CONSTRUCTION OF ASPHALT CONCRETE PAVEMENTS

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CONSTRUCTION OF ASPHALT CONCRETE PAVEMENTS

by

James A. Scherocman
Thomas W. Kennedy

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Kathleen M. Jones

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PREFACE

This is the first of two handbooks to be used in the support of training courses on asphalt paving and mixture design. This handbook is concerned with the construction of flexible pavements using hot mixed asphalt concrete, while the second handbook is concerned with the design of asphalt concrete mixtures.

This handbook contains detailed information related to the construction of hot mixed asphalt concrete pavements and has been subdivided into sections related to asphalt mix plants, paving, and compaction. The section on asphalt mix plants contains information related to stockpiling and to the operation of both drum mix and batch plans, although the primary focus is on drum mix plants. The section on pavers concentrates on basic paving units and automatic controls. The final section on compacting emphasizes the importance of compaction, factors influencing compaction, and the operation of compaction equipment.

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James A. Scherocman
Thomas W. Kennedy

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INTRODUCTION

The purpose of this manual is to provide detailed information related to the construction of hot-mixed asphalt concrete pavements. The manual, which has been subdivided into sections related to asphalt mix plants, laydown operations, and compaction, will be utilized as a resource document for training courses for state and contractor personnel. Courses can be conducted separately or jointly in order to obtain a mutual understanding of the problems.

Section 1 provides detailed information related to the theory, equipment, and operations o drum mix and batch plants. Emphasis is placed on drum mix plants since these plants produce an estimated 60 percent of the asphalt paving mixtures placed in the United States, represent over 90 percent of all new plants being purchased, and are the least understood.

Section 2 provides information concerning laydown theory and includes discussions of haul vehicles and transport of asphalt mixtures to construction sites; the theory, equipment, and operation of paving equipment; joint construction; and mat problems. Section 3 is concerned with the importance and means of obtaining satisfactory compaction of asphalt mixtures, including factors affecting compaction, types of equipment and their operation, and compaction variables.

SECTION 1
ASPHALT CONCRETE PLANT OPERATIONS

CHAPTER 1. INTRODUCTION TO ASPHALT PLANTS

The purpose or function of an asphalt mix plant is to blend together aggregates and binder, normally asphalt cement, to produce a hot mixed, homogeneous asphalt paving mixture. The aggregate can be a single material or can be a combination of different coarse and fine particles with or without mineral filler. Instead of pure asphalt cement, the binder can also be a cutback asphalt, asphalt emulsion, or one of a number of synthetic binders. Various additives, either liquid, solid, or powdered materials, can also be incorporated into the mixture.

Three types of plants are currently utilized in the United States. These are: (1) batch plants, (2) continuous mix plants, and (3) drum mix plants. While each type of plant fulfills the same ultimate purpose, the operation and flow of the various materials through each of these plants are different. The asphalt mixtures produced, however, should be identical, regardless of the type of plant used to manufacture it.

A brief review is provided below of the flow of materials and operation of batch plants, continuous mix plants, and drum mix plants. A more detailed discussion concerning drum mix and batch plants is provided in subsequent chapters.

1.1 BATCH PLANTS

The asphalt concrete batch plant (Fig 1.1) consists of a number of major components, as shown in Figure 1.2. The first major component is the cold feed bins where the aggregates, at ambient temperature, are temporarily stored before processing. Closely associated are the collecting (feeder and gathering) conveyors beneath the cold feed bin and the incline or charging conveyor which carries the combined aggregates to the dryer.

The second component is the aggregate dryer where moisture is removed from the aggregates and where the particles are heated to the proper mixing temperature. The hot, dry aggregates are then carried to the top of the batch plant tower by means of a hot elevator.

At the top of the plant, the material is passed through a set of screens which divide the aggregate into several different sizes, typically four. The heated aggregates are then temporarily stored in the plant hot bins, located directly beneath the screen deck. From these bins, the various sizes are proportioned, by weight, into the weigh hopper. At the same time that the aggregate is being weighed, asphalt cement is pumped from a storage tank to the asphalt weigh bucket on the plant.

The correct blend of material is next dropped into the plant mixer, a twin-shaft pugmill. After the aggregate is introduced into the pugmill, the asphalt cement is sprayed into the mixing unit. The two materials are blended together by the shearing action of the pugmill blades or paddles. The completed mixture is then discharged from the plant, either into a haul truck or into a conveying device to temporary storage in a surge silo to await subsequent delivery to the paving site.

If reclaimed asphalt concrete is being used to produce a recycled asphalt concrete mixture, the reclaimed material can be introduced into the plant: (1) at the bottom of the hot elevator, (2) into the hot bins, or (3) more commonly, directly into the weigh hopper. The reclaimed material, at ambient temperature, is added to the new aggregate, which has been superheated, before the two different materials are dropped into the plant pugmill for mixing.

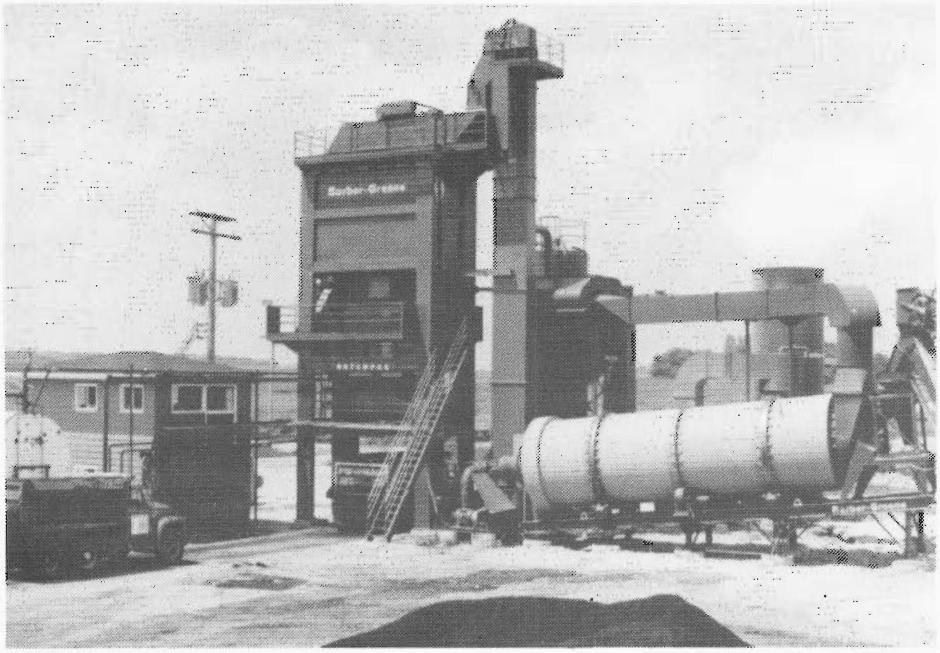


Figure 1.1. A typical batch plant (Ref 4).

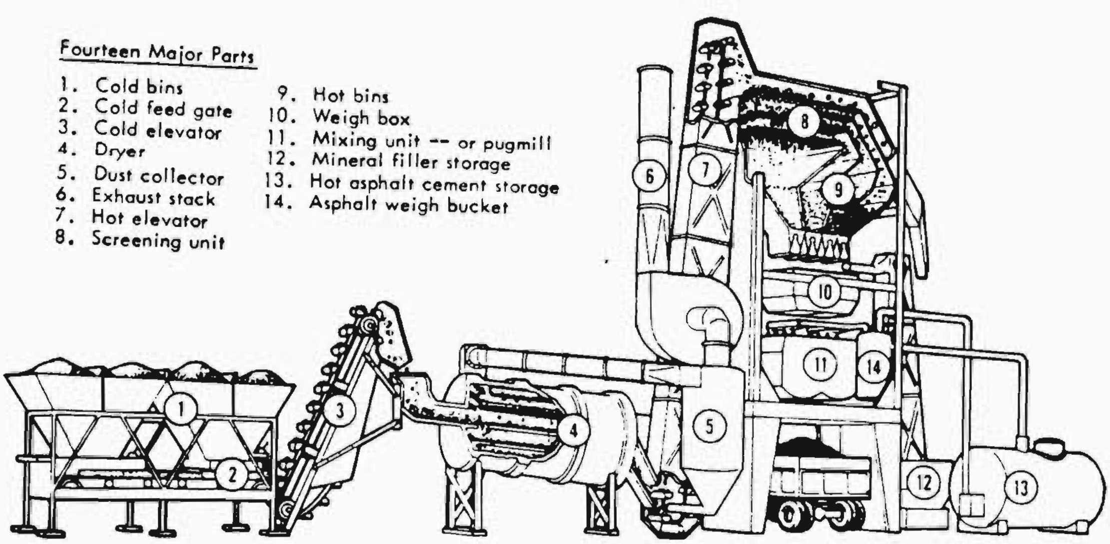


Figure 1.2. Major components of a batch plant (Ref 5).

Due to environmental requirements, each batch plant is equipped with an air pollution control device. This equipment can consist of a dry collector, a wet collector, a fabric filter (baghouse), or a combination of devices. In some cases, the fines collected in the pollution control equipment are wasted; in other cases the dust is returned to the plant for incorporation into the mixture. Sometimes the dust is reintroduced into the bottom of the hot elevator. More often it is fed into the aggregate weigh hopper as mineral filler.

1.2 CONTINUOUS MIX PLANTS

A continuous mix asphalt concrete plant is shown in Figure 1.3 and the components and flow of material are graphically illustrated in Figure 1.4. The cold feed bins are the same as used with batch plants and include both the gathering and charging conveyors. The aggregate dryer is the second component in the process. Here the moisture in the combined aggregates is removed as the material is heated from ambient temperature to the desired mixing temperature, which normally ranges from 270 to 300°F. The dried and heated aggregates are then conveyed up an inclined bucket elevator to the screen deck which divides the aggregates into various sizes before mixing. The sized aggregates are then proportioned and fed into the continuous mix pugmill for mixing.

The asphalt cement is held in the storage tank at a temperature of approximately 325°F to 350°F and subsequently is pumped to the asphalt cement spray bars located above the pugmill. The asphalt binder, measured by volume, is then sprayed continuously over the aggregate. Mixing of the two materials occurs as the aggregates are moved by the paddles toward the discharge end of the pugmill. Mixing time can be increased or decreased by changing the retention time of the material in the pugmill by altering the setting of the pugmill end gate.

Because this is a continuous mixing process, a temporary holding hopper or bin must be provided to store the material until it can be discharged into a haul truck. This bin is typically located directly underneath the pugmill discharge point and has a limited mixture capacity. The surge bin turns the continuous mix process into a truckload haul operation.

Continuous mix plants can produce recycled asphalt concrete mixtures by superheating the new aggregates in the dryer and adding the reclaimed material to the new material in the pugmill. A separate cold feed bin and charging conveyor are used to introduce the reclaimed aggregate, by volume, into the mixing chamber.

For air pollution control purposes, the continuous mix plant can be equipped with dry collectors, wet collectors, or fabric filters. The captured fines can be wasted or can be returned to the plant pugmill if a dry collection system is utilized.

1.3 DRUM MIX PLANTS

The production of asphalt concrete mix in a drum mix plant (Fig 1.5) is also a continuous process. The coarse and fine aggregates are held in the cold feed bins at ambient temperature (Fig 1.6). The aggregates are then proportioned out of the bins, carried by a charging conveyor over a weigh bridge system, and fed into the upper end of the drum mixer. Inside the drum, the aggregates are heated and dried, in a manner similar to that of a batch plant dryer, but in addition, the asphalt cement is added in the lower section of the drum. The aggregates are coated with asphalt. The asphalt cement is supplied from a storage tank and pumped continuously into the drum mixer. The actual location of asphalt cement introduction varies with different types (manufacturers) of drum mix plant.

If reclaimed asphalt concrete material is used to produce a recycled mixture, this material is introduced into the drum at either (1) the upper end of the drum in combination with the new aggregate or (2) through its own entry port near the midpoint of the drum. The point of entry in either case is upstream or prior to the point at which the asphalt cement is injected.

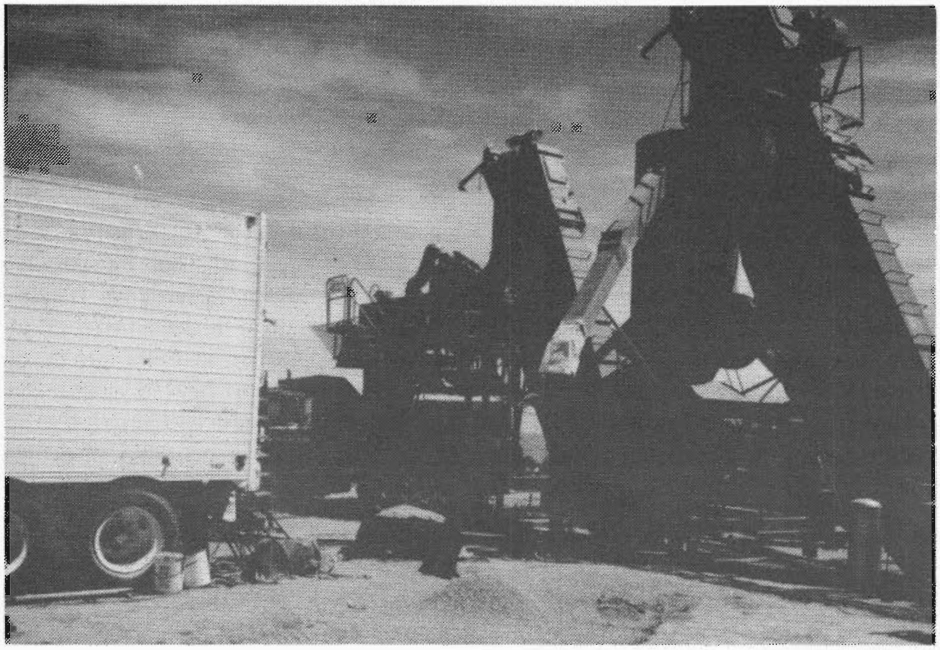


Figure 1.3. A typical continuous mix plant.

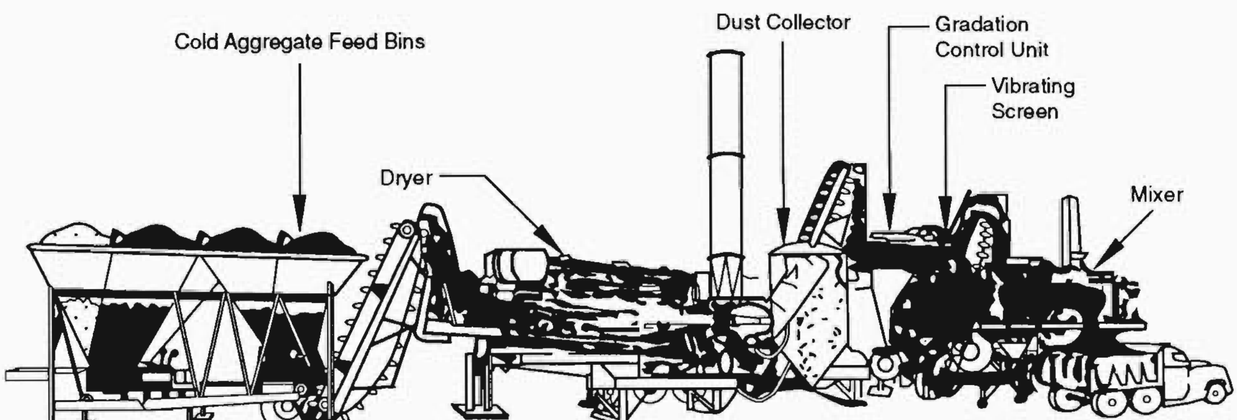


Figure 1.4. Major components of a continuous mix plant (Ref 6).

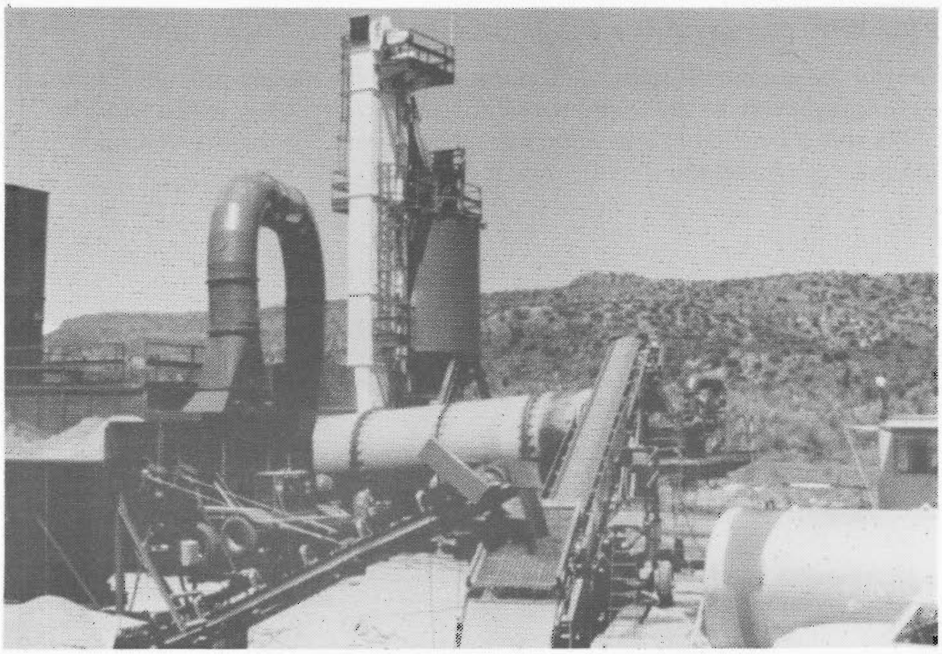


Figure 1.5. A typical drum mix plant (Ref 7).

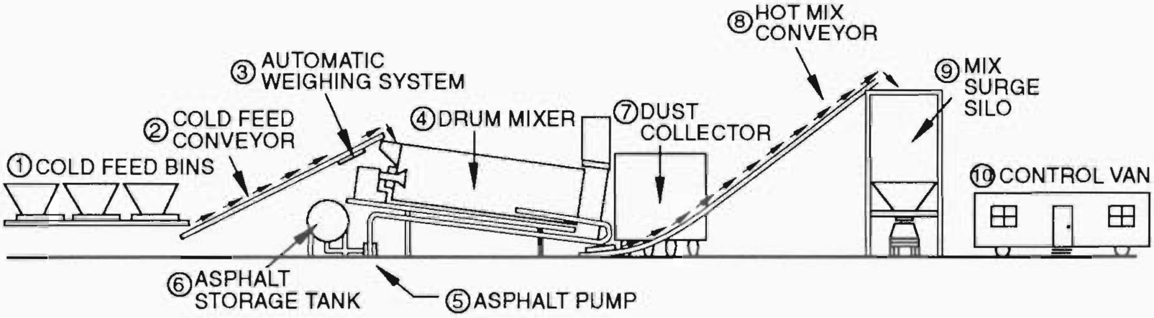


Figure 1.6. Major components of a drum mix plant (Ref 5).

Because it produces mix in a continuous operation, the drum mix plant must be equipped with a temporary mix-holding bin or surge silo. The silo converts the flow from a steady discharge to a batch process (truckloads) for delivery to the laydown machine.

To control the amount of particulate carryout from the mixing process, the drum mix plant can be equipped with a variety of air pollution control systems which include (1) a dry collector, (2) a wet collector, or (3) a fabric filter (baghouse). For the dry collection processes, the collected fines can be returned to the mix, if desired.

CHAPTER 2. AGGREGATE STOCKPILES

Control of an asphalt concrete mixture, regardless of the type of asphalt plant, begins with the stockpiles of aggregates which are to be processed through the plant and incorporated into the mix. Care should be taken to assure that the aggregates in the individual stockpiles are clean and separated, but not segregated. In contrast with an asphalt concrete batch plant, the drum mix plant does not contain a screen deck to separate the aggregates or a weigh hopper to recombine the various aggregate sizes. Materials fed into the plant through the cold feed bins come out directly, and unaltered, in the final mixture. Thus stockpiling is extremely important to drum mix plant operations.

Aggregates should be stockpiled on a clean, dry, stable surface and should not be allowed to become contaminated with dust, mud, or grass. The stockpiles should also be free draining to allow the moisture content of the aggregates to be as low as possible. Excess moisture in the aggregates, particularly the fine aggregate (sand), increases the cost of drying the aggregates and can reduce the production capacity of the plant. Thus it is essential that the moisture in the aggregate, as received from the pit or quarry or subsequently added by rain, be allowed to drain from the piles, to the greatest extent possible.

The stockpiles of the various aggregate sizes should be kept separated. The cold feed bins are calibrated to provide a specified amount of a different size aggregate from each bin. If the various aggregates are co-mingled in the stockpiles, a combination of sizes will occur in each cold feed bin. This blending of the aggregates will cause variations in the gradation of the final asphalt concrete mixture produced by a drum mix plant and can cause problems in a batch plant. Thus, the stockpiles should be kept separated.

Segregation of the stockpiled aggregates is a major problem for all asphalt plants. Aggregates of larger size, particularly when combined with smaller sizes of stone, have a tendency to roll down the face of a stockpile and collect at the bottom (Fig 2.1). Depending on how the stockpiles are handled, a slug of coarse material and then a batch of finer aggregate may be placed on the cold feed bins and fed into the plant at various times, causing severe difficulties in achieving a given job mix formula gradation in the final mixture.

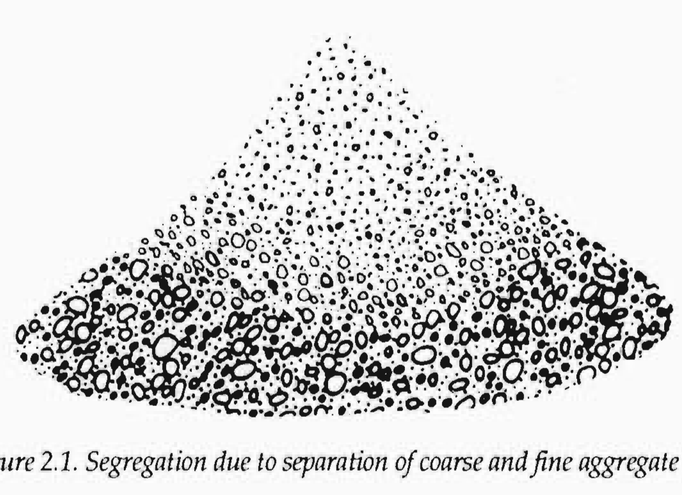


Figure 2.1. Segregation due to separation of coarse and fine aggregate (Ref 12).

Stockpiles should be constructed in layers to prevent or minimize segregation (Fig 2.2). If trucks are used to carry the incoming aggregates to the plant site, each load should be dumped in a single pile (Fig 2.3). If room at the site is a problem, a front end loader can be employed to stack the aggregates in layers. If the aggregates are delivered in rail cars, belt conveyors are usually used to unload the materials. Belt conveyors are also generally used to carry material from a pit or quarry to an on-site plant. When belts are used to convey coarse aggregate, the height of the stockpiles should be limited in order to prevent the larger particles from tumbling down the sides of the pile and segregating (Fig 2.4). High piles with the conveyor dumping new material on the top of a conical-shaped stockpile should not be permitted, since severe segregation of the coarse materials can occur.

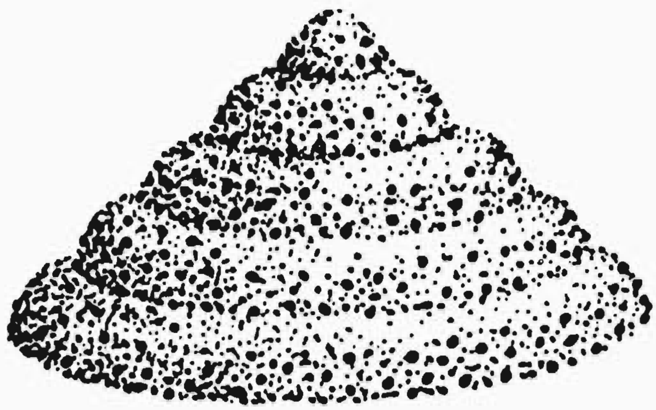


Figure 2.2. Stockpile in layers (Ref 12).

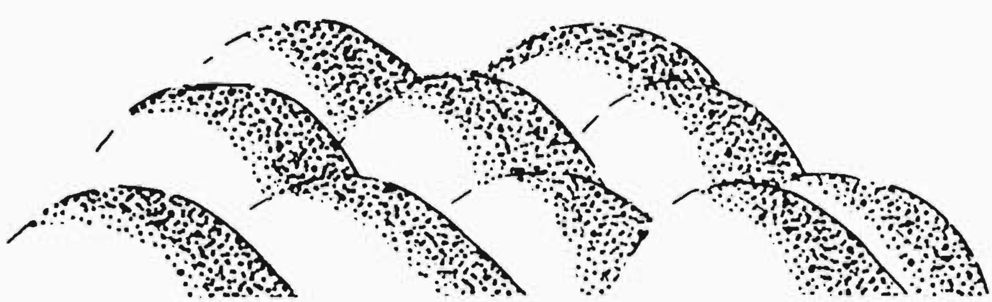


Figure 2.3. Stockpile in piles (Ref 12).

