. Rather, if segregation is suspected, it may be expedient to wet the surface so that distinct patterns can be identified. A sufficient length of surface could be moistened so that the length between repeated patterns could be established. Using this technique will certainly assist in correcting problems.

Second, segregation patterns which are not visible from one viewing angle often become visible from another position. As such, the best perspective seems to be at a time when low angle sunlight (either morning or afternoon) strikes the surface. This phenomenon is not documented in the literature. However, it is conceivable that low angle light causes the coarse particles to cast longer, more visible shadows than when the sun is at a higher position. Again, the shape of the pattern could be defined as well as the length between repeated patterns.

Either of these techniques as well as others discussed in this report are intended to be used during construction. The first priority is identification of segregation as a problem. After identification, the proposed measures can be used to reduce or eliminate causative factors.

TABLE 6.1. Random Segregation

Possible Causes	Possible Treatment	Reference	
1. SEGREGATED STOCKPILE	a. Use multiple stockpiles of single sized aggregates.	p. 9	
	b. Construct stockpile in layers for multiple sized materials.	p. 9, Fig 3.3	
	c. Place material in stockpile rather than casting material.	p. 9	
2. COLD BINS	a. Do not load out of bottom of segregated stockpile or other segregated areas.	p. 12	
	b. Load into center of cold bins.	p. 12, Fig 3.4	
	c. Avoid forming cone in cold bins.	p. 12	
	d. Adjust loading operation to maintain constant aggregate level; do not empty bins.	p. 12	
	e. Check for occasional aggregate spillage between bins due to overloading; install bulkheads if necessary.	p. 12, Fig 3.5	
3. BATCH PLANTS Hot Bins	a. Check for holes in screens.	p. 15	
	b. Check for holes in wall of adjacent bins.	p. 15	
	c. Install baffle in first bin.	p. 15, Fig 4.3	
	Pugmill	d. Inspect paddles for wear.	p. 15
		e. Increase mixing time.	p. 15
4. DRUM MIX PLANTS Drum Mixers	a. Increase mixing time in drum by extending asphalt injection line, decreasing drum slope, installing dams or kickback flights	p. 16, Fig 4.4	
	Surge or Storage Silos*	b. Heat drag conveyor and/or install floating hold-downs.	p. 21
		c. Make sure batcher gates are operating correctly.	p. 21
		d. Make sure rotating chute is revolving.	p. 21
		e. Check for hole in outer edge of chute.	p. 21
		f. Slow down rotation or add chute length to maintain vertical trajectory.	p. 21
5. TRUCK LOADING/ UNLOADING	a. Load truck in 3 or more drops.	p. 27, 4.14	
	b. Surge tail gate during unloading.	p. 27	
6. PAVER	a. Maintain constant gate opening.	p. 31	
	b. Maintain constant auger speed and operation.	p. 31	
	c. Maintain uniform speed of paving operations.	p. 31	
	d. Prohibit random dumping of wings.	p. 31	
	e. Prohibit improper raking operations.	p. 31, Fig 5.7	

* Also applicable to batch plants if used.

TABLE 6.2. Systematic Spot Segregation on Both Sides

Possible Source	Possible Treatment	Reference
1. PUGMILL	a. Inspect paddles for wear. b. Increase mixing time.	p. 15 p. 15
2. DRUM MIX PLANT		
Drum Mixer	a. Increase mixing time. b. Extend asphalt injection line. c. Decrease drum slope.	p. 16 p. 16, Fig 4.4 p. 16
Surge or Storage Silo	d. Make sure rotating chute is revolving. e. Check for hole in outer edge of chute. f. Slow down rotation or add extra chute to maintain vertical trajectory. g. Adjust timing on batcher gates or make sure batcher full indicator is working properly. h. Make sure batcher gates are not leaking. i. Adjust production rate to lower level of material in silo to prevent cone formation. j. Make sure material drops vertically into batcher.	p. 21 p. 21 p. 21 p. 21 p. 21 p. 21 p. 21, Fig 4.9
3. TRUCK	a. Load trucks in two or more drops.	p. 27
4. PAVER	a. Prohibit dumping of hopper wing. b. Maintain constant gate opening between loads. c. Make sure auger is not prematurely turned off or otherwise starved for mixture.	p. 31 p. 31 p. 31

TABLE 6.3. Systematic Spot Segregation One Side

Possible Source	Possible Treatment	Reference
DRUM MIXER	a. Restrict discharge chute.	p. 16
	b. Install fixed plow.	p. 16, Fig 4.6(a)
	c. Heat drag conveyor or install floating hold-downs.	p. 16
	d. Turn drag conveyor at right angle from discharge.	p. 16, Fig 4.6(b)

TABLE 6.4. Continuous Segregation Both Sides

Possible Source	Possible Treatment	Reference
1. SURGE OR STORAGE SILO	a. Make sure batcher gates open and close at the proper time or batcher full indication.	p. 21
	b. Eliminate horizontal trajectory of material being placed in silo.	p. 21, Fig 4.9
2. PAVER	a. Open gates to provide more mixture to augers.	p. 31
	b. Increase speed of augers.	p. 31
	c. Check for worn or improperly installed augers.	p. 31
	d. Prohibit excessive raking of longitudinal joints on multiple lane paving.	p. 31, Fig 5.7

TABLE 6.5. Continuous Segregation One Side

Possible Source	Possible Treatment	Reference
1. DRUM MIX PLANTS		
Drum Mixers	a. Install a fixed plow.	p. 16, Fig 4.6(a)
Surge or Storage Silo	b. Eliminate horizontal trajectory of material being placed in silo.	p. 21, Fig 4.9
2. PAVER		
	a. Check for worn or improperly adjusted gate on affected side.	p. 31
	b. Open gates to provide more mixture to augers.	p. 31
	c. Check for worn or improperly installed auger on affected side.	p. 31
	d. Prohibit excessive raking of longitudinal joint.	p. 31, Fig 5.7

TABLE 6.6. Continuous Segregation Center of Mat

Possible Source	Possible Treatment	Reference
1. SURGE OR STORAGE SILO	a. Eliminate horizontal trajectory of material being placed in silo.	p. 21, Fig 4.9
2. PAVER	a. Open gates to provide more mixture to augers. b. Decrease auger speed. c. Check for worn or improperly installed reverse augers.	p. 31 p. 31 p. 31

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