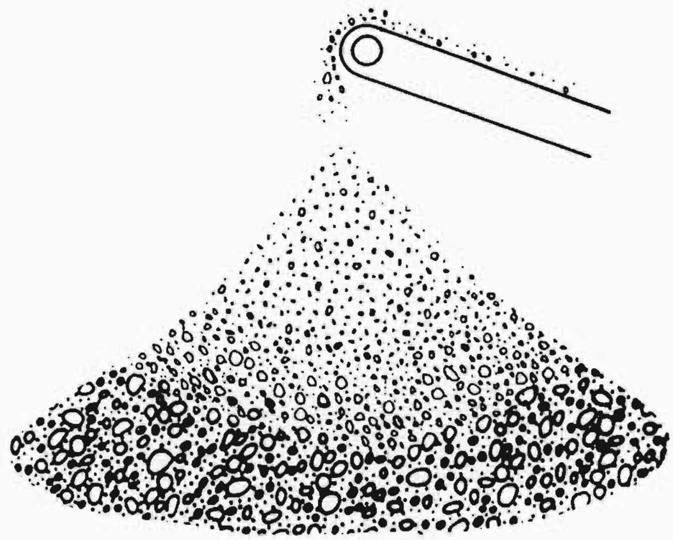


Figure 2.4. Improper stockpiling technique (Ref 13).

The aggregates in a stockpile also should be removed in layers to prevent segregation. If a front end loader is employed to feed the aggregates to the cold feed bins, the face of a large stockpile of aggregates, particularly coarse aggregates, should not be removed from the bottom up; this practice will cause the larger aggregates to roll down the face of the pile and gather at the bottom. If a tunnel system is used to feed the plant, care should be exercised in permitting a dozer to push the aggregates into the hopper at the tunnel opening. Crushing of the aggregates, as well as separation and segregation of the coarser materials, can occur.

If segregation does occur in a stockpile, the loader operator can mitigate the effects to a significant degree by blending the coarser and finer areas in each stockpile loading the aggregates in the cold feed bins. The operator should not feed one or two coarse loads of aggregate and then a couple of loads of fine material into a cold feed bin. The best approach, however, is to prevent the segregation from occurring in the first place through proper stockpiling techniques.

CHAPTER 3. DRUM MIX PLANTS

3.1 BACKGROUND

During the past 18 years, use of drum mix plants, which are often incorrectly called dryer drum plants, has increased to the extent that more than 90 percent of all new asphalt mixing plants are drum mixers. Various studies have indicated that drum mix plants produce asphalt mixtures which are equal to those produced by conventional batch plants (Refs 1, 2, and 3). Nevertheless, there are many engineers and agencies which feel that drum mix plants do not produce satisfactory mixtures. While there are inherent problems associated with both batch and drum mix plants, often problems occur because there is a lack of understanding of how drum mix plants operate and how that operation differs relative to the operation of batch plants.

The drum mix plant consists of a number of major components, which can be divided into three categories: those which handle the aggregates; those which control the asphalt cement binder; and those which process the blend of materials.

The aggregate handling system consists of the cold feed bins, gathering conveyors, charging conveyor, including the weigh bridge and belt speed sensor, mineral filler system (if any), and dust return system (if any). If reclaimed material is being fed into the plant, a separate cold feed system, cold feed bins and charging conveyor, together with its weigh bridge/belt speed system, will be required on most drum mix plants in order to handle the additional material flow.

The components to store and process the asphalt cement are relatively simple. First, a heated storage tank is necessary to hold the asphalt cement (binder) until it is needed. Second, a pump and meter are used to transfer the binder to the plant in proportion to the amount of aggregate being introduced into the drum mixer. The pump must be able to be reversed in order to return unneeded asphalt cement to the storage tank whenever the plant operation is stopped.

The main component of the blending system is the drum mixer itself. Additional plant components involving the asphalt mixture include the hot mix charging conveyor, the hot mix surge silo, and the plant dust collection system. Also included is the control station where the flow of aggregates, asphalt cement, and asphalt concrete mix are monitored and regulated.

3.2 AGGREGATE HANDLING OVERVIEW

Aggregate handling is done by cold feed systems in a drum mix plant. The cold feed system can differ depending on whether only new aggregate are being used or new aggregates plus reclaimed material are being delivered to the mixing drum

New Aggregate System

The cold feed bins are used to proportion the aggregates in order to obtain the correct combined aggregate gradation in the asphalt mixture. Because the drum mix plant operates on a continuous basis, and because there are no screens or hot bins in the system, whatever material is delivered from the cold feed bins ends up in the same proportion as the mix manufactured by the drum mixer. Thus the settings on the cold feed bins, both the gate openings and the speed of the gathering conveyors, must be correct to achieve the desired mixture gradation. The cliché of "garbage in, garbage out" applies equally well to drum mix plants as to computers. If the openings of the cold feed bins or the speed of the bin conveyors are set incorrectly or if the gradations of the different coarse and fine aggregates vary considerably, the gradation of the final mix produced may be out of specification.

Each cold feed bin operates on one of two methods. On older cold feed systems, the cold feed bins had variable gate openings. The amount of material discharged from a bin depended on the setting of the gate opening at the bottom of the bin. The conveyor underneath each bin typically operated at a constant speed. Thus the volume of aggregate transferred from a particular cold feed bin could be changed only within the limits that the bin gate openings could be changed.

With more modern cold feed systems, for a given gradation, the gate opening at the bottom of the bin is constant, and the speed of the belt controls the amount of aggregate introduced into the drum mixer. If only a small amount of material is needed from a particular bin to produce the desired aggregate gradation, then the speed of the conveyor belt under that bin is quite slow. If, on the other hand, the volume needed of a given coarse or fine aggregate in a cold feed bin is large, the speed of the conveyor belt will be increased to handle a greater amount of material. If the speed of the individual bin conveyor belt approaches its lower or upper limit, the size of the gate opening at the bottom of the bin is changed to allow the speed of the conveyor to operate near the middle of its range. The constant opening, variable speed belt system is the most common cold feed operation built into most current drum mix plants.

The aggregate discharged from each cold feed bin and cold feed conveyor is deposited on a gathering conveyor which runs under all of the cold feed bins. On most plants, this conveyor is operated at a fixed speed but on some plants the speed can be varied. If more aggregate is needed as the plant production rate is increased, the speed of the individual cold feed bin conveyors is increased which places more materials on the gathering conveyor. The reverse is true if the plant production rate is reduced.

The combination of aggregates produced from the cold feed bins and gathering conveyor is transferred to the charging conveyor. This can be done directly, from one conveyor belt to another, or the aggregate can be dropped through a scalping screen. If quarry processed aggregates are used, it may not be necessary to incorporate the scalping screen in the cold feed system. If bank run or pit run aggregates are used, it generally is desirable to process these aggregates through a scalping screen to remove any tree roots or other contaminants from the aggregates in order to keep the foreign materials from being introduced into the drum mixer.

The charging conveyor transfers the combined coarse and fine aggregates to the drum. It is equipped with two components to measure the amount of material entering the drum mixer. The first is the weigh bridge, which consists of an idler on the conveyor which acts as a load cell, determining the amount of material passing over the weigh bridge at a particular point in time. The second is the belt speed sensor which monitors the speed of the conveyor belt. These two measurements are combined in the plant computer system to determine the amount of aggregate, in terms of tons per hour, being introduced into the plant.

This aggregate feed rate is the weight of the moist aggregates passing over the weigh bridge. Since the asphalt cement content of the asphalt mixture is proportional to the dry weight of the combined aggregates, this wet weight must be converted by the computer system to a dry weight of the aggregates.

On many drum mix plants, the aggregates on the charging conveyor are dropped directly into the burner end of the drum mixer. These materials are discharged into a chute located above the burner and slide into the drum at its upper end. Some drum mix plants, however, are equipped with a slinger conveyor which is located beneath the burner. The aggregates from the charging conveyor are transferred to the slinger conveyor and then carried into the drum. Depending on the speed of the slinger conveyor, the aggregates can be delivered directly in the front of the drum or can be deposited part way down the drum, away from the burner flame.

If mineral filler is needed in the mix, the material can be added in one of several places. In some cases, it is placed in one of the plant cold feed bins and fed into the plant as an additional aggregate component. The filler can also be fed from a silo onto the aggregate gathering conveyor and then into the drum. In each case, the material must be placed between the layers of other aggregates on the cold feed conveyor to prevent blowing or dusting of the mineral filler which would occur if the filler were spread on top of the coarse and fine aggregates.

Many drum mix plants are equipped to feed the mineral filler into the rear end of the plant through a filler feed line or auger system. A silo is employed to hold the filler and a vane feeder is used to proportion the material volumetrically into the conveying pipe. An air or pneumatic system typically blows the filler into the drum where it is coated with the asphalt cement before it drops into the bottom of the drum.

Reclaimed Material

The cold feed system used on a drum mix plant for reclaimed asphalt materials varies with the make, model, and age of the plant. On many of the original drum mix plants, the reclaimed material is fed into the burner end of the drum mixer in combination with the new coarse and fine aggregates. The same cold feed bin setup is employed for the reclaimed asphalt mixture as for the new material. One or more of the cold feed bins are dedicated to the reclaimed material, and the remaining cold feed bins are used for the new aggregates.

With this system, each aggregate, new or reclaimed, coarse or fine, is proportioned from its own cold feed bin as needed to meet the final mix gradation. The gathering conveyor carries the combined new and reclaimed materials to the scalping screen and then to the charging conveyor. The material is then dropped into a top-loading chute at the burner end of the plant or emptied onto a slinger conveyor under the burner for transport into the drum.

Currently, most drum mix plant operations employ a split feed system to introduce the reclaimed material into the plant. Thus the entry of the reclaimed material is separated from the charging of the new coarse and fine aggregates. The new aggregates are conveyed into the burner end of the plant. The reclaimed asphalt material is fed into the drum through a rotary inlet system located at or near the midpoint of the drum.

Occasionally, one or more of the normal cold feed bins will be used to hold the reclaimed material. In this case, however, the gathering conveyor is split, with one section conveying the new aggregates from their individual cold feed bins to the new aggregate charging conveyor and the other section carrying the reclaimed material in the opposite direction to a separate charging conveyor. As for the new material feed system, the reclaimed material gathering conveyor should feed its material through a scalping screen before placing the reclaimed material on the center inlet charging conveyor.

A separate cold feed bin (or bins) are normally employed to store the reclaimed material. These bins are usually more steep sided than the normal new aggregate cold feed bins and typically have slightly larger bottom openings to handle the reclaimed asphalt material more easily. The reclaimed material is normally fed out of the bins on a gathering conveyor, through a scalping screen, and onto the charging conveyor. The latter is equipped with a weigh bridge system to measure the wet weight of the reclaimed material being fed into the plant. This wet weight is automatically converted to the dry weight of the reclaimed material by the plant computer.

3.3 DRUM MIXER OVERVIEW

New Aggregate-Asphalt Mixtures

The main component of a drum mix plant is the drum mixing unit itself. In the drum, the new aggregates are fed into the upper, burner end of the drum. The aggregates move down the drum by gravity and the action of the flights as the drum rotates. As the aggregates are carried through the drum, the material is heated and the moisture is removed. This occurs through heat transfer from the exhaust gases of the burner. These gases and the aggregates both travel in the same direction, from the upper end of the drum (aggregate inlet) to the lower end of the drum (mix discharge).

The drum mix plant thus operates on a parallel flow principle, i.e., the aggregates and heated air both move in the same direction inside the drum (Fig 3.1). This parallel flow concept is in contrast to the counterflow process used in a conventional batch or continuous mix plant dryer (Fig 3.2). On a regular dryer, the aggregates move by gravity and the action of the flights down the drum. The burner, however, is located at the discharge, or lower, end of the drum. The exhaust gases move upstream, opposite to the aggregate flow. Thus, on a batch plant dryer, a counterflow drying process is employed while on a drum mix plant the aggregates and burner exhaust gases move in a parallel flow system.

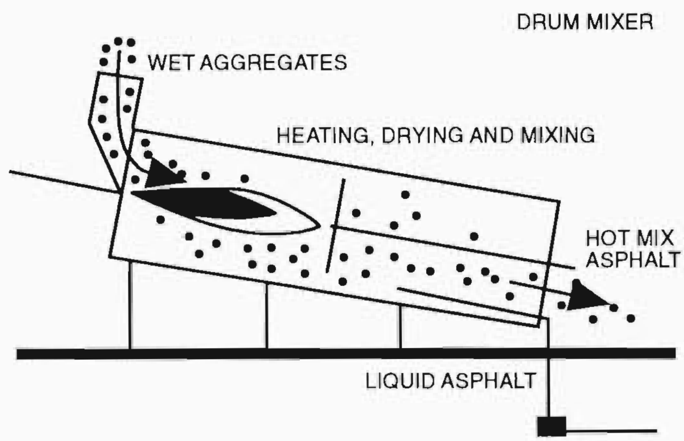


Figure 3.1. Parallel flow process of a drum mix plant (Ref 9).

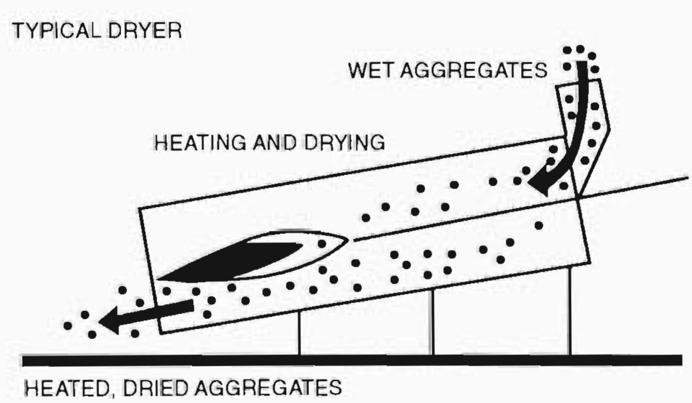


Figure 3.2. Counterflow process of a batch plant dryer (Ref 9).

As the aggregates move down the drum, they are tumbled by the flights or vanes located inside the drum (Fig 3.3), and the aggregates are dried and heated. As the exhaust gases move down the drum, in parallel with the aggregates, the heat is transferred to the aggregate.

At the upper end of the drum, the heating of the aggregates and removal of surface moisture commences. Part way down the drum, when the temperature of the aggregates approaches the boiling point of water and stabilizes temporarily, moisture begins to be driven off from the internal pores of the aggregates . When the aggregates have shed most of the moisture, the heating of the aggregate commences once again, reaching the selected discharge temperature at the lower end of the drum. The initial temperature of the burner gases is over 2,500°F. By the time the gases exit the drum and enter the ductwork to the air pollution control system, the temperature of the gases should be reduced to approximately 300°F.

The veil (amount) of aggregate placed in front of the burner flame and exhaust gases, control the efficiency of the heat exchange process. Within the capacity limits of each plant, the more aggregate in the drum, the more complete the heating and drying operation. To increase the efficiency of the drying process, the drum mixer can be modified to increase the dwell time of the aggregates in the drum. This increased retention time can be accomplished by changing the number of flights in the drum, by using flights of different types and configurations, by reducing the slope or angle of the drum, by reducing the speed of rotation of the drum, and/or by placing internal restrictions or dams in the drum to retard the flow of aggregates.

The asphalt cement binder can be discharged into the drum through a pipe coming in from either the upper or lower end of the drum mixer. On a few of these plants, the asphalt cement injection pipe enters from the burner end of the drum and the asphalt cement is added to the aggregates upstream of the drum midpoint. At this particular entry point, the binder may be exposed to the high temperatures of the burner gases.

On most drum mix plants, however, the asphalt cement is pumped into the drum through a pipe entering the drum from the discharge end. The length of the pipe inside the drum can be varied, but usually the asphalt cement is injected at a point approximately 30 to 40 percent of the way up the drum from the rear (60 to 70 percent down the length of the drum from the burner end). Once the asphalt cement is discharged, it comes in contact with available moisture, foams, and increases in volume. The foamed asphalt cement coats the new aggregates and any reclaimed material in the drum. The coating process usually takes place in a very short period of time. The asphalt coated materials are then heated to the proper temperature as they travel down the remaining length of the drum. The completed mixture is then discharged from the plant.

Recycled Mixtures

For recycled asphalt mixtures, the reclaimed material can be introduced into the drum at the burner end, together with the new aggregates. In this system, a heat-diffusing device or heat shield (Fig 3.4) is sometimes used to reduce the immediate exposure of the asphalt-coated reclaimed material to the hot exhaust gases. This is done to reduce the generation of hydrocarbon emissions (blue smoke) when the aged asphalt is subjected to the very high gas temperatures.

In most drum mix plants, however, the reclaimed material is fed into the plant through a separate entry port located near the middle of the drum length (Fig 3.5). By introducing the reclaimed mixture at this point, the asphalt-coated material is exposed to exhaust gases which are at a lower temperature, thus lessening the amount of blue smoke generated. The reclaimed aggregates are partially protected from the exhaust gases by the veil of new aggregates in the upper half of the drum.

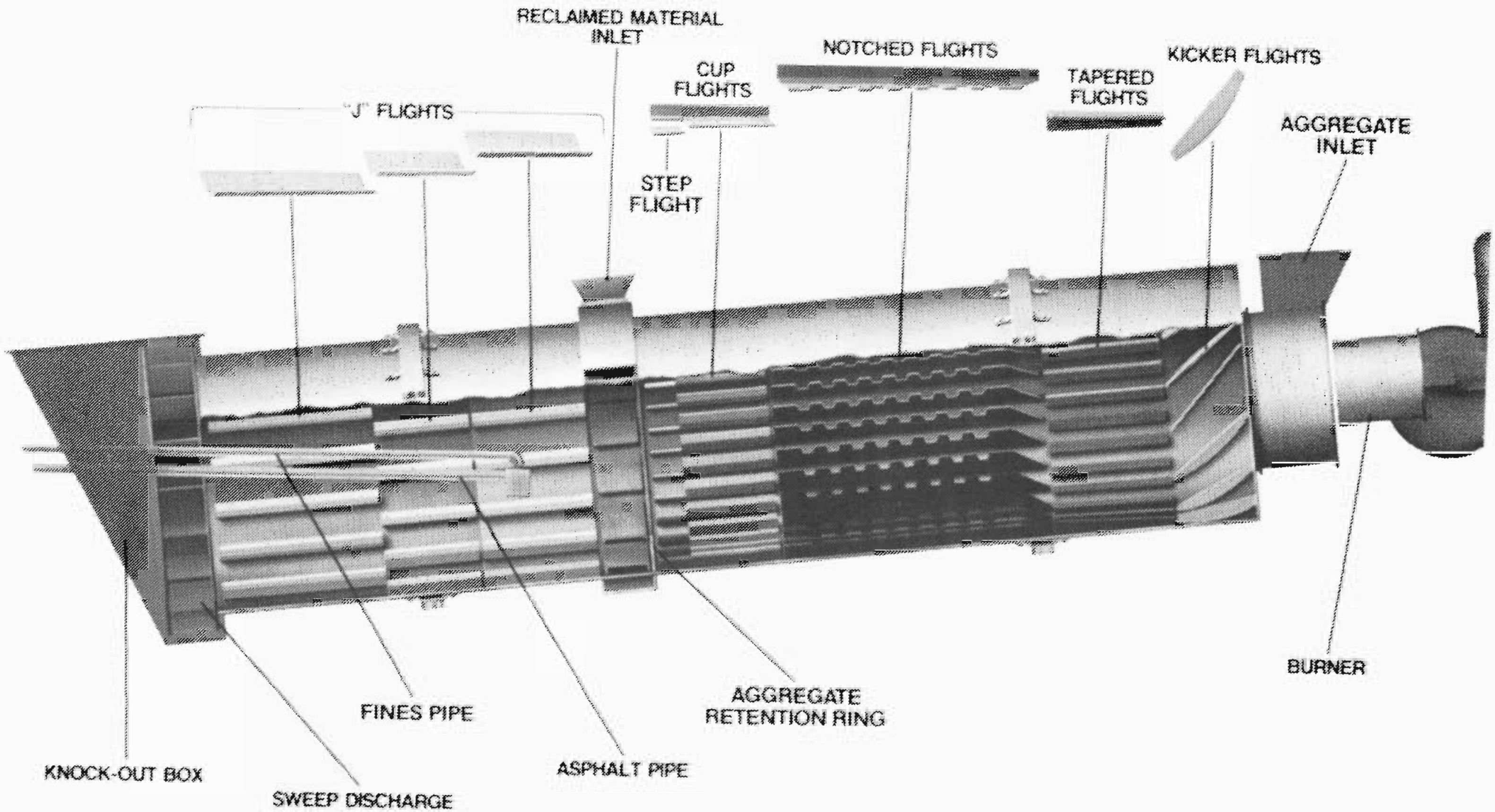


Figure 3.3. Flight configuration and locations inside a Barber-Greene drum mixer, Ref 10.

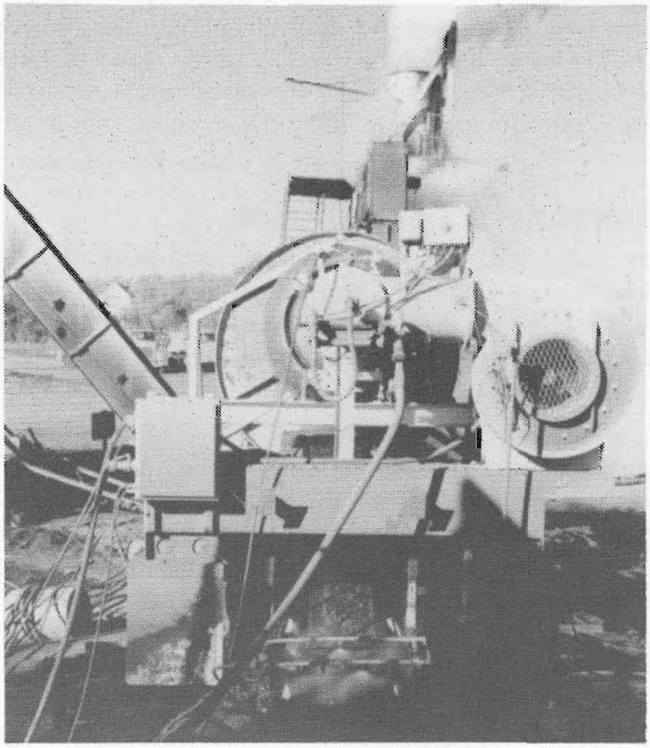


Figure 3.4. Burner-end inlet for reclaimed material entry.

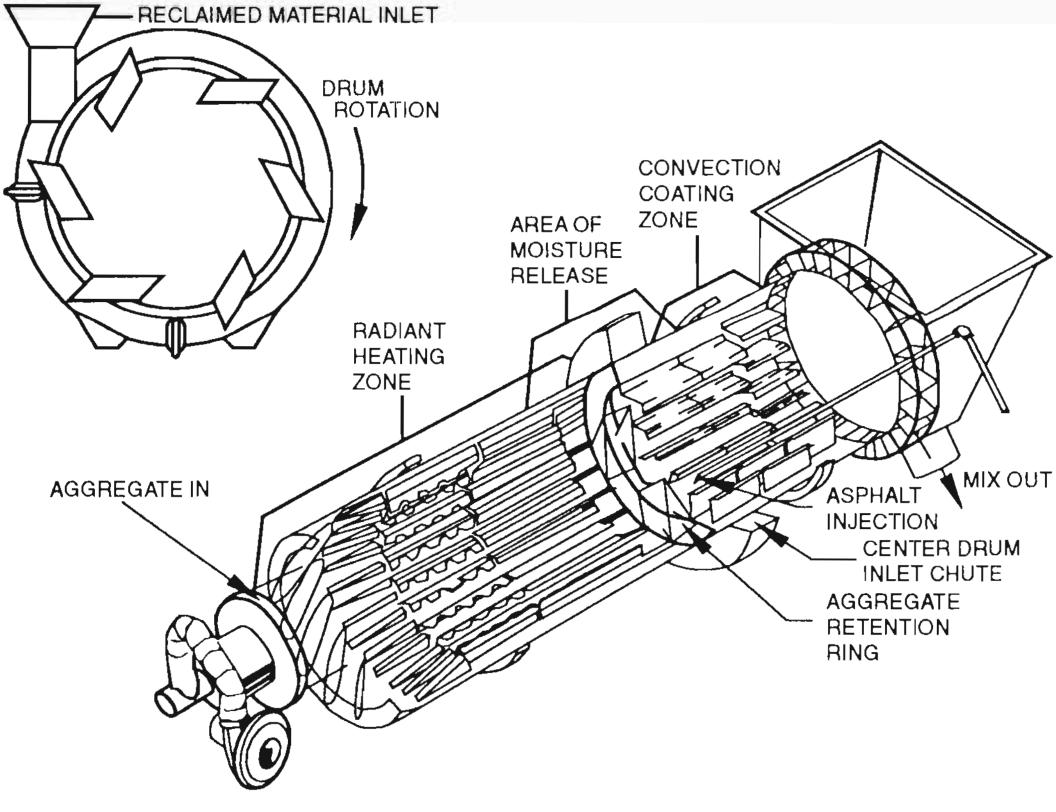


Figure 3.5. Center inlet for reclaimed material entry (Ref 11).

In the midpoint entry system, the new aggregates are heated to a temperature above normal in the front end of the drum to facilitate the transfer of the heat to the reclaimed material. The superheated new aggregates and the ambient temperature reclaimed aggregates are blended together in the lower half of the drum. The reclaimed material is thus heated both by exposure to the burner exhaust gases and by contact with the superheated new material. The asphalt cement is introduced in essentially the same manner as with new aggregate-asphalt mixtures.

3.4 ASPHALT CEMENT SUPPLY SYSTEM OVERVIEW

The asphalt cement, received from the refinery by tank truck or railcar, is offloaded into a hot storage tank. The cement is stored at an elevated temperature, usually in the range of 300 to 350°F, until needed. Most storage tanks have the capability of circulating the asphalt cement within the tank or between tanks when the material is not being pumped to the drum mix plant.

Because the drum mix manufacturing process is a continuous one, the asphalt cement is pumped steadily to the plant. After passing through the pump, the binder moves through a valve or series of valves which proportion the correct amount of asphalt cement for the mixture, returning any excess material to the storage tank. The amount of asphalt cement fed to the plant is measured by a meter and is determined by the amount of aggregates (new aggregates or combined new and reclaimed material) measured by the weigh bridge on the charging conveyor. As the weight of aggregates being introduced into the plant changes, the computer controls automatically alter the volume of asphalt cement passing through the meter to the drum.

3.5 MIXTURE STORAGE SYSTEM

The drum mix plant produces the asphalt concrete mix on a continuous basis. The transport of the mix to the laydown site, however, is a batch type process, i.e., truckload to truckload. Therefore, a temporary holding bin or surge silo is used to convert the continuous flow of material to a batch basis.

Several different types of conveying devices can be employed to carry the asphalt concrete from the discharge end of the drum mixer to the surge silo. Bucket elevators, drag slat conveyors, and belt conveyors are the three most common means of transport. Each device has its own advantages and disadvantages. The means of carrying the mix is not as important as how the material is delivered from the conveying device into the top of the silo. Segregation problems can begin with the improper discharge of the asphalt cement mix into the surge bin.

A variety of methods are used to collect the asphalt concrete from the conveying device and drop the mix into the silo. Usually some type of batcher or "gob-hopper" is employed, with the mix being held temporarily until the hopper is nearly filled. The asphalt concrete is then dropped as a mass into the silo. The bucket elevator, drag slat conveyor, or belt conveyor must place the mix into the center of the holding hopper, if used, or into the center of the silo. The batches must be situated to allow the discharged mix to fall into the center of the surge silo. This will reduce the tendency for the mix to build up on one side of the silo and then roll to the other side, causing segregation.

Most surge silos are round; however, a number of different shapes (rectangular, square, and elliptical) are being used. Most of the surge silos are insulated to reduce the amount of heat loss while the mix is in storage. Some of the bins are completely heated, while many have heat applied only to the cone of the silo. The silos are generally equipped with double gates at the bottom of the cone to control the rate of discharge of the asphalt mixture into the hauling vehicle.

In some cases, it is possible to store the mix overnight or even for several days in the surge bin. The silo must be well insulated and the amount of asphalt mixture held in the bin should approach the capacity of the silo, i.e., the silo should be full. If the storage is to be longer than overnight, an inert gas, such as nitrogen, can be charged into the top of the silo to purge the oxygen and reduce the rate of hardening of the mix. The mixture, which can be stored for minutes, hours, overnight, or several days, is then delivered at the appropriate time to the trucks for transport to the paver.

3.6 AIR POLLUTION CONTROL SYSTEM

Two basic types of air pollution control systems, i.e., a wet process or a dry process, are used on most drum mix plants. The exhaust gases from the plant burner pick up particles of dust as the air moves through the drum. That dust-laden air is carried out the rear end of the plant through ductwork and into an air pollution control device.

Wet Scrubber

If a wet scrubber system is employed, the dust-laden exhaust gases are usually fed through a venturi where the speed of the gases is increased significantly. As the dirty air leaves the restricted space, water is sprayed on it. The speed of the airstream atomizes the water droplets, and the dust particles collide with the minute droplets of water.

The speed and direction of the air are altered, and it enters a cylindrical drum where the dust particles are separated from the exhaust gases by centrifugal force.

The moisture-laden dust particles, being heavier, fall out of the gas stream and drop to the bottom of the wet collector. The efficiency of the wet scrubber system depends on the size of the dust particles in the gas stream, the speed of the dusty air, and the size and volume of the water droplets used in the spray system. A wet wash system must be properly maintained to function well. The water being sprayed should be clean and all the nozzles in the system should be open and functioning.

The dirty water collected in the bottom of the scrubber is pumped to the waste water pond. The purpose of the pond is to allow the dust particles to settle out of the collector water. The settling pond must be of sufficient size to hold at least the volume of water that will be carried through the scrubber in a half day's production. This volume will usually allow enough time for the dust to settle out before the water is circulated back to the plant. A pond which is too small in area and depth will be filled with sediment and will allow dust-laden water to be fed back through the wet wash system, clogging the nozzles and reducing the efficiency of the scrubber.

Because it is a wet system, the dust collected by a wet scrubber must be wasted. The material cannot be fed back into the plant. Thus the gradation of the aggregate in an asphalt mixture produced in a drum mix plant, equipped with a wet wash system, will be somewhat different than that determined in the original mixture design because a portion of the fines will be missing.

Baghouse

A baghouse is really a fabric filter. The dust-laden air passes through a cloth filter where the dust particles are caught and dropped out of the exhaust gas stream. Many times an expansion chamber or knockout box is located at the end of the plant ductwork at the front of the baghouse. The exhaust gases enter the expanded area and are slowed. The heavier dust particles decrease in speed enough to fall out of the gas stream to the bottom of the house. The still-dirty air then circulates through the chamber and around the numerous bags which are filter cloth stretched over a wire frame. The air is pulled through the filter by the exhaust fan, depositing the dust particles on the outside of the bag.

If the dust coating on the filter cloth is too light, many fine dust particles will pass through the filter cloth and be carried up the plant stack into the environment. If the dust coating is too heavy, the exhaust fan is unable to pull enough air through the filter cloth, reducing the production capacity of the plant. In order to obtain the correct amount of dust coating on the bags, the bags are cleaned periodically. The cleaning is accomplished either by flexing or shaking the bags or by back flushing the bags with a blast of air. Only a few rows of bags in the fabric filter chamber are cleaned at one time, allowing the baghouse to continue to operate during the cleaning cycle.

The dust collected in the expansion chamber and the dust which is collected on the bags falls into one or more screw augers at the bottom of the baghouse. The collected fines can be wasted or can be returned to the drum mixer.

Generally, baghouse fines which are returned to the plant are fed into the lower portion of the drum through a fines pipe. They are typically conveyed pneumatically and exit the pipe downstream of the drum midpoint, but can also be carried back by an auger system. In some plants, the baghouse fines are deposited some distance in front of the asphalt cement injection point. Thus the dust is mixed with the aggregates before they are coated with the binder. In other plants, the dust is discharged into a mixing chamber where it is coated with asphalt cement before it comes in contact with the other aggregates. This latter system reduces the amount of baghouse fines which are reentrained into the exhaust gas stream and carried back to the fabric filter.

The efficiency of the fabric filter in collecting the dust particles depends on many factors. The exhaust fan must be able to pull the air through the filter cloth. This is monitored by measuring the pressure drop across the bags—the change in pressure from the dirty side to the clean side of the bag house. Too little pressure drop means that dust particles will be pulled through the bags; too much pressure drop means that the bags are dirty, and the plant is not operating efficiently.

3.7 SUMMARY

A modern drum mix plant consists of five major components: (1) the cold feed aggregate bins and charging conveyor, (2) the asphalt cement supply system, (3) the drum mixer, (4) the hot mix surge silo, and (5) the air pollution control system. If reclaimed asphalt concrete materials are used, a second cold feed system may be employed on most plants.

The details of the operation of each of these major components are provided in the following chapters.

CHAPTER 4. COLD FEED SYSTEMS

For the most part the cold feed system is essentially the same for both batch and drum mix plants. The following discussion, however, relates primarily to drum mix plants.

4.1 COLD FEED BINS

The flow of aggregates through a drum mix plant begins at the cold feed bins (Figs 4.1 and 4.2). The plant can be equipped with a single bin or with multiple bins to handle the new aggregates being used in the mix. In addition, if a recycled asphalt concrete mix is being manufactured, one or more reclaimed asphalt concrete cold feed bins will also be needed.

Most cold feed bins are rectangular in shape. The bins have sloping sides and a rectangular or trapezoidal opening at the bottom (Figs 4.3 and 4.4). The sides of the bins, designed specifically for reclaimed asphalt mixtures, are usually steeper than the sides of bins for new aggregates. This reduces the tendency of the asphalt-coated reclaimed material to "hang up" in the bin and bridge over the discharge opening.

Ideally, a bulkhead or divider should be used between cold feed bins (Figs 4.1, 4.2, and 4.5). The width of each bin, depending on the capacity of the drum mixer and whether the plant is portable or stationary, is usually slightly wider than the bucket on a front end loader. If no dividers are used between the bins, the loader operator can overfill (Fig 4.6) a bin and allow the aggregates of one size to spill over into the aggregates in an adjacent bin. This combining of the aggregate sizes can cause significant variations in the mixture gradation. Some plant manufacturers provide bulkheads on the cold feed bins; others do not. If bulkheads are not being used to separate the aggregates between the various bins, they should be installed, but only between adjacent bins.

The cold feed bins are equipped with gates which can be set to provide a number of different openings. They are also normally provided with a variable speed conveyor belt beneath the bin (Fig 4.7), rather than a fixed speed belt. The quantity of the aggregate delivered from each bin is determined by the size of the gate opening as well as the speed of the belt feeder. If a large volume of one particular aggregate is desired from a bin, the gate can be opened and/or the speed of the belt conveyor can be increased.

4.2 FEEDER GATHERER CONVEYORS

Feeder Conveyors

In years past, the conveyor belts (belt feeder) under each cold feed bin were run at a constant speed. To vary the quantity of aggregate fed from a bin, the gate opening had to be changed. Currently, for most asphalt plants, a preset gate opening on a bin is used and the belt speed is increased or decreased to draw the proper proportion of aggregate from the bin for a given blend of aggregate. The gate opening is typically set manually on each bin. This is done by raising or lowering the gate by a hand crank or wheel, or by unbolting, moving, and rebolting a sliding plate on one end of the hopper. Because the gate setting is usually done manually, the gate opening can be changed or can be incorrect without the plant operator being aware of it since there is no indication of the setting of the gate opening on the plant control panel. Thus, the gate setting should never be altered without the knowledge of the plant operator.

As the speed of the belt feeder under a bin is changed, the amount of aggregate discharged from the bin is also changed. Theoretically, it is possible to withdraw material from the hopper using the full range of belt speeds, from 0 percent to 100 percent of the maximum speed. It is desirable practice, however, to operate a belt feeder in the range of 20 to 80 percent of its maximum speed in order to permit the plant operator to vary the production rate to match haul truck availability or laydown conditions. If the bin opening is set so that the

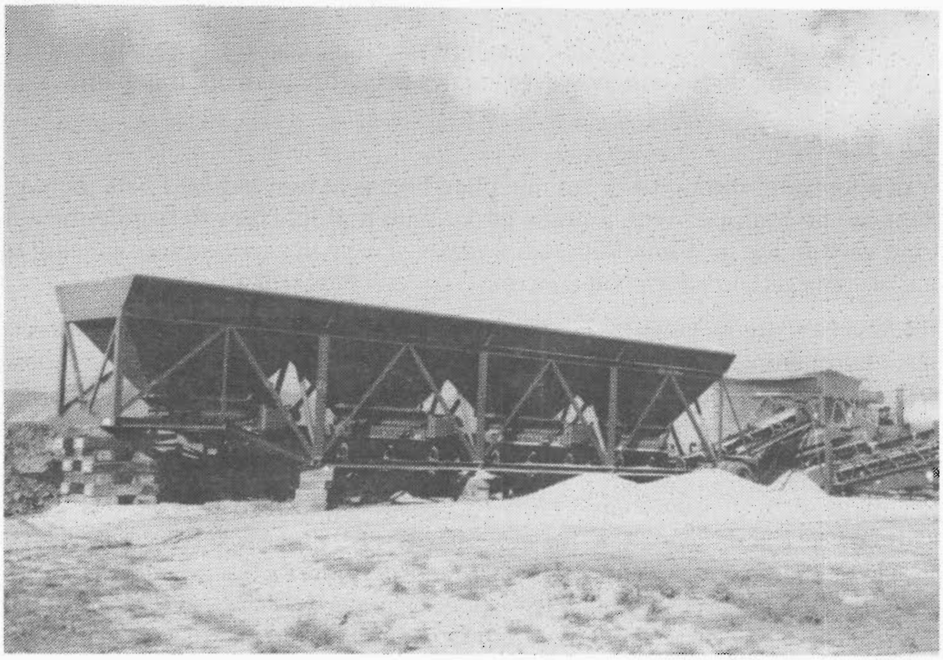


Figure 4.1. Cold feed bins.

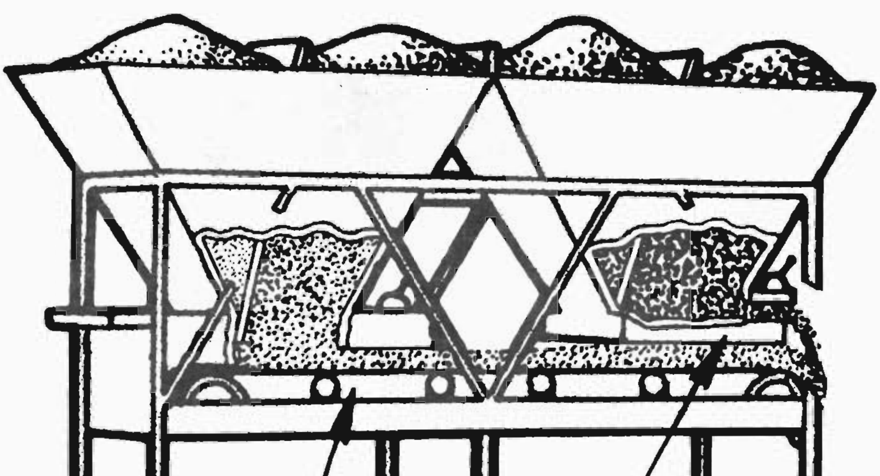


Figure 4.2. Schematic of cold feed bins (Ref 12).

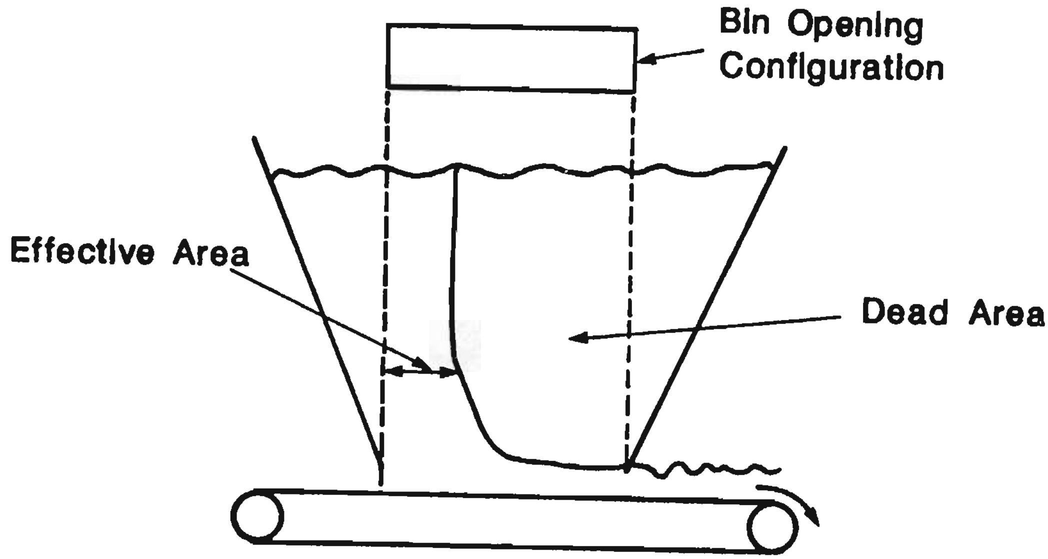


Figure 4.3. Cold feed bin with rectangular opening (Ref 14).

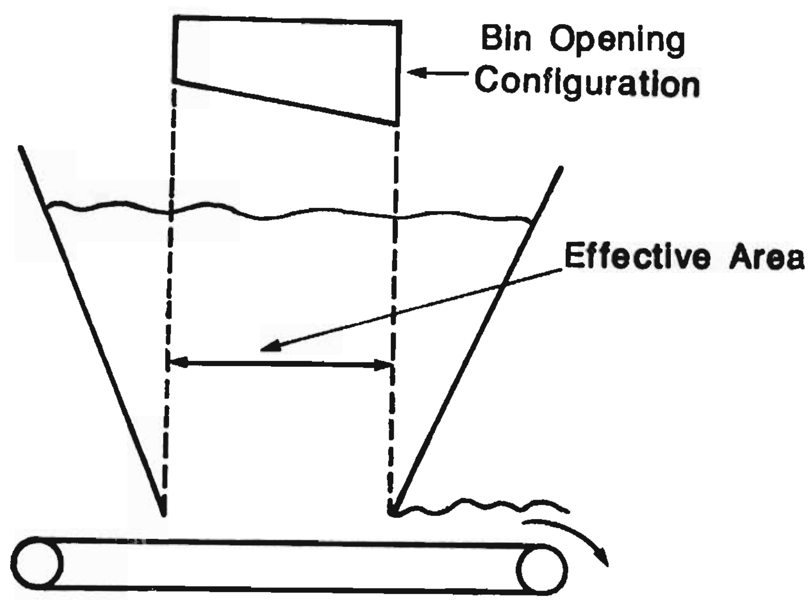


Figure 4.4. Cold feed bin with trapezoidal opening (Ref 14).

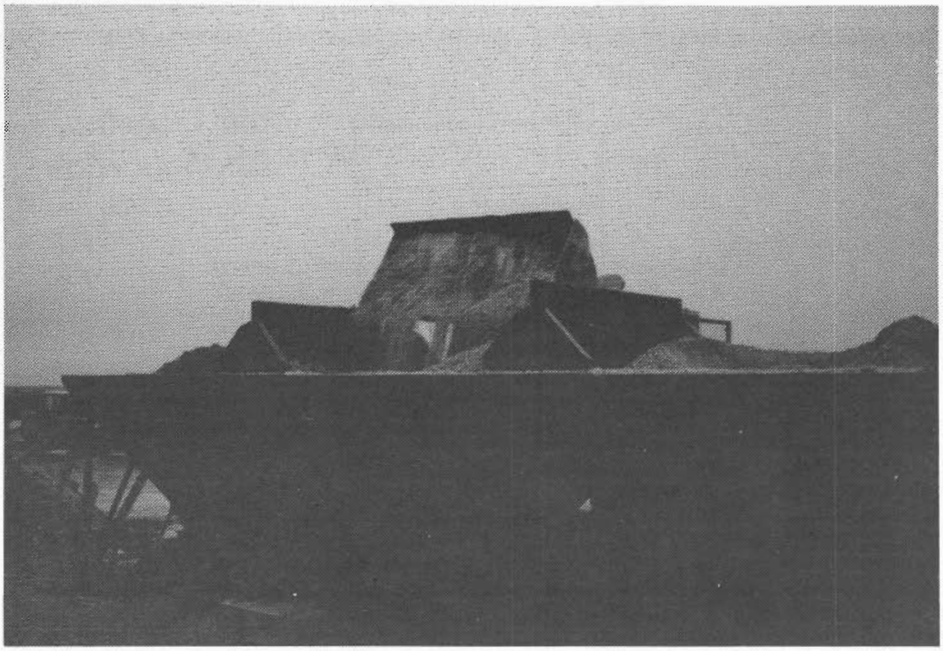


Figure 4.5. Cold feed bins with bulkhead between bins.

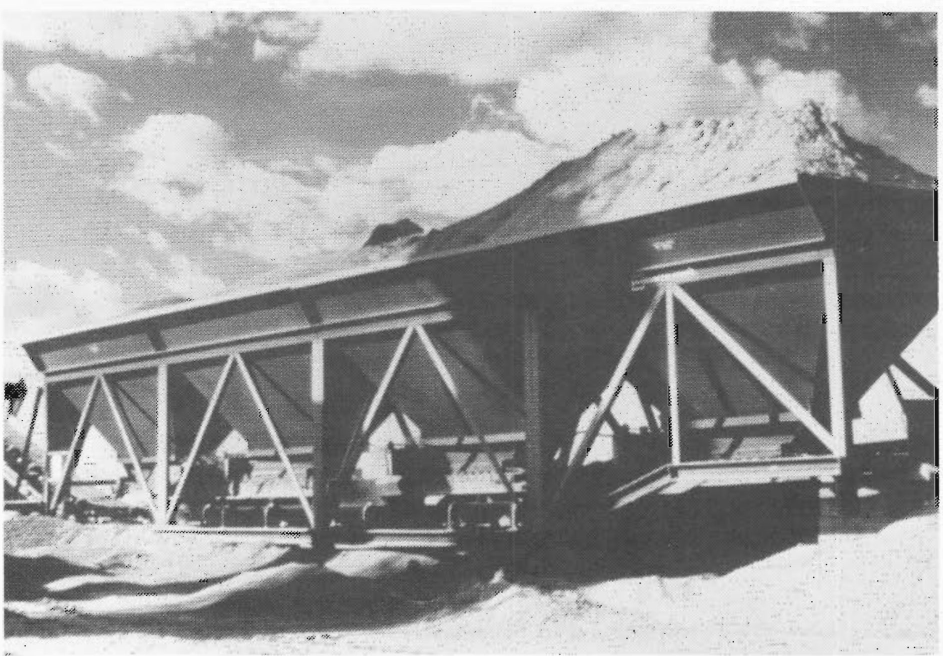


Figure 4.6. Overfilling cold feed bins.

belt feeder is functioning near the upper or lower end of its speed range, the operator may not be able to change the plant production volume to any significant degree. Thus, the gate on the cold feed bin should be set in a position to allow the feeder conveyor to run near the midpoint of its speed range.

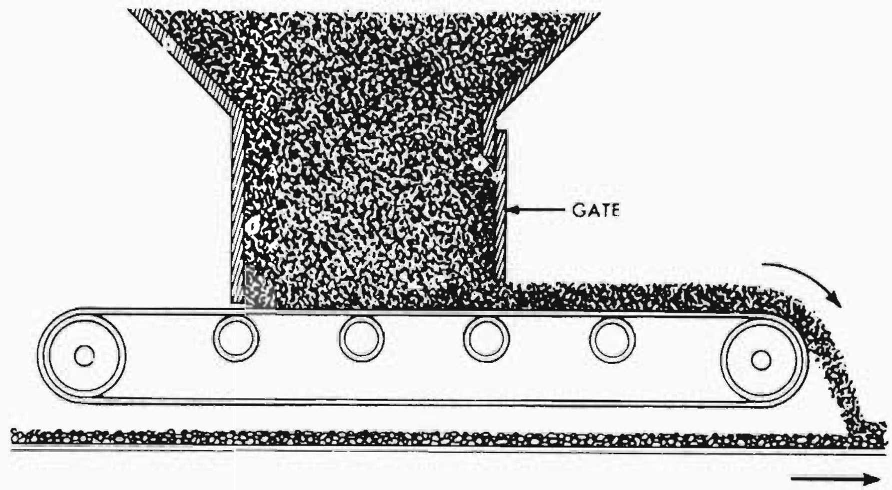


Figure 4.7. Feeder conveyor and gathering conveyor under a cold feed bin (Ref 5).

Example. Suppose a drum mix plant is rated at 400 tons per hour (at 5 percent moisture removal), but is actually producing mix at a rate of 300 tons per hour due to conditions at the paving site. The plant is thus operating at 75 percent of its rated capacity. Assume that one particular cold feed bin is supplying 30 percent of the aggregate needed for the mix, or 90 tons per hour of material (ignoring, for this example, the moisture in the aggregate and the asphalt cement in the mix). Further, the gate on the cold feed bin is partly closed, so that the belt feeder conveyor is running at 85 percent of its maximum speed.

The plant operator receives word from the laydown superintendent that he can now place 400 tons of mix per hour. The operator increases the speed of all the conveyor belts proportionally to meet the increase in demand for mix. On the cold feed bin in question, however, increasing the output from 90 to 120 tons per hour is not possible because the speed of the belt feeder would have to be greater than 100 percent, which is impossible. Thus, by not operating in the middle of the belt speed range for each cold feed bin, the operator has lost the ability to easily alter the output of the drum mix plant to meet changing production needs.

In this example, the operator would have to increase the gate setting or size of the opening on the cold feed bin in order to discharge enough material to meet the new production requirements. In all too many cases, the tendency is to run the feeder belt speed of the one cold feed bin at 100 percent and make up for the loss of aggregate from this bin by increasing slightly the amount of material drawn from the other cold feed bins. This is done by increasing the feeder belt speed under each of the remaining bins. This procedure obviously changes the gradation of the asphalt mixture being manufactured.

The speed setting of each belt feeder is displayed on the operator's console in the control trailer. The current speed is typically shown as a percentage of the maximum belt speed. If the feeder belt, under a given cold feed, bin is operating at a level under 20 percent or over 80 percent, the gate setting should be changed as soon as convenient. This will allow the belt to operate closer to the center of its speed range for that particular blend of aggregate and production rate.

The speed setting for each individual belt feeder is set independently to allow the proper amount of aggregate to be pulled from each particular bin. Once determined, the speed of all the belt feeders is synchronized so that a change in the speed of one belt feeder is proportional to the change in the speed of all the other belt feeders. Thus, if the production of the plant is increased from 250 to 350 tons per hour, for example, a change in the master control setting causes a corresponding proportional change in the speed of all the belt feed conveyors.

Gathering Conveyor

The aggregate deposited on each belt feeder is discharged onto a gathering conveyor located beneath all of the cold feed bins (Figs 4.8 and 4.9). In most cases, all the belt feeders are run in the same direction as the gathering conveyor. In some cases, particularly on portable drum plants, the last cold feed bin nearest the plant may have the direction of the belt feeder reversed. The aggregate in that bin moves on its belt feeder in a direction opposite to the direction of the gathering conveyor. The direction of the belt feeder conveyor in relation to the gathering conveyor is primarily a function of the design of the cold feed bin system. It is important, however, that the material on each belt feeder be placed uniformly on the gathering belt conveyor.

4.3 SCALPING SCREENS

On plants which are handling bank run or pit run aggregates, it usually is desirable to insert a scalping screen or screens into the cold feed system at the end of the gathering conveyor (Figs 4.10 and 4.11). Bank or pit run aggregates often contain a variety of deleterious materials such as tree roots and vegetable matter, as well as oversized pieces of gravel. Thus, the scalping screen can be put into the cold feed system at the discharge end of the gathering conveyor to remove all such material. For quarry processed aggregates, it is not normally necessary to pass the aggregates through a scalping screen.

Most often, the scalping screen is a single deck unit with only one screen cloth. The openings in the screen can either be square or slotted. The advantage of using the slotted screen is that a smaller screen area can handle a given volume of material. On some portable drum mix plants, a two-deck scalping screen is used to allow two different top-sized aggregates to be used without changing the screen cloth (Fig 4.12). If the top screen is being used and aggregate (which needs to be included in the mix) is caught on the bottom screen, a flip gate at the lower end of the second screen redirects the aggregate back to the incline or charging conveyor and into the drum mixer. The flip gate can be operated either manually or automatically.

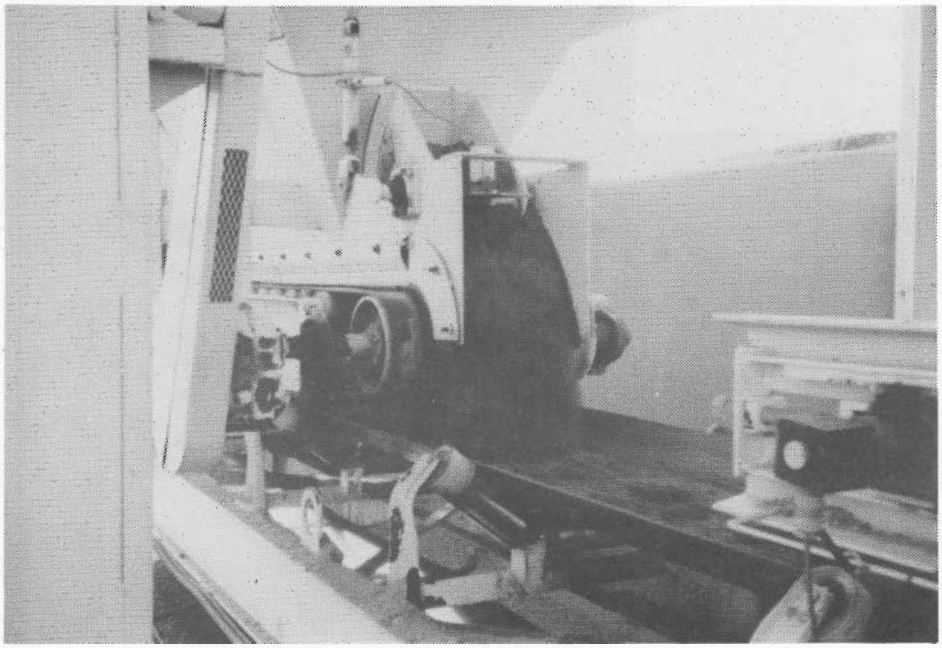


Figure 4.8. Feeder conveyor and gathering conveyor.

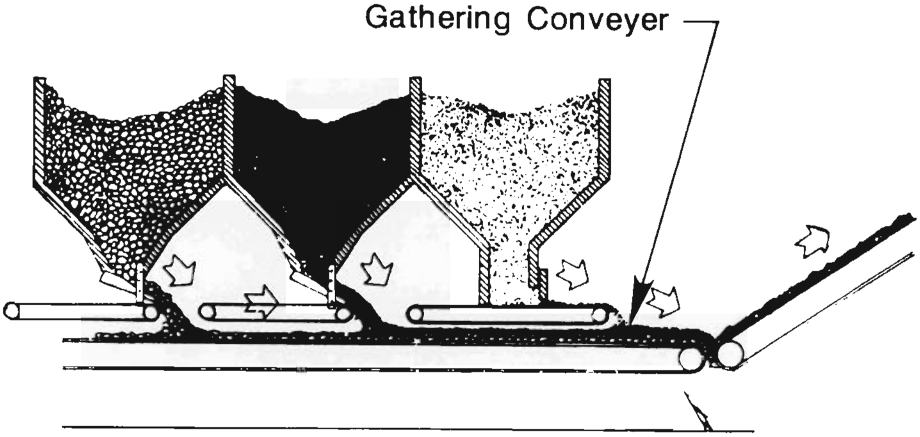


Figure 4.9. Gathering conveyor (Ref 5).

Figure 4.10. Scalping screen between gathering conveyor and incline conveyor (Ref 15).

Figure 4.11. Scalping screen.

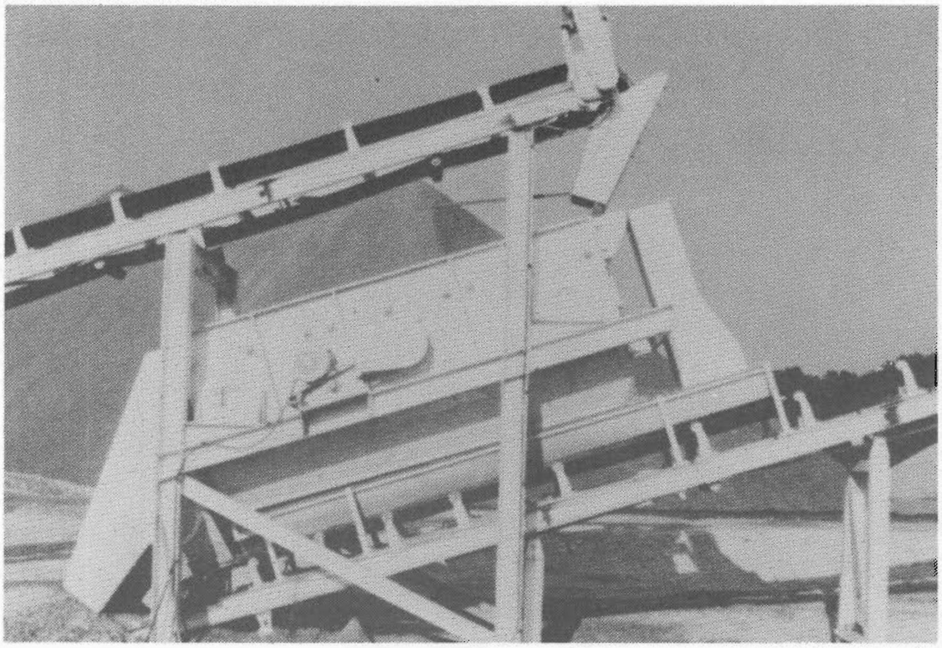


Figure 4.12. Inclined double deck scalping screen with bypass gates (Ref 16).

Some scalping screens are equipped with a bypass chute. This chute allows the aggregates on the gathering conveyor to be deposited directly on the incline conveyor without passing through the screen. This procedure is used when quarry-processed aggregate is being fed to the drum mixer or when the scalping screen is temporarily plugged or broken. In the latter case, the scalping screen can be repaired without shutting down the whole plant.

In addition to a scalping screen at the end of the gathering conveyor, some cold feed bin systems include a small scalping screen under each cold feed bin (Fig 4.13). The aggregate from a particular bin falls off the belt feeder and onto the scalping screen. Properly sized material passes through the screen and onto the gathering conveyor. Oversize pieces are rolled down the screen into a reject chute which deposits the aggregates in a pile near the cold feed bins for subsequent disposal. The size of these individual scalping screens is quite small. If the screens become blinded or clogged, the proper amount of aggregate will not pass through the screen onto the gathering conveyor resulting in an incorrect proportioning of the aggregates and a variation in the gradation of the mixture. Further, if a high proportion of aggregate is being drawn from one particular bin, the capacity of the scalping screen may not be enough to provide the necessary rate of feed. Thus the operation of such individual scalping screens should be monitored regularly.

4.4 INCLINE OR CHARGING CONVEYOR AND WEIGH BRIDGE

The combined coarse and fine aggregates are discharged from the gathering conveyor, through the scalping screen (if used), and onto the incline conveyor for transport to the drum mixer (Fig 4.14). The incline conveyor, or charging conveyor, carries the aggregates to a charging chute above the burner on the drum or to a slinger conveyor under the burner. From one of these two entry points, the aggregates are introduced into the mixing drum.

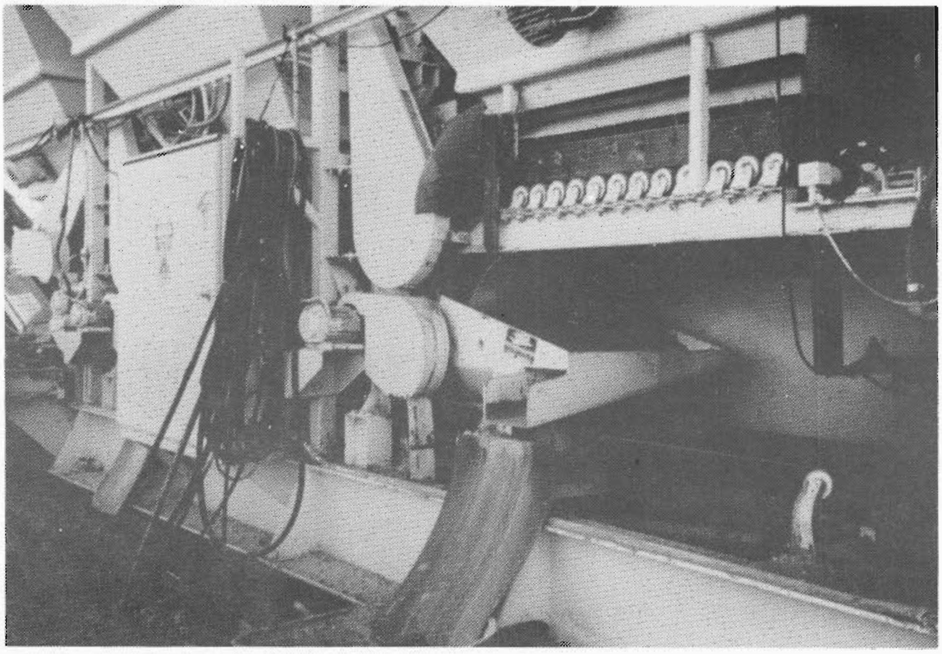


Figure 4.13. Individual scalpers under each feeder (Ref 17).

Figure 4.14. Inclined conveyor.

The incline conveyor contains a weigh bridge system which measures the amount of aggregate being fed to the drum mixer (Fig 4.15). The weigh bridge, or belt scale, determines the rate of flow of material over the moving belt at any given time. The incline conveyor normally operates at a constant speed, independent of the feeder conveyors or gathering conveyor. The weigh bridge itself is located near the midpoint of the charging conveyor, between the head and tail shaft pulleys.

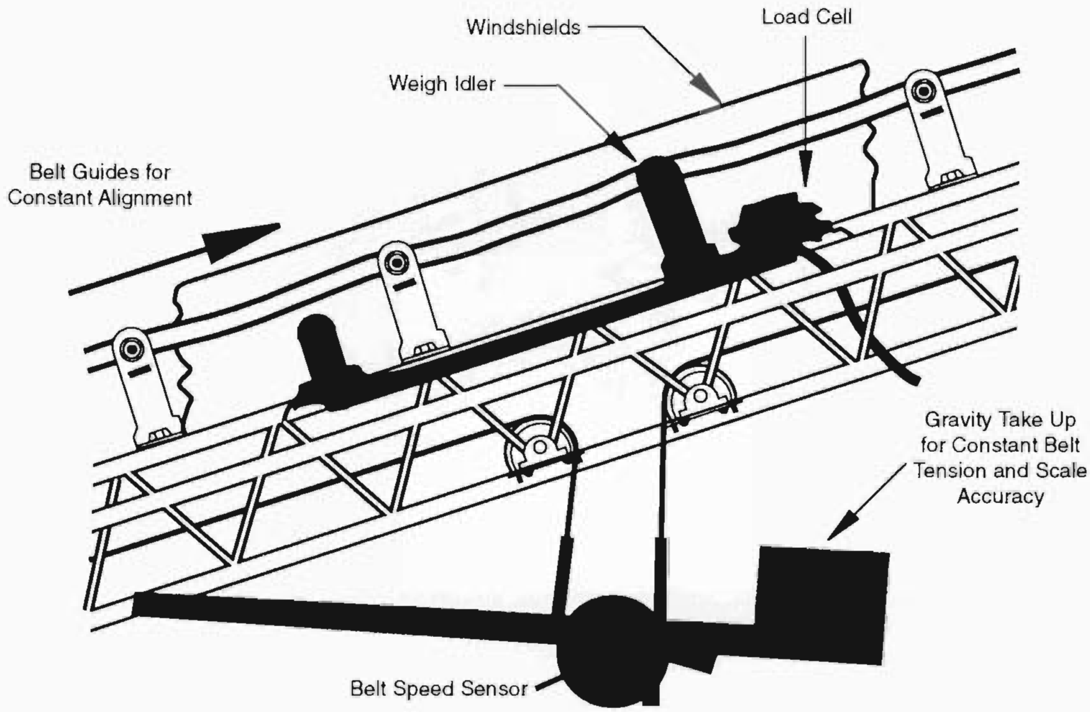


Figure 4.15. Weigh bridge system for drum mix plants (Ref 18).

A weigh idler is the heart of the weigh bridge (Fig 4.16). This idler is different from the fixed idlers on the conveyor frame. It is free to move and is attached to a load cell. As the aggregates pass over the weigh idler, the weight of the material at a given point of time is recorded as an electrical signal in the computer control system. The weight value by itself is meaningless because it covers only an instant of time. Thus, the charging conveyor is also equipped with a belt speed sensor (Fig 4.17). This device, usually located on the belt take up pulley, is a tachometer which measures the actual speed of the conveyor belt.

The information from the weigh idler on the belt scale and from the belt speed sensor is combined to determine the actual weight of aggregate, in terms of tons per hour. This value is the wet weight of the aggregate and includes the moisture in the aggregate. The wet weight of this material is converted to dry weight (without moisture) by the plant computer, using a manual input of the average moisture content in the combined coarse and fine aggregates.

To obtain an accurate belt speed reading, it is essential that the charging conveyor belt be tight. Any slippage of the belt over the speed sensor will result in an erroneous reading and an incorrect tonnage input value to the drum mixer. In addition, it is important that the incline conveyor be equipped with a scraper to clean off the belt as it revolves around the head and tail shaft pulleys.

If the aggregates being carried on the belt are relatively dry, all the aggregates that pass over the weigh bridge will enter the drum. If the moisture content of the aggregate is high, some fine aggregate may stick to the incline conveyor belt. This "extra" material will not be fed into the drum, but will remain on the belt. If not removed by a scraper blade, the additional material will be continually weighed by the weigh bridge, creating a false weight reading. The computer will be told that more aggregates are entering the drum than actually are. This will cause additional asphalt cement to be pumped to the plant. Thus the belt scraper should be used to clean the incline conveyor belt as it carries aggregates to the mixing drum.

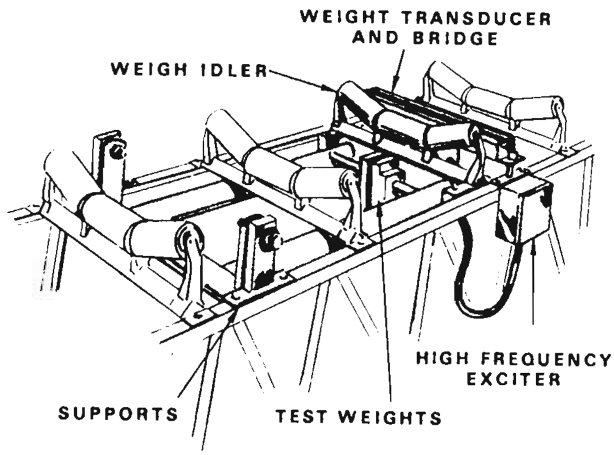


Figure 4.16. Continuous automatic belt weighing system for drum mix plants (Ref 18).

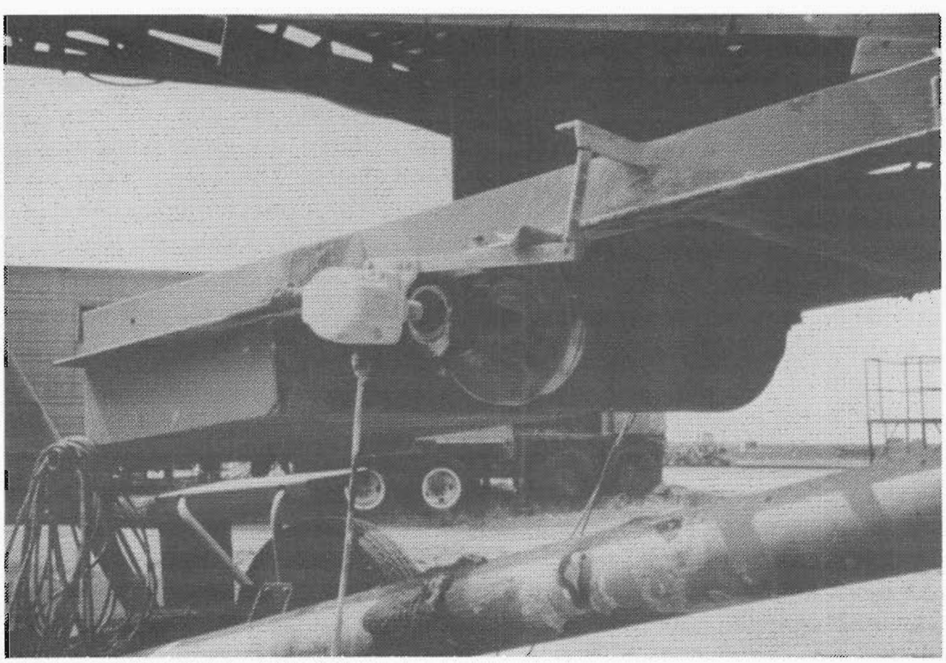


Figure 4.17. Belt speed sensor on belt take-up pulley (Ref 15).

The belt speed sensor is usually mounted on the conveyor belt take-up pulley. This latter device is essentially a gravity take-up, used to keep the conveyor belt in tension (Fig 4.15 and 4.17). If the pulley weight is restricted from free movement, the belt speed determined by the sensor will be incorrect. The same is true if the belt is slipping as it passes over the pulley. Thus, it is important that the conveyor belt be tight and not slipping in order to obtain an accurate belt speed reading.

Some incline conveyors are equipped with an air-actuated take-up system which is located on the tail shaft pulley and operates in a manner similar to the gravity take-up system. Its purpose is to keep the conveyor belt tight. Thus, the belt speed sensor still can measure the true velocity of the belt.

Individual Bin Weigh Bridges

On some plants, some of the individual cold feed bins will be equipped with weigh bridge systems located on the individual belt feeder conveyor. Thus, instead of one weigh bridge on the incline or charging conveyor, multiple weigh bridge units are used. For this type of setup, the conveyor belt under each individual cold feed bin must be wider and longer than the feeder belt without the weigh bridge.

Usually, a plant with individual cold feed weigh bridges will not have a weigh bridge installed on the last feeder conveyor closest to the drum mixer. Another separate weigh bridge is installed on the incline conveyor. This latter system provides data on the combined weight of all the aggregates, the same as the weigh bridge system on most drum mix plants.

The plant computer and controls are thus able to display the amount of aggregates being pulled from each cold feed bin. The amount of material delivered from the bins equipped with individual weigh bridges is read directly after deducting the amount of moisture in each aggregate fraction. The amount of aggregate discharged from the last bin is determined by subtracting the amount of aggregate weighed by the individual feeders from the total aggregate weight measured by the weigh bridge located on the incline conveyor, adjusted for moisture content.

For batch plants, a weigh bridge on the changing conveyer is not needed since the amounts of aggregate are controlled at the weigh hopper.

4.5 COLD FEED SYSTEM FOR RECLAIMED MATERIAL

The cold feed system for handling recycled material is essentially the same as the conventional cold feed system. On most plants, this is done through the use of a separate cold feed bin setup (Fig. 4.18). The bin or bins are similar to the cold feed bins used for new aggregates except that the sides of the reclaimed material bins are usually steeper. The steeper sides allow the asphalt-coated aggregates to be more easily discharged from the bins. This is particularly important in hot weather when the reclaimed materials can become sticky. The steeper sides reduce the tendency of the reclaimed material to bridge the opening at the bottom of the bin.

If a separate cold feed bin arrangement is used for the reclaimed material, the bin or bins are equipped with a variable speed belt conveyor under each bin. The bins are also provided with a gate which can be set at various openings. The reclaimed aggregates are deposited on the feeder conveyor and then transferred to a gathering conveyor. In some cases, if only one cold feed bin is used, a gathering conveyor is not used and the reclaimed material is deposited directly on the charging conveyor after passing theough a scalping screen. The asphalt-coated aggregates are then usually passed through a scalping screen to remove any oversized pieces of asphalt mixture or deleterious material. Thus, the handling of the reclaimed material is similar to the feeding of new aggregates.

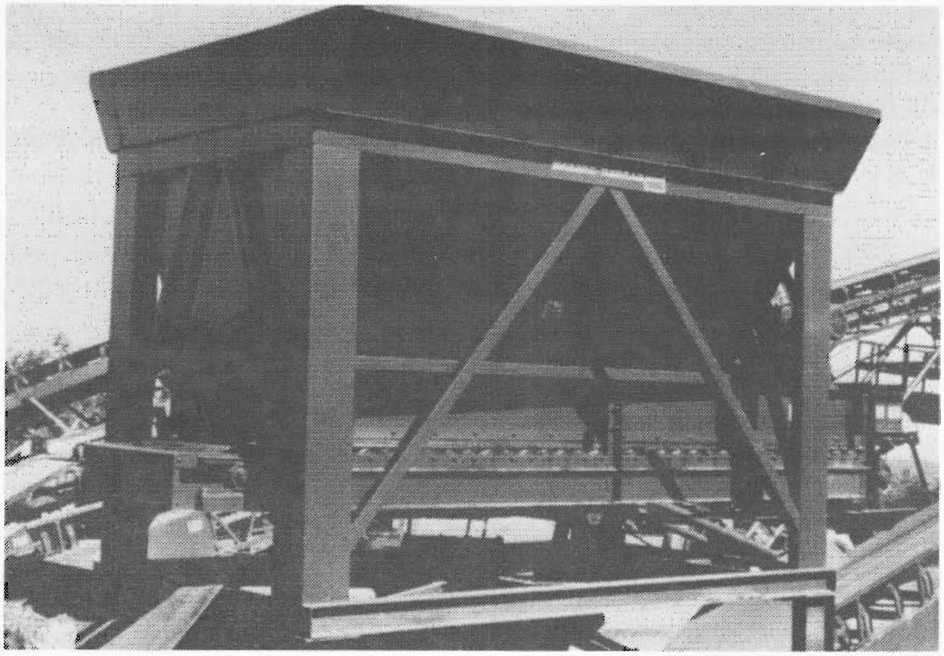


Figure 4.18. Reclaimed material hopper with steeper slides and larger gate opening (Ref 10).

After exiting the scalping screen, the reclaimed asphalt concrete is dropped onto the inclined conveyor for transport to the drum mixer. This conveyor is also equipped with a weigh bridge system which measures the weight of the material passing over it, as well as the speed of the belt itself. This weight, in tons per hour, includes the moisture in the reclaimed material. The moisture content value is manually input into the plant controls and the dry weight of the reclaimed material calculated by the plant computer. The information determined from the weigh bridge system on the reclaimed material incline conveyor is combined with the data from the new aggregate weigh bridge system to determine the plant tonnage rate.

Some drum mix plants have the reclaimed asphalt concrete material cold feed bins combined with the new aggregate cold feed bins. The conventional bins are split, some holding new material and some reclaimed material (Fig 4.19 and 4.20). For one type of plant, the new and reclaimed aggregates are both fed at the same time into the burner end of the drum mix plant. In this case, the reclaimed asphalt concrete is handled exactly like the new aggregates. It can be deposited underneath or on top of the new aggregates, depending on which cold feed bins are selected to hold the asphalt-coated aggregates. The reclaimed material is often deposited on top of the new aggregate so that it can be exposed to a water spray when traveling up the incline conveyor.

When manufacturing recycled asphalt concrete mixtures, most drum mix plants use a split feed system to handle the reclaimed material: If a separate cold feed bin for the reclaimed asphalt concrete is not used, the material is placed in one or more of the conventional cold feed bins. The gathering conveyor under the bin or bins is modified by dividing it into two different sections, each moving in a different direction (Fig 4.20). The gathering conveyor under the feeder belts for the new aggregates carries this material to a charging conveyor moving to the burner end of the drum mix plant. The gathering conveyor under the feeder belts for the reclaimed aggregates transports the reclaimed material to a separate incline conveyor which carries the asphalt-coated aggregates to an inlet point near the midpoint of the drum mixer length.

As for the case where a completely separate cold feed bin system is used for the reclaimed material, a weigh bridge and belt speed sensor are employed to measure the amount of reclaimed material moving up the charging conveyor and into the drum. While using the split cold feed bin system to handle both new and reclaimed aggregates saves the cost of a separate cold feed bin or bins for the reclaimed material, the chance of bridging the opening at the bottom of the bin increases because of the more shallow angle of the sides of the conventional cold feed bins compared to a separate, specially built, cold feed bin for reclaimed asphalt cement material.

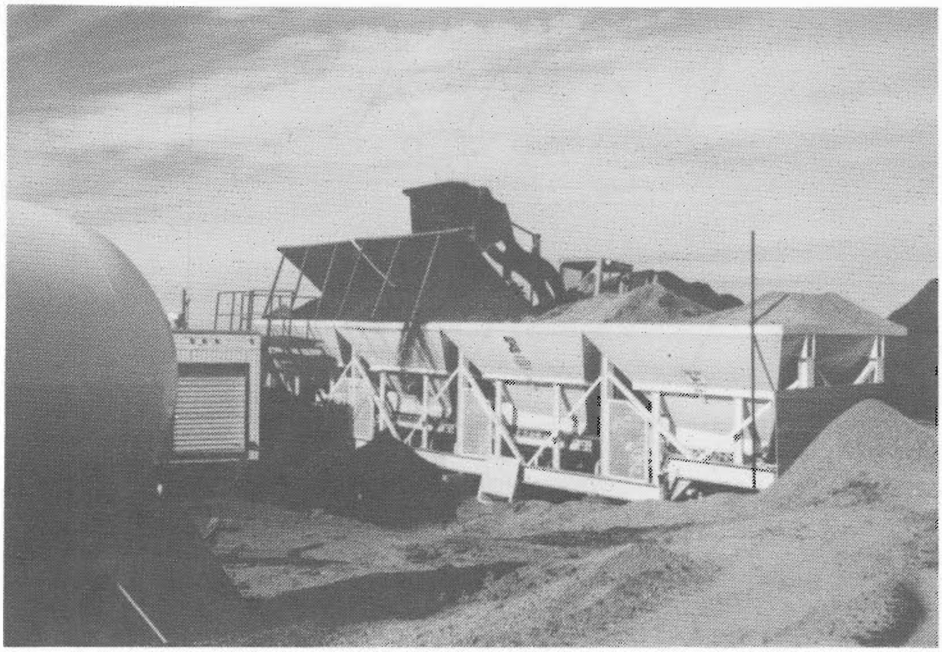


Figure 4.19. Combined new and reclaimed material cold feed bins.

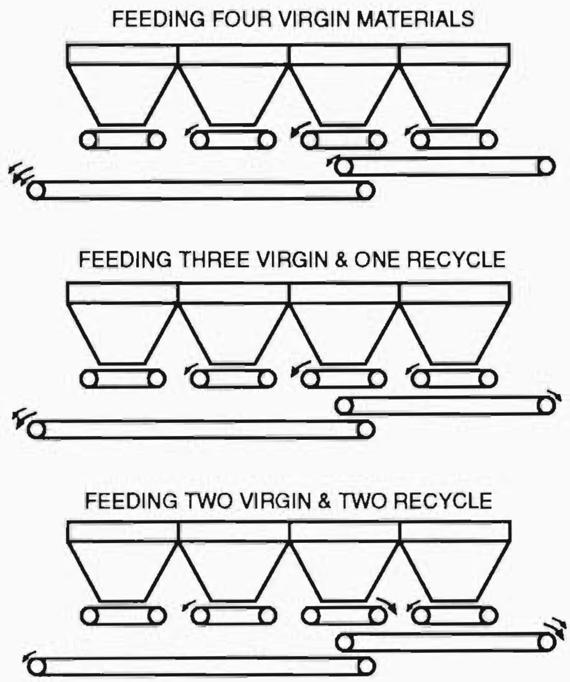


Figure 4.20. Conveyor under cold feed bins (Ref 20).

CHAPTER 5. ASPHALT CEMENT SUPPLY SYSTEM

The asphalt cement supply system consists of storage tanks and a pump metering system.

5.1 STORAGE TANKS

Most asphalt cement storage tanks are heated with a hot oil system (Fig 5.1). A small burner is used to heat and maintain the temperature of the heating oil, which is circulated through a series of coils inside the asphalt cement storage tank (Fig 5.2). The heat is then transferred from the oil, through the coils, to the asphalt cement (Fig 5.3). This heat transfer process causes the asphalt cement to flow and causes new, lower temperature asphalt cement to come in contact with the heating coils. Thus the hot oil system maintains the proper temperature of the asphalt cement, generally in the range of 300°F to 350°F, depending on the grade and type of asphalt cement being used.

All storage tanks should be completely insulated and heated, and all the lines for both asphalt cement and heating oil should be jacketed to prevent loss of heat. The discharge line for the asphalt cement should be located near the bottom of the tank, as should the line used to fill the tank from the asphalt cement transport truck or rail car. The return line from the pump should be located so that the asphalt cement enters the tank at an elevation beneath the surface level of the asphalt cement stored in the tank and does not fall through the air (Fig 5.4).

If the asphalt mix plant is equipped with more than one asphalt cement storage tank, the capability normally exists to pump material from one tank to another. Thus the piping is available to circulate asphalt cement within one tank or from one tank to another. It is important that the plant operator be aware of which tank he is pulling material from, especially if more than one grade or type of asphalt cement is being stored in different tanks.

All asphalt cement storage tanks contain a "heel" of material at the bottom of the tank. This asphalt cement, located beneath the heating coils, does not circulate efficiently. The volume of material in the "heel" depends on the type and style of the storage tank, the location of the heating coils, and the amount of time since the tank was last emptied and cleaned. It is recognized, however, that some asphalt cement will typically remain in the bottom of an "empty" tank. Further it should be noted that mixing of two different types as two different grades of asphalt cement can cause an alteration of the properties of the asphalt such that it no longer meets specifications.

The capacity of an asphalt cement storage tank can be calculated from its diameter and length measurements. The amount of material in the tank at any particular time can be determined by measuring the depth of the asphalt cement using a tank stick. The stick or rod is marked in inches and is lowered into the tank through a port in the top of the tank to the top of the asphalt material. The distance from the port to the asphalt cement is read from the stick. A calibration chart, supplied with the tank by the manufacturer, is used to convert this distance to the top of asphalt cement to volume.

Asphalt cement expands slightly when heated. Thus the volume of asphalt cement at 325°F will be somewhat greater than its volume at 275°F and significantly greater than the volume at 60°F. For standardization purposes, all asphalt cement volumes are measured at 60°F, using conversion charts which are based on the specific gravity of the asphalt cement (Ref 28). If the specific gravity of the asphalt cement and its temperature are known, the volume measure at the elevated temperature can be easily converted to the "standard" volume at 60°F.

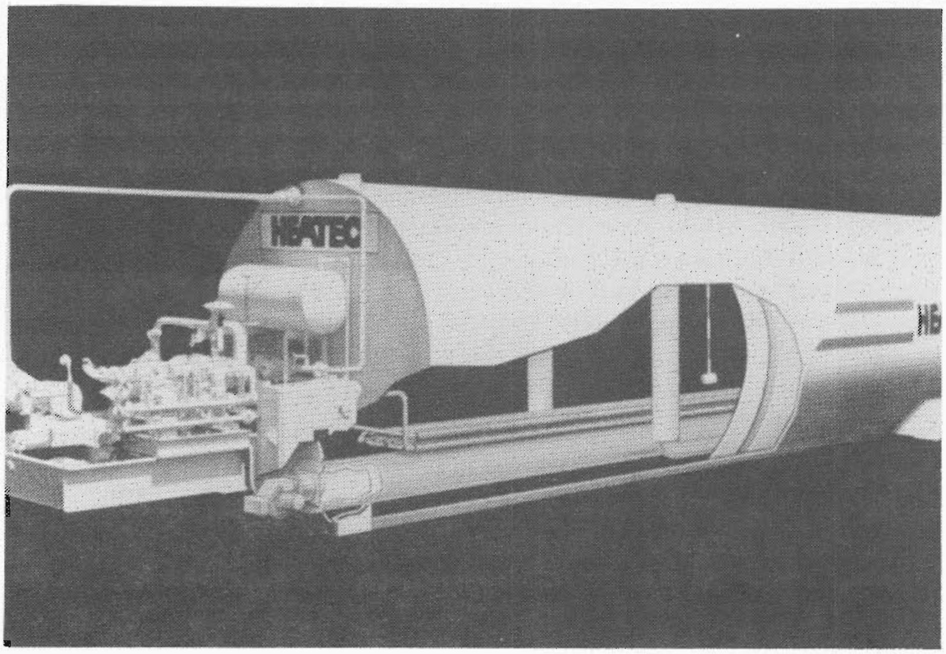


Figure 5.1. Asphalt cement storage tank (Ref 21).

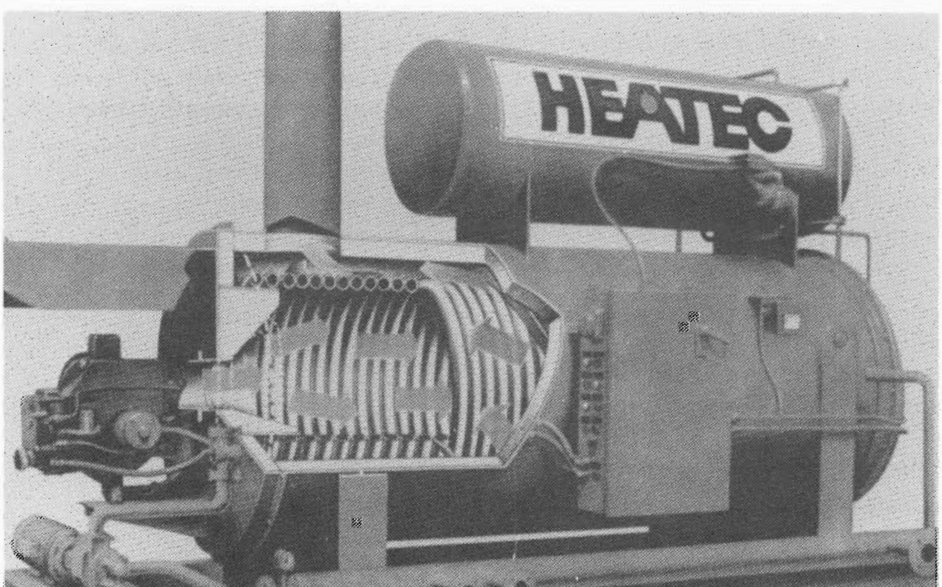


Figure 5.2. Asphalt cement storage tank with helical coil hot oil heater (Ref 21).

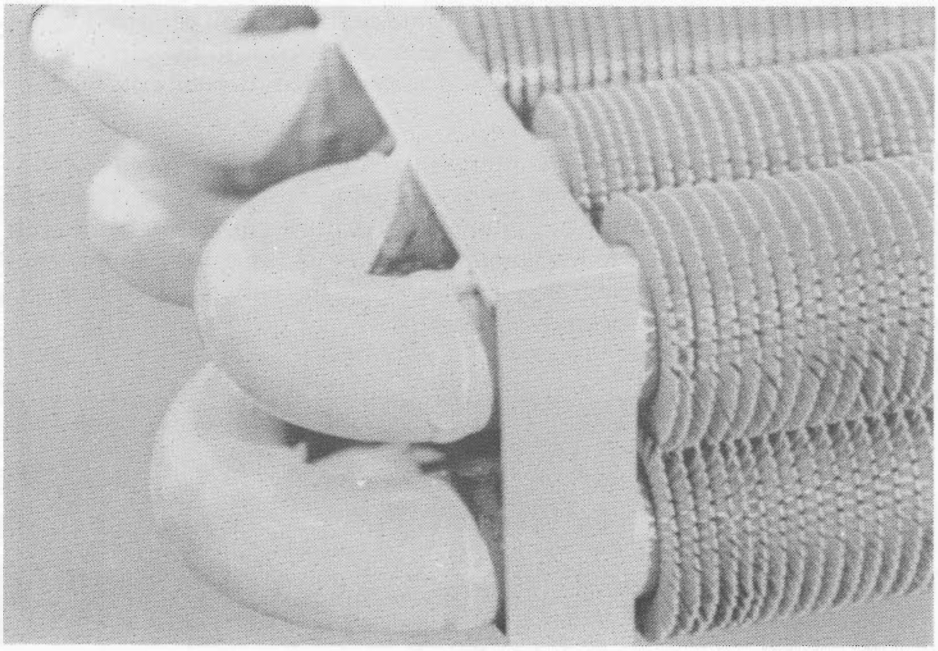


Figure 5.3. Heat transfer coils (Ref 21).

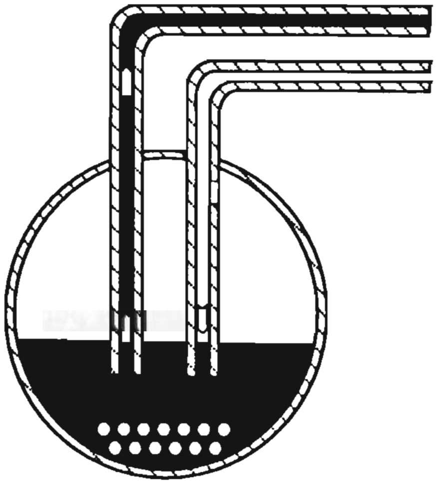


Figure 5.4. Asphalt return line (Ref 12).

5.2 PUMP AND METER SYSTEM

The asphalt cement is pulled from the storage tank by a pump (Figs 5.5 and 5.6). It is sent, in part, through a meter which measures the volume. The asphalt cement is then transported through a pipe to the drum mixer. It is also returned, in part, to the asphalt cement storage tank. The exact functioning of the pump and meter system depends on the type of system employed.

One system uses a variable volume pump driven by a constant speed electric motor. The amount of asphalt cement drawn from the storage tank is controlled by changing the volume of material pulled by the pump. The volume needed at the pump is determined by the plant computer and is in proportion to the amount of aggregate being fed into the drum mixer. As the amount of aggregate entering the plant increases, the volume of asphalt cement pulled through the pump also increases, and vice versa.

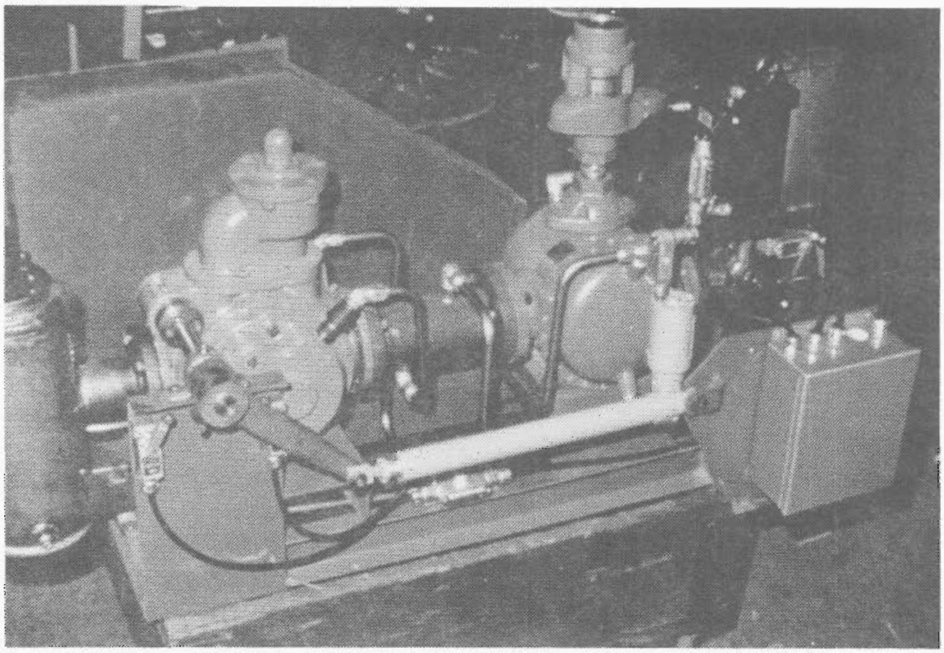


Figure 5.5. Typical asphalt pump (Ref 18).

When the plant is not using asphalt cement, the material continually passes through the pump and meter and through a valve which is set to circulate the asphalt cement to the storage tank instead of to the plant. The meter automatically puts the asphalt cement into the recirculate mode whenever the aggregate supply is shut down. During operation, the plant controls continually monitor the aggregate feed rate and proportion the variable volume pump accordingly.

A second system incorporates a fixed displacement pump driven by a hydraulic motor, which is in turn driven by a constant speed electric motor. A valve system is used to vary the rate of flow of the hydraulic fluid, thus controlling the quantity of asphalt cement delivered to the meter and then to the drum mixer. The amount of material sent to the plant is dependent on the aggregate feed rate, with the volume supplied increasing as the amount of aggregate charged into the drum mixer increases. A valve in the system downstream of the meter allows the asphalt cement to be circulated back to the tank when not needed by the plant.

A third commonly used asphalt cement supply system consists of a constant volume pump driven by a constant speed electric motor. In this setup, the same volume of asphalt cement is pulled from the storage tank at all times. A proportioning valve is placed in the line between the pump and the asphalt cement meter. The position of the valve determines the volume of material sent through the meter. The proportioning valve sends some of the asphalt cement through the meter and the rest back through the recirculate line to the storage tank. The system also has a valve downstream of the meter which allows the asphalt cement sent through the meter to be circulated to the tank. This valve is needed during the warm-up period for the meter and during the calibration process. Again, the position of the proportioning valve is determined by the aggregate feed rate into the drum mixer.

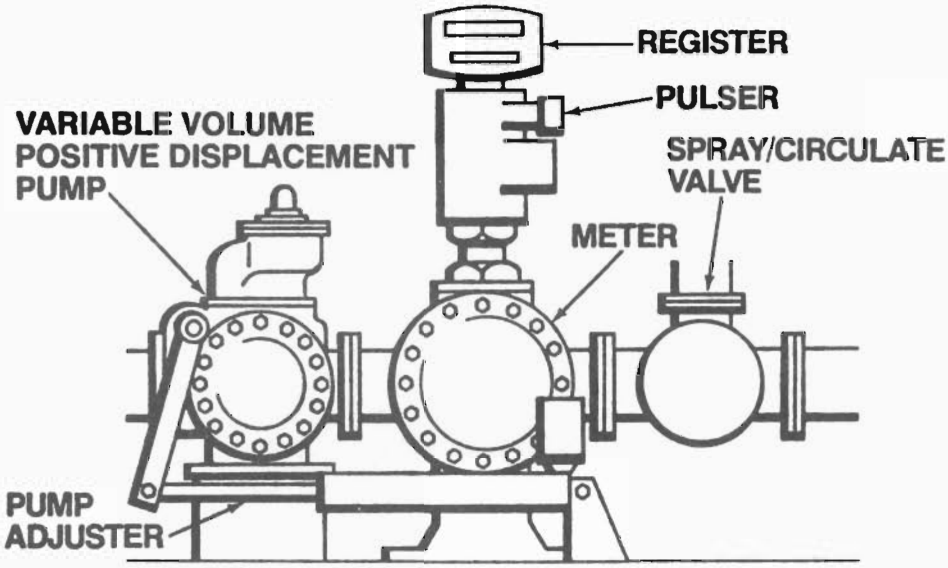


Figure 5.6. Schematic of asphalt pump system (Ref 18).

The volume of asphalt cement moving through the meter changes with temperature. Some meters are set to measure the temperature of the asphalt cement moving through them and to send the data together with the volume information to the plant computer. The specific gravity of the asphalt cement is set manually in the controls. The computer then calculates the volume of asphalt cement, at the standard temperature of 60°F, being fed to the plant.

On some meters, a temperature-compensating device is installed directly on the meter stand itself. As the temperature of the asphalt cement changes, the meter senses the change and, based on the specific gravity of the asphalt cement, calculates the volume of asphalt cement at 60°F passing through the meter. This corrected volume is then sent to the plant console for display.

Regardless of the system employed, the asphalt pump system must be capable of changing the volume of asphalt cement sent through the meter in direct response to the demand of the aggregate supply. The response of the pump must be directly related to the change in the amount of material measured by the aggregate weigh bridge system. In addition, the volume of asphalt cement measured at any given temperature must be converted to the volume of asphalt cement at 60°F. At this standard reference temperature, the weight of the asphalt cement can be determined in terms of tons of material per hour, the same as for the aggregate feed rate. The total of the aggregate input (new aggregates and, if used, reclaimed aggregates) and the asphalt cement weight provides the production rate for the drum mixer, in tons of asphalt concrete per hour.

CHAPTER 6. PLANT CALIBRATION

For all drum mix plants, it is necessary to calibrate both the aggregate and the asphalt cement feed rates (Figs 6.1 and 6.2). This should be done periodically to assure that the amount of material processed through the plant is correct. The calibration process should be carried out when the plant is relocated. It should also be done when the plant has been shut down for a relatively long period of time, such as a month or more or over the winter. Finally, the plant should be recalibrated when there is reason to believe that some aspect of the system is operating erratically, such as abnormal variations in the aggregate gradation or the asphalt cement content.

Because of the differences in the aggregate weigh bridge systems employed by the various plant manufacturers, it is difficult to discuss all the small variations which can occur in the calibration procedure. The following comments, therefore, are general in nature but should be applicable to most drum mix plants. The plant operation and calibration manual for each particular make and model of drum mixer should be consulted for the exact calibration process to be used on an individual plant.

6.1 A NOTE OF CAUTION

The calibration procedures outlined require the use of a truck scale to measure the amount of aggregate which passes over the weigh bridge and the amount of asphalt cement which passes through the asphalt meter. It is usually assumed, often incorrectly, that the weight measured by the truck scale is totally accurate. In addition, the weight measured is often taken as an absolute value, without variation. These assumptions can cause a considerable amount of difficulty in calibrating the plant. Indeed, often the belt scale and asphalt meter are more accurate than the truck scale used for comparison purposes.

In summary, in calibrating either the belt scales or the asphalt cement meter on a drum mix asphalt plant, the comparison value determined through the use of a truck scale must be treated as a variable value rather than as an absolute and exactly correct number. This consideration will eliminate the usually incorrect conclusion that the accuracy of either the belt scale or the asphalt cement meter is suspect when both devices may be operating properly.

6.2 WEIGH BRIDGE CALIBRATION

The weigh bridge system, located on the incline charging conveyor and/or on the individual cold feed bin feeder conveyor, determines the quantity of aggregates being delivered to the drum mixer. The input value of the aggregate feed in turn determines the amount of asphalt cement pumped to the plant. Thus, the belt scale must be calibrated by comparing the weight measured by this scale with the weight determined using a scale of known accuracy. Usually, this latter device is a truck scale which has been checked and certified by the appropriate state or local governmental agency.

Before any calibration is attempted, the conveyor belts on the drum mix plant should be operated for a minimum of 20 minutes in an unloaded condition. This warm-up period is important for several reasons. First, it allows the controls to heat up and stabilize at operating temperature. It also allows the conveyor belts to stretch and sit on the idlers. Thus, the conveyors should be run for at least 20 minutes before the calibration procedure is started. The warm-up period requirement is also used for normal daily start-up operation.

In order to properly calibrate the weigh bridge scale, a number of items are needed: (a) a dump truck, (b) a certified truck scale, and (c) scale test weights. The calibration should not be carried out on windy or rainy days since these environmental conditions can affect the accuracy of the weight measurements. Normally, the aggregate feed rate can be measured by passing the aggregate over the weigh bridge and through a diverter chute at the top of the

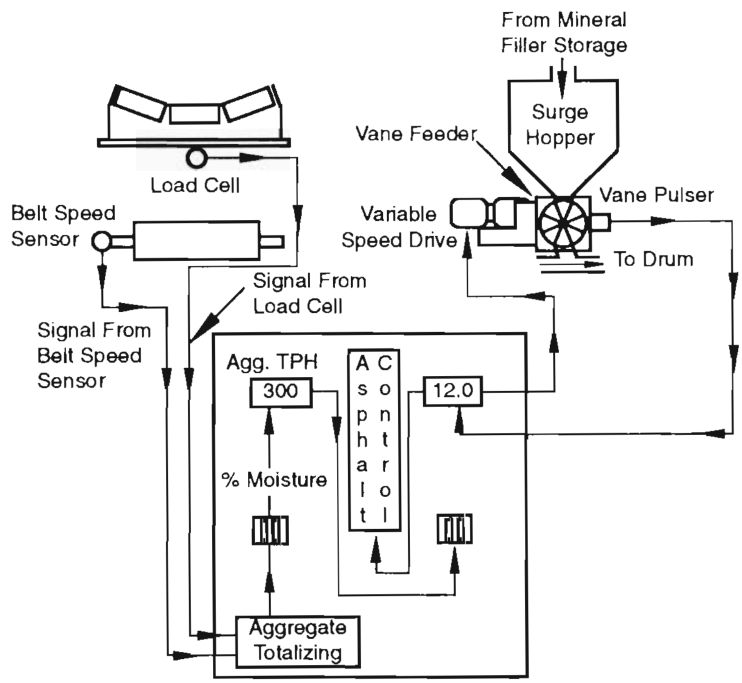


Figure 6.1. Schematic of aggregate feed system (Ref 18).

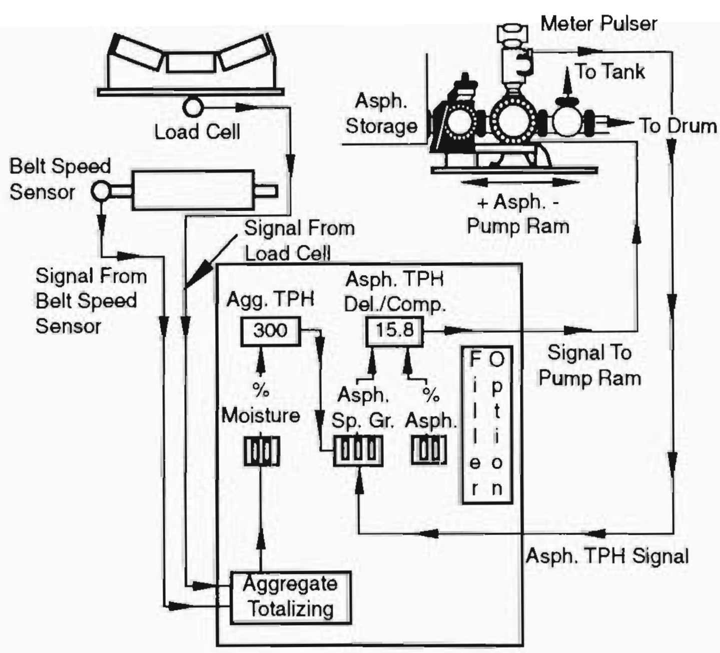


Figure 6.2. Schematic of asphalt feed system (Ref 18).

incline conveyor and into the dump truck (Fig 6.3). If the drum mix plant is not equipped with a diverter chute, it may be necessary to pass the aggregate through the drum and surge silo and then into the truck, although this process is not recommended.

The process of delivering the aggregates to be weighed directly to the truck from the top of the charging conveyor is the preferred and most accurate method. There is little chance to "lose" material from the conveyor if it is deposited in the truck through the diverter chute. If the aggregate is passed through the plant, multiple opportunities exist for a small amount of aggregate to be retained inside the drum, in the conveying equipment between the drum and the silo, and in the surge silo itself. Each loss of material affects the accuracy of the comparison between the belt scale reading and the truck scale weight. Thus, the aggregate should not be carried through the plant unless there is no means to divert the aggregates before entering the drum.

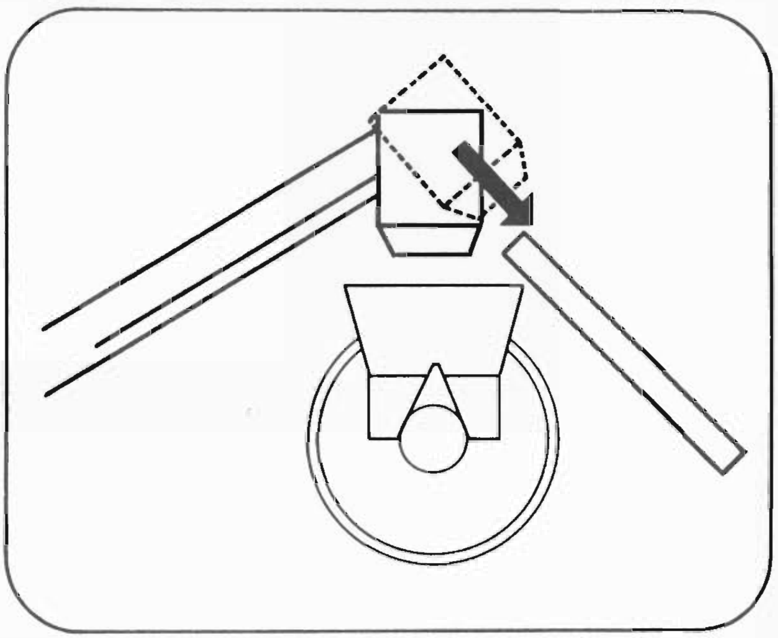


Figure 6.3. Schematic of calibration diversion chute (Ref 9).

The calibration procedure, test method TEX-920-K (reference 22), commences with the nulling or zeroing of the belt scale. With the conveyor belt running, the plant controls for the weigh bridge are adjusted to indicate a zero weight on the weigh idler. Some minor variation in the zero reading, both plus and minus, may be recorded due to irregularities in the conveyor system. But the average weight reading on the empty conveyor belt should be zero. Once the weigh bridge is nulled out (set to a zero weight), this adjustment control should not be changed again.

The empty truck used to collect the aggregate should be weighed on the certified truck scale. This tare weight should be kept as constant as possible during the calibration operation. The driver should either remain in, or out of the truck at all weighings. Nothing should be done to increase or decrease the tare weight. Thus, the truck engine should be shut off when the truck is stationary to keep the change in weight due to fuel consumption at a minimum. As a check, the tare weight should be measured again *after* the aggregate has been weighed and emptied from the truck bed. The average tare weight value should be used if the two weights are similar or an investigation should be made if the two readings differ by more than 0.4 percent.

Once the truck has been tared, the aggregate should be fed from one or more cold feed bins, across the individual belt feeders, onto the gathering conveyor, and then onto the charging or incline conveyor. At this time, the moisture content control should be set at zero percent. The rate of feed should be equal to the typical operating rate of the plant. Thus, if the drum mixer is to be run at an average rate of 350 tons per hour, the initial weigh bridge calibration should be carried out at that operating rate. The aggregate should be passed over the weigh idler and then be diverted into the waiting truck. As large a sample as feasible should be taken. If the truck is capable of holding 15 tons of material, a sample size approaching 15 tons should be used. All the aggregate passing over the belt scale should be deposited in the truck.

The amount of aggregate measured by the weigh bridge should be recorded and compared to the net weight of the material calculated from the truck weights. If the two values are within the required tolerance (see above discussion on allowable tolerances), the weigh bridge system is in calibration. If the two weights are out of tolerance, an adjustment needs to be made to the weigh bridge controls to move the weight measurement into compliance.

Most drum mix plants are equipped with a span control on the belt scale. Following the calibration instructions supplied by the plant manufacturer, the span control should be adjusted to a new setting, upward or downward, by a calculated percentage of the difference in the two weight readings. The cold feed bin feeder conveyors should then be started again and the aggregate passed over the weigh bridge and into the truck. If the truck aggregate weight and the belt scale weight is within tolerance, the initial calibration process is finished. If not, another adjustment is made in the span control setting, and the procedure repeated once again.

Once the belt scale has been calibrated, the weigh bridge can be checked periodically by hanging test weights on the weigh idler. The test weights are used to simulate a load traversing the weigh idler. The charging conveyor is started once the test weights are in place. A stop watch is used to measure a period of time the incline conveyor is run, usually five to ten minutes. The value of the test weights multiplied by the conveyor time is used to calculate the simulated number of tons per hour of material passing over the weigh bridge. This calculated value should be compared to the number shown on the plant control console. Thus the test weights can be employed as a quick check for the weigh bridge calibration.

The test weights can also be used to verify the operation of the moisture content control on the plant. With the test weights in place, the moisture content value should be initially set at zero. This value should then be increased, indicating some moisture in the aggregate. The dry weight of the aggregate displayed on the console should decrease in proportion to the amount of moisture dialed in. For example, if the 0 percent moisture content feed rate is 350 tons per hour, a setting of 3 percent moisture on the dial should decrease the dry weight value shown by 3 percent, or to approximately 340 tons per hour.

6.3 COLD FEED CALIBRATION

Once the weigh bridge calculation is completed, the belt feeders under each cold feed bin must be calibrated. This is done by determining the amount of material delivered from a bin for different gate openings and different belt speeds. It is important, however, that the feeder conveyor operate within a range of 20 to 80 percent of its maximum speed. Ideally, the gate opening on each individual cold feed bin should be set so that the belt feeder will operate near the midpoint of its speed range under normal production circumstances.

To begin the calibration procedure, the maximum production rate to be run by the drum mixer should be determined. Next the relative proportion of each particular aggregate size for each cold feed bin is calculated. The percentage of each aggregate is then converted to a ton per hour rate. From experience, a gate setting is selected which, should provide enough material from a bin to meet the required maximum feed rate. For a given gate opening, three different belt speeds are used. These usually are 20, 50, and 80 percent of the maximum feeder belt rate, but other speed percentages can be used as long as they cover a range of values.

The moisture content setting for the aggregate is set at 0 percent, and the belt feeder under one bin is started. The aggregate from this bin is discharged onto the belt feeder running at the preselected calibration speed. The aggregate is delivered to the gathering conveyor and then to the incline conveyor. It is run over the weigh bridge on the charging conveyor and the amount of material delivered for each feeder conveyor belt speed is determined from the plant computer system. The weight of material at a given belt speed is then plotted on a graph against the belt speed to determine the amount of aggregate to be drawn for a particular bin with a given gate opening at any feed belt speed (Fig 6.4).

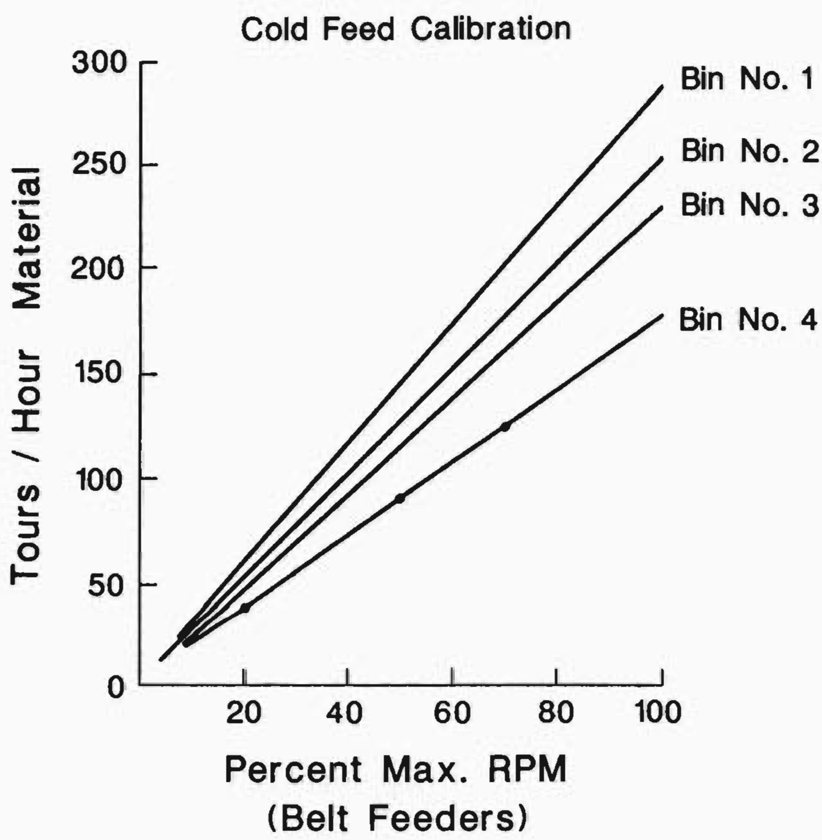


Figure 6.4. Example cold feed calibration plot (Ref 12).

From the graph, a belt speed setting is chosen that allows the proper amount of aggregate for that particular bin to be discharged to meet the required ton-per-hour rate. If the speed selected for the bin is too slow to be practical, a smaller gate opening should be selected and the calibration procedure repeated for the new gate setting at least three different feeder belt speeds.

Because most drum mix plants are usually operated near their maximum capacity, at a given aggregate moisture content, it is good procedure to select an operating belt feeder speed at the upper end of the speed range, between 50 and 80 percent of the maximum belt speed. This will allow the plant operator to reduce the plant production rate without shutting the plant down because the belt feeder cannot run slowly enough to meet the lower production rate. Thus, given a choice of a belt speed of 40 percent at one gate setting and 70 percent at a smaller gate setting, the logical solution would be to choose the gate opening which allows the higher belt speed, not to exceed 80 percent of maximum.

Each cold feed bin is calibrated in the same manner. This includes calibration of the cold feed bin or bins holding the reclaimed material to be used in a recycled asphalt concrete mixture. For cold feed bins equipped with their own weigh idler and weigh bridge system, the cold feed bin would be calibrated using the same method as for the weigh bridge located on the incline conveyor, rather than with the variable belt speed method outlined above.

6.4 ASPHALT CEMENT SUPPLY CALIBRATION

In order to calibrate the asphalt cement supply system, test method Tex-921-K (Ref 22), an asphalt distributor truck is needed. It must be assured that the tank on the distributor is clean so that the asphalt cement can be pumped back into the asphalt cement storage tank. In addition, if the distributor has been used for either cutback asphalt or asphalt emulsion, those materials must be removed from the distributor tank to prevent the contamination of the asphalt cement and foaming of the emulsified asphalt. The distributor tank should have enough capacity to hold at least 1,000 gallons of asphalt cement.

The tare weight of the distributor should be determined by running the truck over a certified scale. The asphalt pump and valve system should be able to be set so that the asphalt cement can be passed through the meter and then through a sample valve downstream of the meter. A flexible line is then used to transport the asphalt cement to the distributor tank.

The asphalt cement should be initially circulated through the pump and meter and then back to the storage tank to bring the system up to the proper operating temperature. When the temperature has stabilized, the pump should be shut down and the valves set to allow the asphalt cement to enter the line to the distributor. Enough asphalt cement should be pumped into the line to just fill the line, without emptying any asphalt cement into the tank. The meter on the asphalt cement line should then be set to a zero reading. The pump is then activated once again, and at least 1,000 gallons of asphalt cement is delivered to the distributor.

The asphalt pump is shut off and the meter reading determined. The pump is then reversed to pull back all the asphalt cement left in the line. The distributor is weighed and the net weight of the asphalt cement calculated. This value is compared to the weight reading on the computer console. The two readings should be within 0.4 percent of each other. If the asphalt meter reading and the net weight of the asphalt cement in the distributor are within 0.8 percent of each other, the meter value is probably accurate. Indeed, in most cases the asphalt cement reading is more exact than the truck scale supplied value.

6.5 AGGREGATE ASPHALT CEMENT RATIO

The last function in the calibration procedure is to assure that the asphalt cement and the aggregate feeds are in proper proportion to each other (Fig 6.2). To accomplish this, the asphalt cement pump and meter system are put in the circulate mode, with the asphalt cement passing through the meter. Next the test weights are placed on the weigh idler on the incline conveyor, and the conveyor system warmed up for at least 20 minutes. In this process, no actual aggregate is used, only the test weights to simulate the presence of material on the conveyor belt.

The asphalt content control is set on the console to any selected percentage. The amount of asphalt cement needed for the preset aggregate feed rate is calculated and compared to the actual rate of asphalt cement feed shown on the meter. If the values agree, the whole calibration procedure is completed. If the values are different, an adjustment should be made in the asphalt supply system, according to each particular plant manufacturer's requirements. Then the aggregate/ asphalt cement ratio calibration procedure is repeated.

CHAPTER 7. CONVENTIONAL DRUM MIXERS

7.1 AGGREGATE ENTRY

The new aggregate to be incorporated into the asphalt mixture is discharged from its respective cold feed bin to its individual feeder conveyor, to the gathering conveyor under all the cold feed bins, through a scalping screen, and to the charging conveyor for delivery to the drum mixer. Upon reaching the end of the charging conveyor, the aggregate is typically introduced into the drum in one of two ways, through an inclined chute or on a slinger conveyor.

Inclined Chute

If the aggregate is carried on the charging conveyor to a point above the plant burner, the aggregate is fed into the drum by sliding down a sloped chute into the drum (Fig 7.1). The chute is angled to slide the aggregate toward the far end of the drum, away from the burner flame. The aggregate feed is by gravity, with the incoming material falling to the bottom of the drum.

Slinger Conveyor

On some drum mix plants, the new aggregate is deposited from the charging conveyor to another conveyor located beneath the plant burner. This belt (slinger) conveyor transports the aggregates into the drum (Fig 7.2). On many plants, the speed of this conveyor can be varied, and thus the point at which the aggregate falls into the bottom of the drum can be altered within limits. The faster the speed of the slinger belt, the farther down the drum the aggregate is deposited. The slinger conveyor belt speed is usually increased when reclaimed aggregate being jointly fed into the burner end of the drum with the new aggregate.

7.2 FLIGHT DESIGN

The aggregate fed into the burner end of the drum mix plant moves down the length of the drum by gravity and by the flights as the drum rotates. The time it takes for an individual aggregate particle to pass through the drum depends on many factors. Among these factors are the length of the drum, the slope of the drum, the number and type of flights inside the drum, the speed of rotation of the drum, the size of the aggregate particles, and the production rate of the plant. In general, it takes about 3 to 5 minutes for the incoming aggregates to reach the discharge end of the drum mixer.

Flight design is an art, not a science. Each drum plant manufacturer uses a different pattern, shape, number, and location for the flights inside the drum. Each has reasons why a particular series of flights is needed to better heat and dry the aggregate in the drum. The flight design used yesterday by one given manufacturer is probably not the same as the flight design incorporated into a drum made today and probably will not be similar to the design of the flights used on a drum mix plant produced tomorrow. Interestingly, even with the numerous flight design variation used in drum mix plants, the aggregate does get heated and dried by all of the various types of plants.

On a drum mix plant, the burner is located at the upper end of the drum, at the same location as the incoming new aggregate. Compared to the burner on an aggregate dryer in a batch plant where the flame is long and thin and extends well into the dryer, the burner flame on a drum mix plant is typically short and bushy and does not extend very far down the drum (Figs 7.3 and 7.4). The exhaust gases from the burner move in the same direction as the aggregate, a parallel flow process (Fig 3.1). This flow is in contrast with the operation of a batch plant dryer, which heats the aggregates using a counterflow principle in which the burner exhaust gases move in the opposite direction of the aggregate flow (Fig 3.2). On a

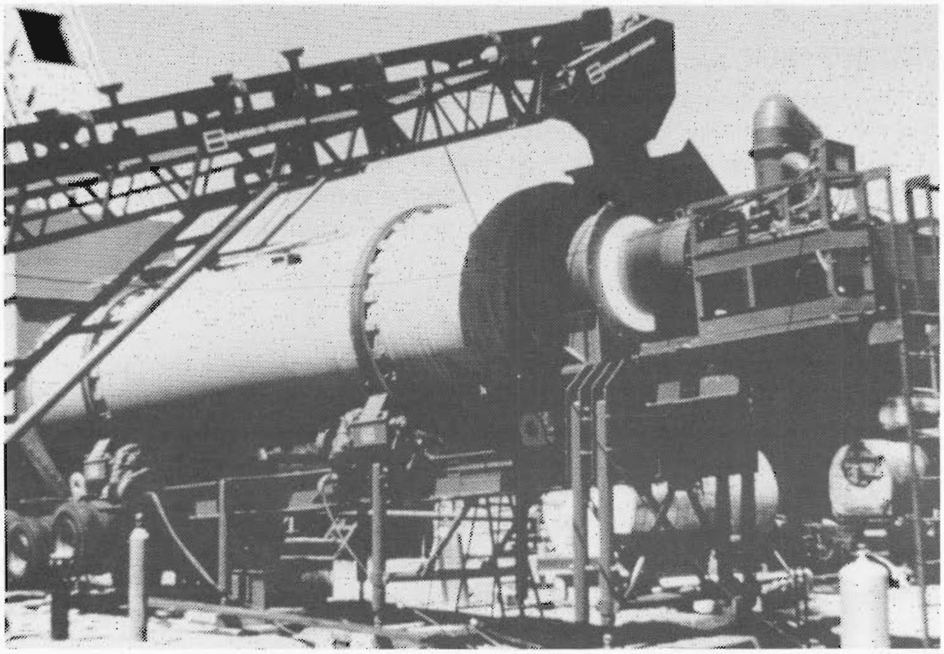


Figure 7.1. Introduction of aggregate into a drum mixer with an inclined chute (Ref 15).

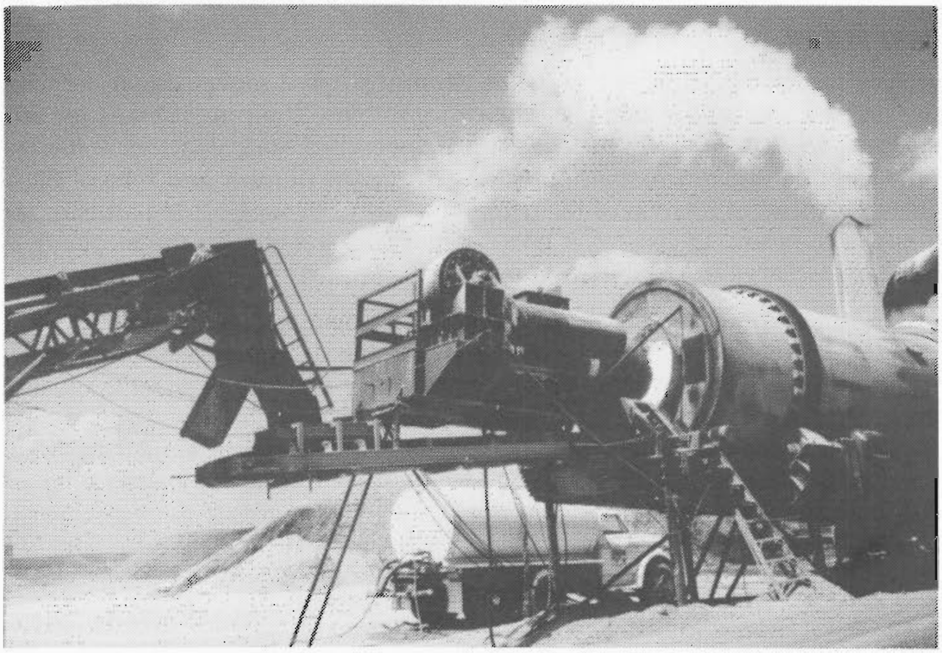


Figure 7.2. Introduction of aggregate into a drum mixer with a slinger belt.

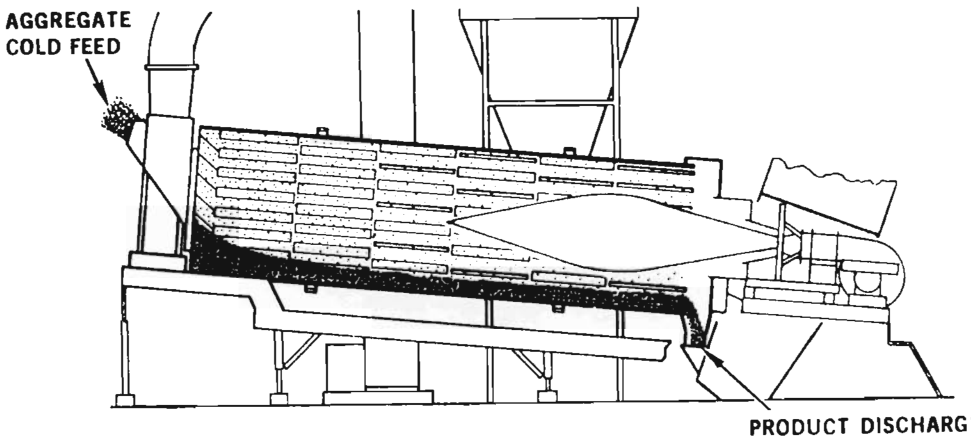


Figure 7.3. Aggregate dryer showing long flame (Ref 23).

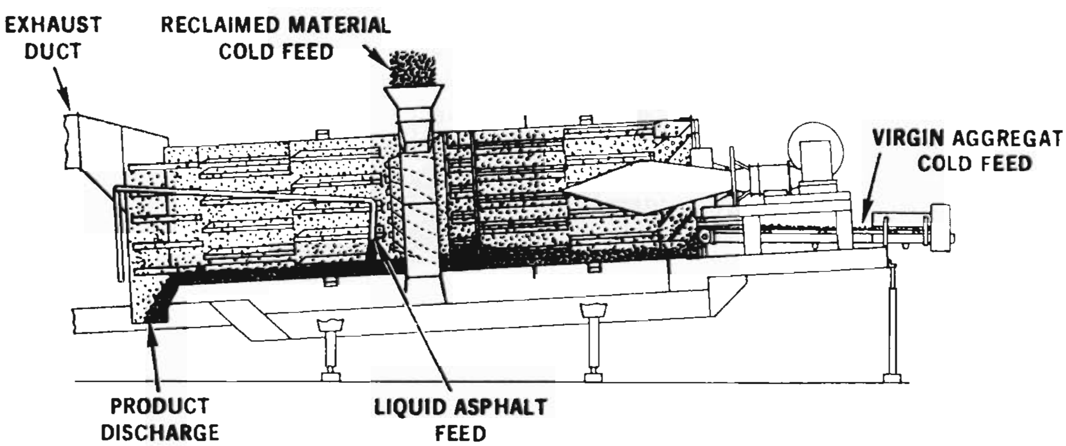


Figure 7.4. Drum mix plant showing short, bushy flame (Ref 23).

conventional dryer, the aggregate is introduced into the dryer at its upper end while the burner is located at the lower or discharge end of the dryer.

The first flights normally encountered inside a drum mixer are used to move the incoming aggregate away from the burner flame and down the drum (Figs 3.3 and 7.5).

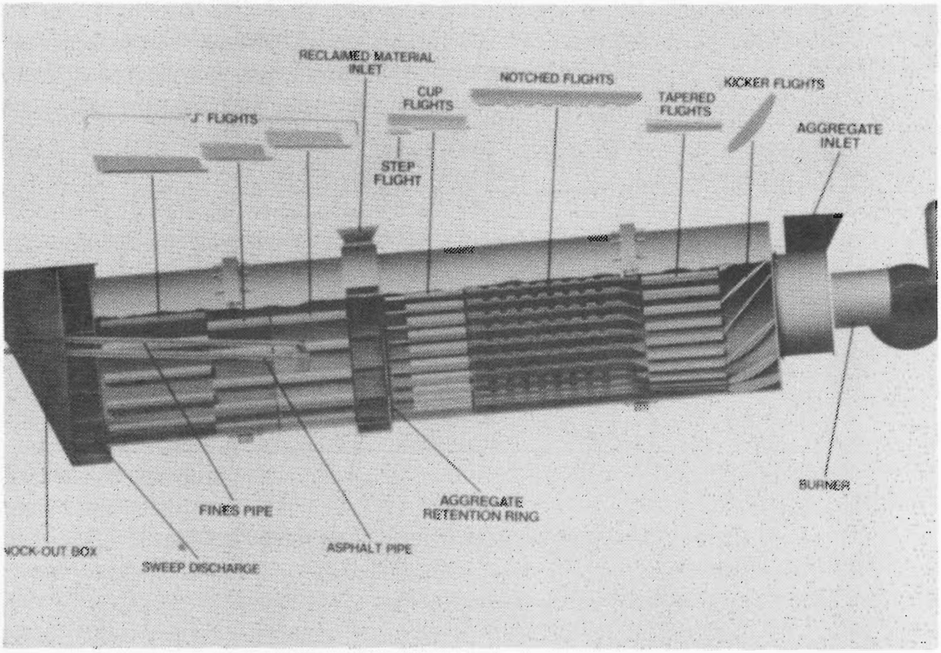


Figure 7.5. Flight configuration and locations inside a Barber-Greene drum mixer (Ref 10).

This procedure allows the burner flame to expand in the front part of the drum and radiate its heat as quickly and completely as possible. These initial flights do not lift the aggregate.

The next flights (cup, notched, and tapered flights in Fig 7.5) usually found inside most drums start to lift the aggregate from the bottom of the drum and begin the cascading action. Only a portion of the total aggregate volume is caught and tumbled, but by the time the quarter point in the drum length is reached, most of the aggregate particles are being lifted from the bottom of the drum and carried up and over the top of the drum. The lifting, or cup flights, are used to build a veil of aggregate in front of the burner flame. The flights are designed so that a curtain of cascading aggregate is developed across the whole drum. This curtain is absolutely essential as a barrier for the burner exhaust gases so that the heat transfer process can take place.

The key to the heating and drying process with the aggregate is the density of the veil of material presented across the circumference of the drum. The more complete the veil of aggregate, the more efficient the heat transfer process. It is important to assure that, whatever flight design is used in the drum at this point, the cascading aggregate will be carried by the lifting flights in such a manner that some portion of the aggregate is tumbled through the exhaust gases at each point across the whole circumference of the drum.

Near the midpoint of the drum length some manufacturers have installed a number of different kinds of devices to retard the flow of the aggregate down the drum. In some cases a retention ring or "donut" is placed around the drum circumference. This ring or dam essentially reduces the diameter of the drum at this location. The aggregate moving downstream in the drum builds up in front of the ring. This creates a heavier or denser veil of material as the aggregate is tumbled. Instead of a retention ring, some manufacturers install "kicker" flights which intercept the aggregate and turn it back upstream. These special flights are angled such that they retard rather than enhance the flow of aggregate toward the discharge end of the drum. The reason for any of these types of devices is to assure a complete and heavy veil of aggregate near the drum midpoint to accomplish the transfer of heat from the burner gases to the aggregate.

On most drums, at some location just beyond the middle of the drum, the "mixing" type flights (J flights, Fig 7.5) are installed. These flights are used to blend the aggregate and asphalt cement together. The mixing flights are basically used to allow the aggregate particles to be properly exposed to the foaming mass of asphalt cement. These flights also continue to allow the asphalt-cement-coated aggregate particles to cascade across the exhaust gas airstream to complete the heat transfer process and raise the mix temperature to the desired level for discharge.

A set of discharge flights is located at the end of the drum. The style and shape of these flights is chosen to change the direction of the mix moving down the drum. The exact shape and angle of the discharge flights depends on whether the asphalt mixture exits the drum from the side or the end. The discharge flights occupy only a small section of the drum length immediately in front of the discharge chute.

The above description of the types of flights inside a typical drum mixer is very general in nature. This is because there really is no "standard" or uniform design. Thus, it is impossible to accurately describe the exact tumbling process for the aggregate and the asphalt concrete mixture which occurs inside all drum mix plants. Figures 7.6 through 7.10 illustrate some additional typical flight designs and the flow of material through the drum.

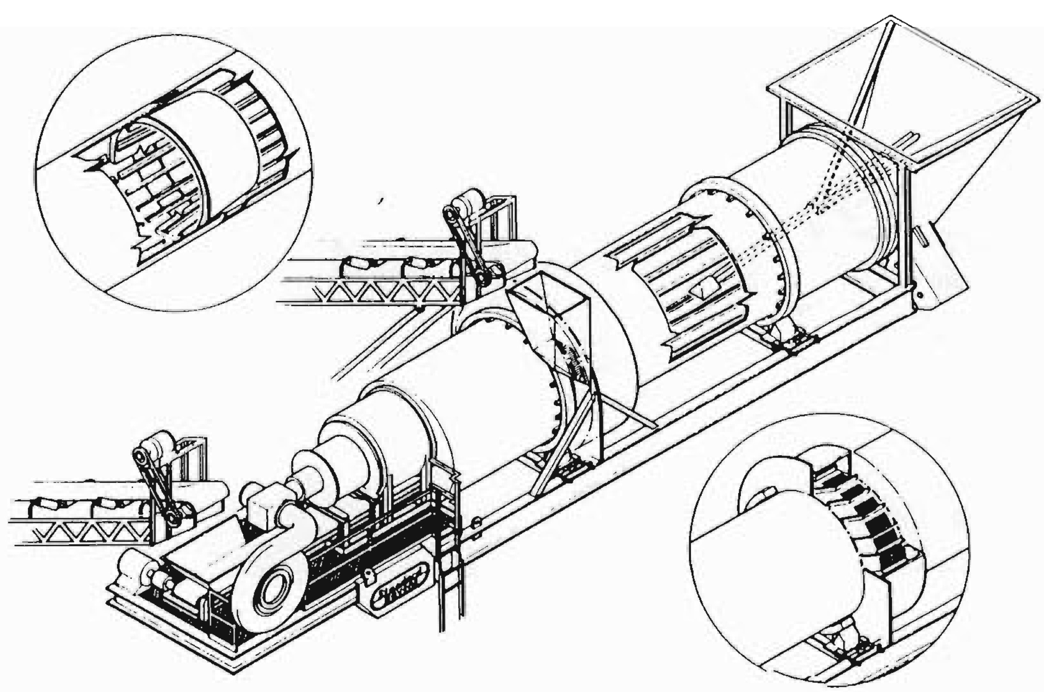


Figure 7.6. Cutaway views showing Standard Havens flights (Ref 24).

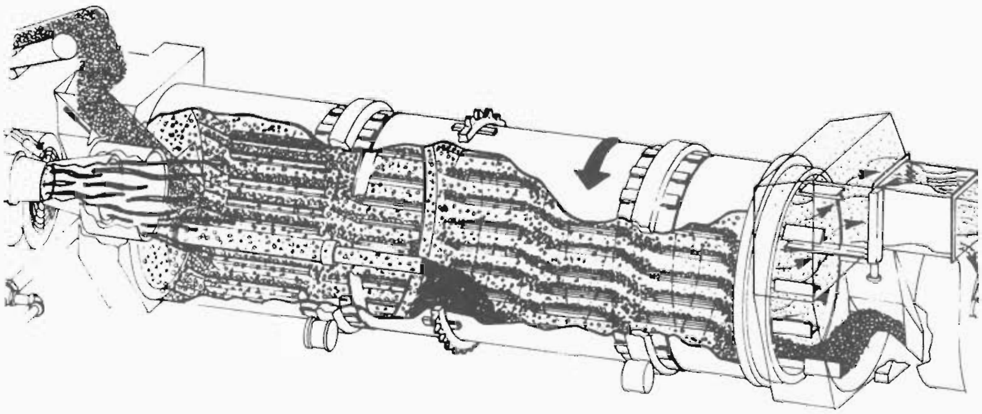


Figure 7.7. Flights and flow of material through a Cedarapids drum (Ref 25).

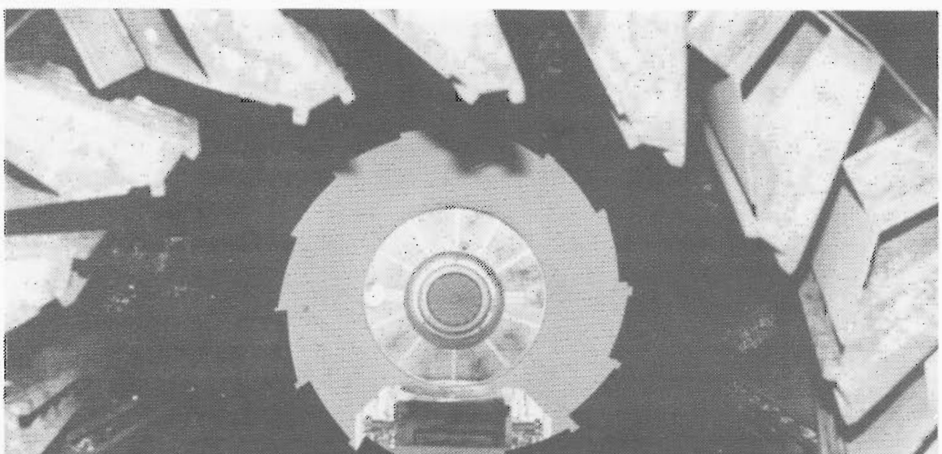


Figure 7.8. Cedarapids drum interior viewed from discharge end (Ref 25).

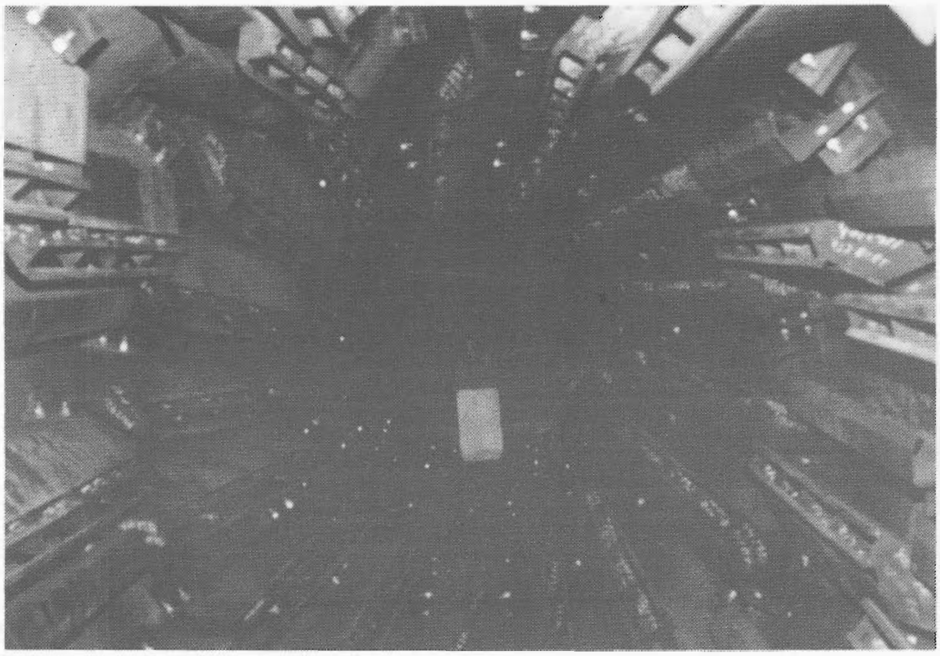


Figure 7.9. Cedarapids drum interior viewed from intake end (Ref 25).

7.3 BURNER SYSTEM

The purpose of the plant burner is to provide the necessary heat input to allow the aggregate to be heated and dried. Burners are sized in terms of output capacity by a Uniform Burner Rating Method, developed by the Bituminous and Aggregate Equipment Bureau of the Construction Industry Manufacturers Association (CIMA).

The burner rating method employs eight different criteria to calculate an output value or "maximum" rating for a burner. These eight criteria are: (a) 25 percent excess air, (b) 5 percent leakage air, (c) 10 percent casing (shell) loss, (d) 350°F fan gas temperature, (e) 5 percent moisture removed from the aggregates, (f) 300°F asphalt concrete mix discharge temperature, (g) the use of #2 fuel oil for burning, and

(h) an aggregate specific heat value of 0.2. The maximum amount of heat produced by the burner, in terms of Btu/hour is also dependent on the actual flow of exhaust gases through the drum, measured in cubic feet of gas per minute.

Thus, the ability of the burner to provide enough heat to properly heat and dry the aggregate is a function of the volume of exhaust gases moving through the drum, mix discharge temperature, stack temperature, amount of available excess air, draft system leaks, and combustion efficiency of the burner fuel. The maximum output for any particular burner can be determined from the burner rating plate attached to each burner.

Fuel

A wide variety of fuels can be used to fire a burner on a drum mix plant. Some burners are capable of burning several different fuels with only minor alterations in the burner settings. Other burners are only able to fire alternate fuels with more complex changes in the burner setup.

Three major types of fuel can be used in the drum mix plant burner. The first is gaseous fuels which includes both natural gas and vaporized LPG (liquid petroleum gas). The second

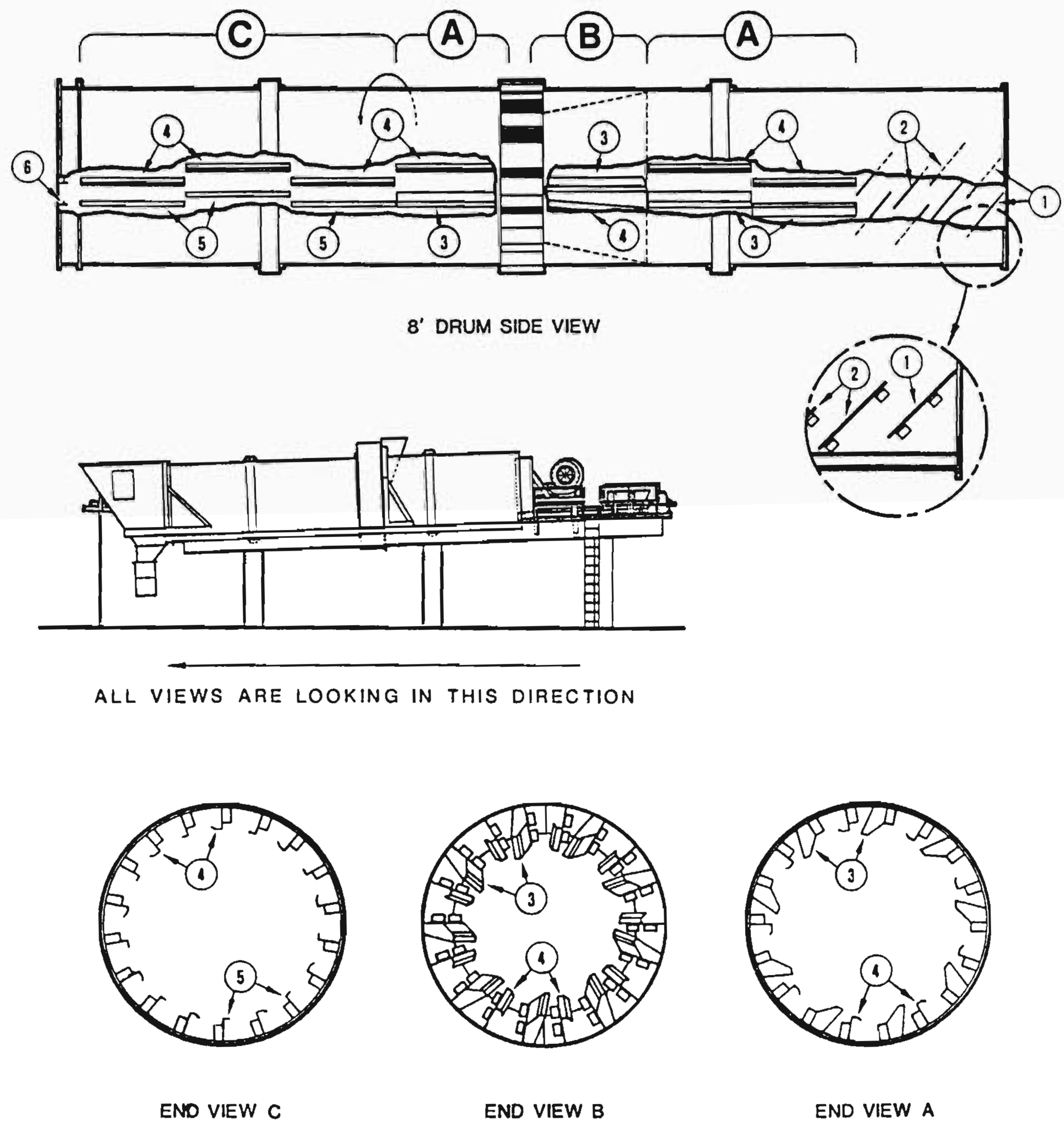


Figure 7.10. Standard Havens flight design (Ref 24).

type of fuel includes liquid materials such as propane, butane, fuel oil (#2), heavy fuel oil (#4 -#6), waste oil, and slurried coal. The third category includes solid fuels such as pulverized coal and pelletized biomass. Each of the above fuel types has its own particular heating benefits, disadvantages, and economic considerations, all of which should be considered when a fuel choice is made.

It is important that the fuel selected be at the proper consistency for complete atomization at the time of combustion. No. 2 fuel oil, for example, will typically burn at ambient temperatures, without preheating. This is because its viscosity at most temperatures is less than 100 ssu (saybolt seconds universal). Heavy fuel oils have viscosities which are above 100 ssu at normal ambient temperatures. Thus, these fuels *must* be preheated before burning to lower the viscosity of the material and obtain complete combustion. Fuel oils which are too viscous will not burn properly, creating burner and mix problems.

The use of waste oils in plant burners has become more prevalent as the cost of conventional fuels has increased. Some waste oils, those which have been filtered and dewatered, burn well. Other waste fuels, contaminated with heavy metals and containing water, burn erratically and incompletely. The sound of the burner provides important information as to the efficiency of the combustion process. A uniform, constant roar is a good sound. A coughing, sputtering, spitting burner is a sure sign of incomplete combustion.

Unburnt fuel can cause multiple difficulties. First, the fuel can coat the aggregate tumbling in front of the flame. This is evidenced by brown stains on the aggregate particles and a lack of asphalt cement coating on that aggregate. Second, the incomplete combustion reduces the amount of heat available to heat and dry the aggregate and increases fuel consumption. In addition, the unburnt fuel can increase the costs of maintenance on the burner and cause clogging of the nozzle. Finally, incomplete combustion can result in unburnt fuel entering the baghouse (if the plant is so equipped), coating and blinding the bags, thereby reducing the efficiency of the fabric filter to remove particulate matter from the stack gas discharge. In addition, such a coating on the fabric bags significantly increases the opportunity for a baghouse fire.

Burners

The burners used on most drum mix plants are hybrid burners. If the air used to burn the fuel is provided by a pressure blower, the burner is a forced draft unit (Fig 7.11). If air is pulled through the burner by an exhaust fan, it is called an induced draft burner (Fig 7.12). On most burners, some part of the air is forced through the burner. This is called "primary" air. Some of the air is induced through the burner and is called "secondary" air (Fig. 7.13).

A specific amount of air is needed to burn a given amount of fuel. A lack of either air or fuel will reduce the burning rate. Usually, the availability of air is the limiting factor. Typically, about 30 percent of the combustion air is primary air and 70 percent is secondary air. The exhaust fan, besides providing the induced air, must also handle the water vapor (steam) created in the drying process (Fig 7.14). Thus, the exhaust fan volume (size) is usually the controlling device in the heating and drying procedure.

The burner usually includes an automatic control which alters the fuel input to maintain a constant mix discharge temperature. Therefore, the balance of fuel usage and airflow is actually only in balance when the burner is operating at capacity. When the burner is running at less than full capacity, more air than needed is pulled through the system and heated. On the other hand, when the moisture content of the aggregates is high, less fuel can be consumed since the exhaust gas volume is constant and water vapor displaces air in the exhaust gas stream.

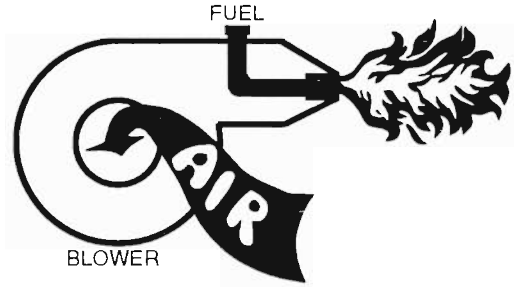


Figure 7.11. Forced air burner (Ref 26).

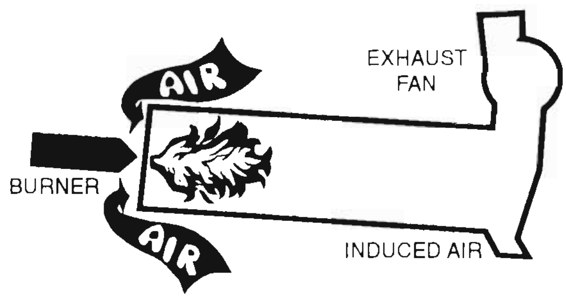


Figure 7.12. Induced draft burner (Ref 26).

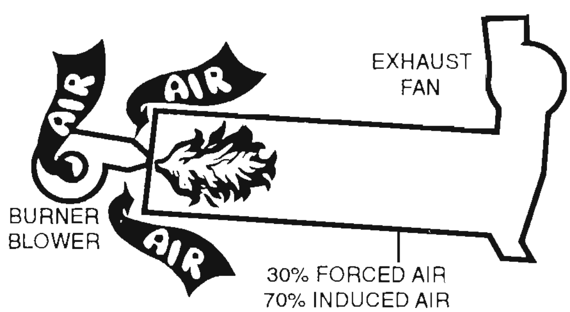


Figure 7.13. Combined forced and induced air burner (Ref 26).

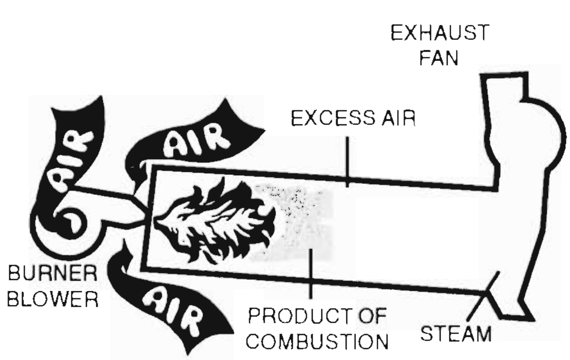


Figure 7.14. Burner products exhausted through the drum mixer (Ref 26).

The volume of air pulled through the drum is changed by the amount of air leakage. Any air entering the drum except at the burner reduces the efficiency of the combustion process. This leaked air, however, should not be confused with the "excess air" needed by the burner. The latter term refers to the amount of air in excess of that volume needed for complete combustion of the fuel. For most burners, up to 85 percent excess air might be needed to assure total burning of the fuel. As the amount of leaked air entering the drum increases, the efficiency of the heat transfer process is reduced because extra air is heated, reducing the amount of fuel which can be burned (keeping the total exhaust gas volume — product of combustion, water vapor or steam, and excess air — constant).

7.4 HEATING, DRYING, HEATING

The temperature of the burner flame exceeds 2,500°F. The temperature of the exhaust gases when they pass through the air pollution control equipment should be above the dew point and in the range of 250 to 375°F. Typical temperature profiles along the length of the drum are shown in Figure 7.15. The difference in the initial and discharge gas temperature represents the amount of heat that is used to dry and heat the aggregate inside the drum. The efficiency of the heating and drying process can be readily by the temperature of the exhaust gases going up the stack and the amount of moisture remaining in the asphalt concrete mixture.

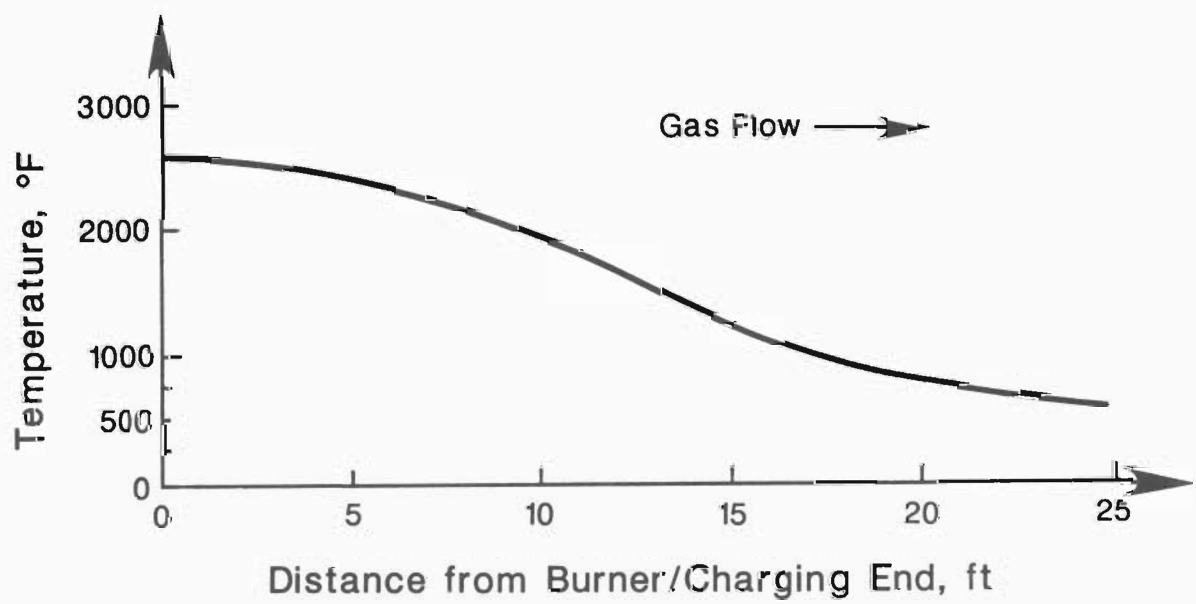


Figure 7.15. Typical temperature profile along the length of the drum (Ref 18).

Batch plant dryers typically were manufactured using a ratio of 4:1 for drum length versus drum diameter. A dryer that was 5 feet in diameter was usually 20 feet in length, and an 8-foot diameter dryer was normally made 32 feet long. Early drum mix plants used the same length to diameter ratio even though the heat transfer process was a parallel flow operation instead of a counterflow procedure. In recent years, there has been a trend toward the use of longer drums to better control and complete the heat transfer from the exhaust gases to the aggregate. This trend is also due in part to the use of drum mix plants to produce recycled asphalt concrete mixtures. Some drum mix plants manufactured lately use length-to-diameter ratios of 5:1 or even 6:1. Thus, an 8-foot diameter drum mixer might be 40 to 48 feet in length.

The length of the drum is not particularly important if all the heat possible is removed from the exhaust gases and used to dry and heat the aggregate and mix. Perfect heat transfer would require that the mix discharge temperature and the temperature of the exhaust gasses at the discharge end of the drum be equal. Excellent heat transfer (using all new aggregate with no reclaimed material) means that the temperature of the exhaust gases at the discharge end of the drum is within 20°F of the mix discharge temperature. Thus, if the mixture exits the drum at 280°F, and the exhaust gas temperature is under 300°F, the drum mixer is running efficiently. If the exhaust gases temperature, however, is 360°F while the mix discharge temperature is still 280°F, the veil of aggregate inside the drum is incomplete, and the drum is being operated very inefficiently.

Inside the drum, the temperature of the exhaust gases decreases as the gases move from the burner to the air pollution control ductwork. The rate of decrease depends on the amount of aggregate in the drum to intercept and cool those gases. In recycling, discussed in more detail below, it is desirable to lower the temperature of the exhaust gas to about 800°F, or less, at the midpoint of the drum where the reclaimed material is introduced (in most plants). This keeps the old, aged asphalt cement around the reclaimed aggregate from being incinerated and turning into blue smoke coming out the plant stack.

In addition, another internal temperature control point is the location where the asphalt cement is injected into the drum. It is known that certain asphalt cements may contain a small amount of "light ends" or materials which are volatile at elevated temperatures. The volume of the volatiles depends both on the source of the crude oil and the refining process used to produce the asphalt cement. If the temperature of the exhaust gases is below about 600°F at the place where the asphalt cement enters the drum, the volatiles or light ends will not be drawn off from the asphalt cement and minimal hydrocarbon emissions will result.

Thus, in terms of heating the aggregate, it is desirable to reduce the temperature of the burner gases to about 800°F at the drum midlength and to less than 600°F at the asphalt cement injection point. Further, the temperature of these gases should be lowered to the same level as the mix discharge temperature when these gases exit the plant stack. This temperature reduction profile can be achieved only by keeping a complete, uniform veil of aggregate tumbling in the drum upstream of the drum midpoint (Fig 7.16).

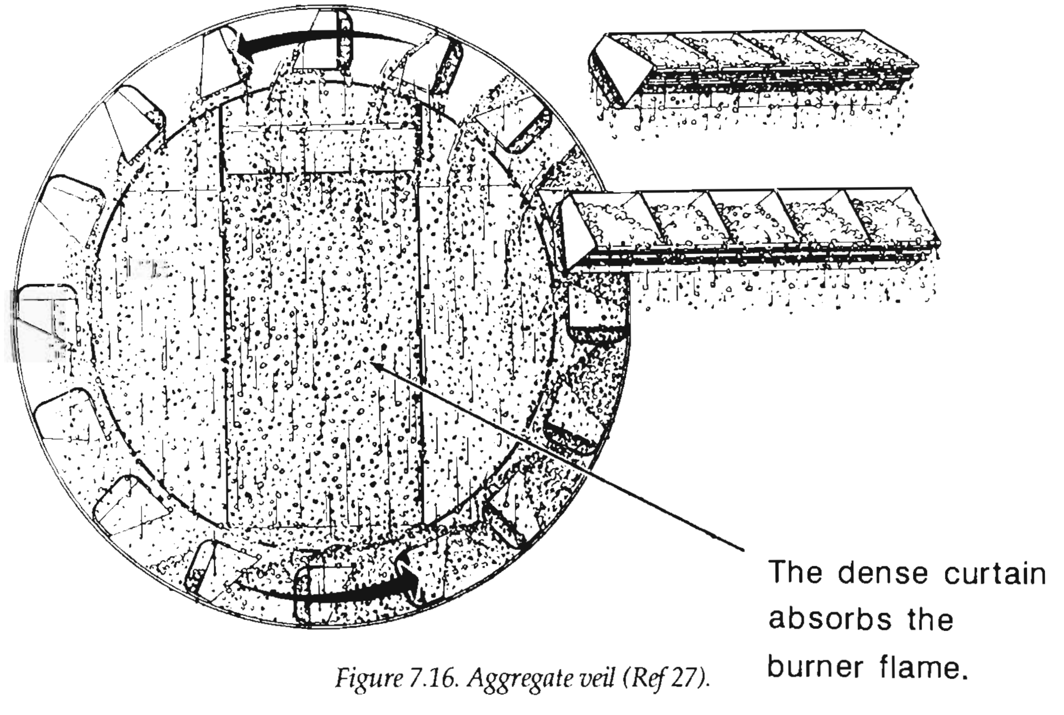


Figure 7.16. Aggregate veil (Ref 27).

To control the density of the aggregate veil inside the drum, kicker flights, dams, donuts, or retention rings are often used to retard the flow of the aggregate down the drum. Another way to achieve the same effect is to lower the slope of the drum (Figs 7.17 through 7.19). The decrease in the angle of the drum itself causes the aggregate passing through the drum to take a longer time to reach the discharge end of the mixer. This increases the dwell time in the drum, providing more time for the aggregate to heat and dry. More importantly, the additional aggregate in the drum provides for a more dense veil of material cascading around the circumference and thus better heat transfer.

Lowering the slope of the drum does not cause a change in the plant production rate. Although it takes somewhat longer for the first aggregate particles to leave the drum when the slope is reduced (from 3.5 minutes to 3.7 minutes, as an example), the actual plant mix rate remains constant in terms of tons per hour. Power requirements for the electric motors used to turn the drum are increased slightly because of the extra weight of aggregate in the drum. The net result, however, is a better veil of aggregate, more complete heat transfer, and a reduction in the temperature of the exhaust gases at all locations in the drum. The minimum slope of the drum, however, is about 3 degrees.

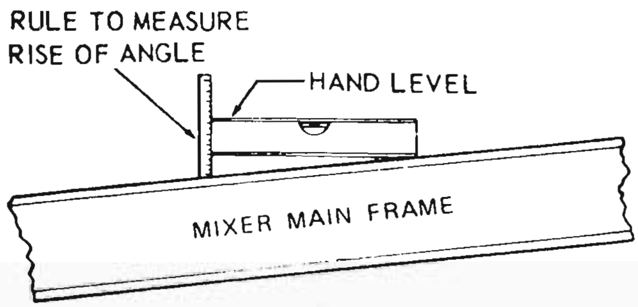


Figure 7.17. Measurement of drum slope (Ref 18).

Several manufacturers have developed drum mix plants which are not of constant diameter along the length. The drum is one diameter at both ends and a lesser diameter in the center or mid portion of the drum (Fig 7.20). The change in diameter in essence provides for development of a denser veil of aggregate in the center of the drum. For example by squeezing the same volume of material that was tumbling in an 8-1/2 foot diameter drum, into an area 7 feet in diameter, is the density of the aggregate veil is significantly increased. This rise in the aggregate density in turn improves the efficiency of the heat transfer process. The velocity of the exhaust gases, however, is also increased.

While the exhaust gas temperature is being reduced as these gases move down the drum, the temperature of the aggregate is increasing as they move in a parallel direction (Fig 7.21). The heat transfer process takes place in three ways: (a) by convection, from the heat in the exhaust gas; (b) by conduction, from the temperature difference between one heated aggregate particle and another aggregate particle at a lower temperature; and (c) by radiation, from contact with the drum mixer flights and drum shell which have been heated by the burner gases.

The aggregate enters the drum at ambient temperature. The heating of this material begins as soon as the aggregate begins to be tumbled inside the drum by the flights. As the aggregate moves along the drum length by gravity, it is heated. At some point in the drum, usually upstream of the drum midlength point, the temperature of the aggregate remains relatively constant at 180° to 200°F (Fig 7.20). Moisture in the aggregate particles starts to be

Figure 7.18. Changing slope of the drum.

Figure 7.19. Changing slope of the drum.

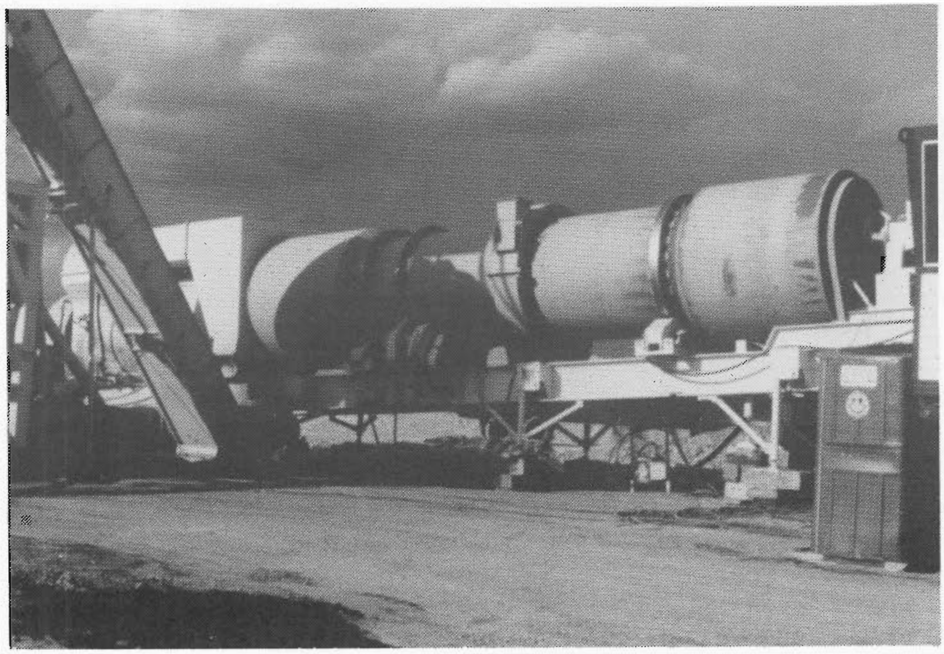


Figure 7.20. Variable diameter drum.

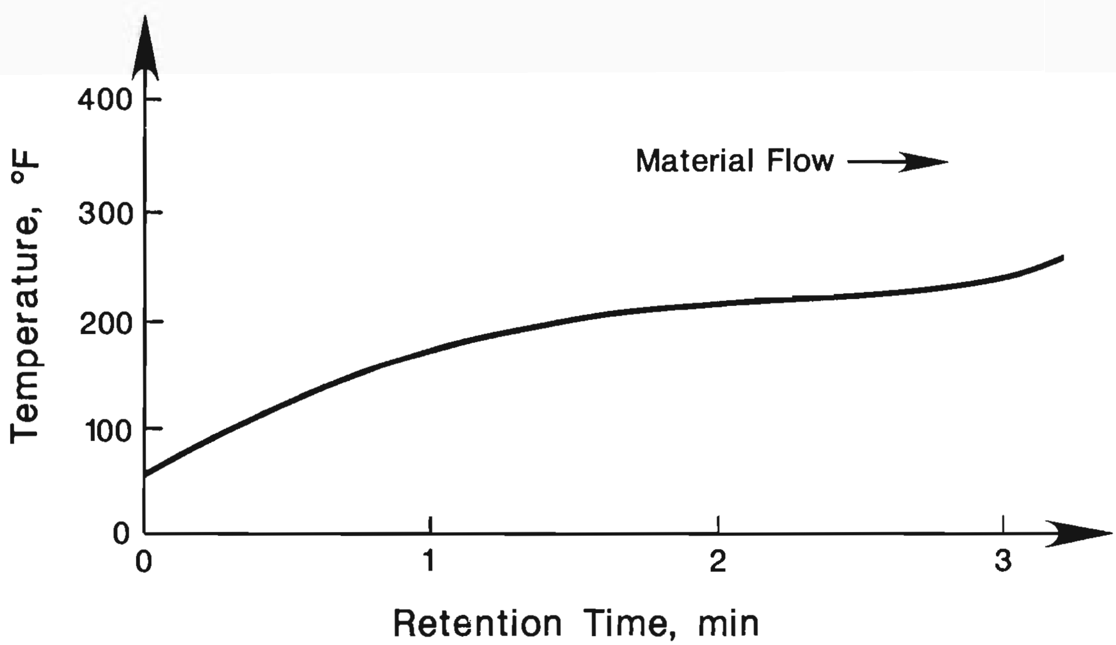


Figure 7.21. Aggregate temperature profile inside the drum (Ref 18).

driven off as the boiling point of water is usually reached. Because of the inert atmosphere and reduced oxygen content in the drum, the moisture is usually driven from the aggregate particles at a lower temperature than 212°F, the boiling temperature of water at sea level.

The amount of time the aggregate temperature remains constant depends in part on the amount of moisture in the aggregate. The higher the amount of moisture in the incoming aggregate, the longer the time at a relatively constant aggregate temperature. The porosity of the aggregate also is a factor, with the more porous material taking longer to be relieved of its moisture. Finally, because of their lesser mass and greater surface area, the fine aggregate (sand) in the drum mixer is typically heated more quickly than the coarse aggregate.

Once most of the moisture has been removed from the aggregate, its temperature begins to rise again. As the asphalt cement is added to the aggregate, coating occurs. The "mixing" flights continue to tumble the mix, continually exposing the material to the burner gases. The mix eventually reaches the required discharge temperature as it reaches the end of the drum. Thus the aggregate, as it proceeds down the drum, undergoes a heating, then a drying, and then another heating cycle.

The moisture content of the aggregate decreases gradually in the front portion of the drum. As the aggregate reaches the temperature needed to boil water under reduced pressure, the moisture content in the material is reduced rapidly. If the dwell time in the central section of the drum is long enough, the moisture content of the mix can be reduced to essentially zero. The water in the aggregate is turned into vapor or steam and moves out of the drum as part of the exhaust gases.

7.5 ASPHALT CEMENT INJECTION

On most drum mix plants, the asphalt cement is introduced in the drum through a pipe coming in from the rear of the drum (Fig 7.5). The size of the pipe used depends on the capacity of the plant, with 2- to 4-inch diameter line being typically used. In most cases the asphalt cement is merely discharged close to the side or the bottom of the drum. It is not normally sprayed or delivered through any type of nozzle.

On a few drum mix plants, depending on the manufacturer, the asphalt cement supply line enters the front of the drum, at the burner end, and the asphalt cement emptied into the side or bottom of the drum. The actual location of discharge varies widely, but for front end entry pipes it tends to be toward the midpoint of the drum length.

One advantage of front end asphalt cement introduction is quick capture of the dust particles in the aggregate with the binder material. This action reduces the amount of particulate matter carryout by encapsulating the fines in the asphalt cement. Three disadvantages are present, however: (a) the asphalt cement can be hardened more by exposure to the higher temperature exhaust gases; (b) the production of blue smoke from light ends from certain asphalt cements can be increased because of the higher exhaust gas temperature to which the binder is exposed; and (c) an increase in the moisture content in the mix can occur because the asphalt cement coats the aggregate particles before all the water in the material is removed.

When the asphalt cement supply line enters from the rear of the drum, the discharge location can also be varied significantly. On many plants, the pipe extends upstream to a point about 40 percent from the rear end of the drum (60 percent of the length downstream from the burner). At this location, the moisture remaining in the aggregate causes some foaming of the asphalt cement. The aggregate passes through the expanded volume of the binder and the coating takes place. In a drum mix plant, coating rather than mixing may be the more appropriate term for the blending of the asphalt cement with the aggregate.

If the moisture content in the aggregate is still high at the place where the asphalt cement is injected, the coating of the aggregate particles may be delayed until more moisture is removed during the drying process. The asphalt cement foams due to the boiling of the water and the production of steam, but the actual coating process may take place more toward the discharge end of the drum. If the moisture content of the incoming aggregates is very low, incomplete coating of the aggregates may occur. If water and steam available inside the drum are insufficient, foaming of the asphalt cement may be minimal. In this case, it may be necessary to add some water to the incoming aggregate on the charging conveyor to improve the coating of the asphalt cement on the aggregate in the mix.

If the asphalt cement being used contains a significant proportion of highly volatile material it may be advantageous to pull the asphalt cement supply line farther back toward the rear of the drum. This action reduces the exposure of the asphalt cement to the higher temperature exhaust gases, and the generation or release of the hydrocarbon volatiles is decreased. If the veil of aggregate farther up the drum is adequate, however, it should not be necessary to pull the asphalt cement line back. Furthermore, the rearward movement of the supply line can decrease the uniformity of the coating of the binder on the aggregates.

One drum mix plant manufacturer has removed the asphalt cement injection line from the drum completely. Thus the plant is no longer truly a drum mixer but a modern version of the old continuous mix plant. The aggregate is heated and dried in the drum, but exits uncoated. The aggregate is discharged into a single shaft inclined screw conveyor where the asphalt cement is sprayed on the aggregate (Figs 7.22 and 7.23). The mixing of the materials occurs as the aggregate and asphalt cement are pushed up the screw conveyor.

7.6 FINES FEED SYSTEM

Two types of aggregate fines can be fed into a drum mix plant, either individually or, occasionally, in combination with one another. The first is mineral filler and the second is baghouse fines. The equipment needed to handle each type of material is essentially the same. The primary differences between the various systems concern the degree of sophistication in the controls used to meter the materials.

If a mineral filler material such as hydrated lime, portland cement, or limestone dust is needed for the asphalt concrete job mix formula, the filler is usually delivered to the plant site by tank truck. The material is conveyed pneumatically from the haul truck to a storage silo. That silo is typically vertical, but can also be set in an inclined position.

A vane feeder system is located at the bottom of the silo (Fig 7.24). This feeder operates in response to signal from the drum mix plant computer controls. The more filler needed in the mix, the more rapidly the vane feeder turns. The feeder is normally equipped with an air system to keep the filler flowing uniformly into the vanes. The air keeps the mineral filler from packing into a tight mass above the feeder and bridging the opening to the vane feeder. If the flow of filler is restricted, the vane feeder will still rotate, but no material will be sent to the plant.

The vane feeder can be calibrated by weighing the amount of filler discharged in a measured amount of time. The plant controls are set to provide a certain amount of mineral filler per unit of time. The vane feeder is turned on and the filler allowed to flow through that equipment into the delivery pipe. The material in the pipe is diverted from the drum mixer to a suitable container, which has been weighed empty. The time the vane feeder is operated is measured, the gross and net weight of the material in the container is determined, and the flow of the material in terms of tons per hour is calculated.

The mineral filler flow rate is measured at several different quantity settings. The calculated values are compared to the numbers shown on the computer console. If the numbers are in agreement, the calibration procedure is complete. If the values disagree, the plant

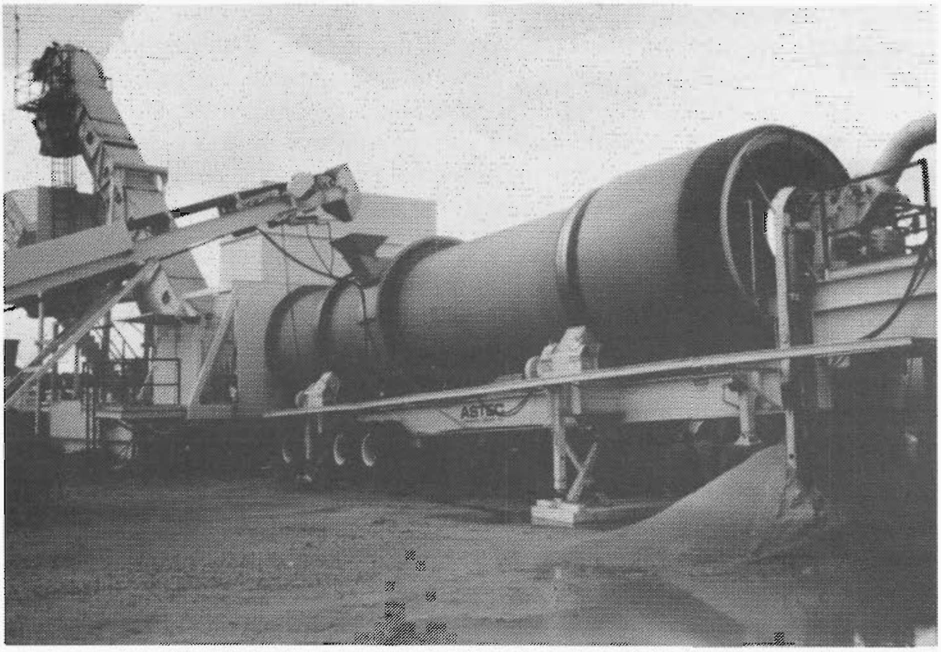


Figure 7.22. "Coater" plant (Ref 17).

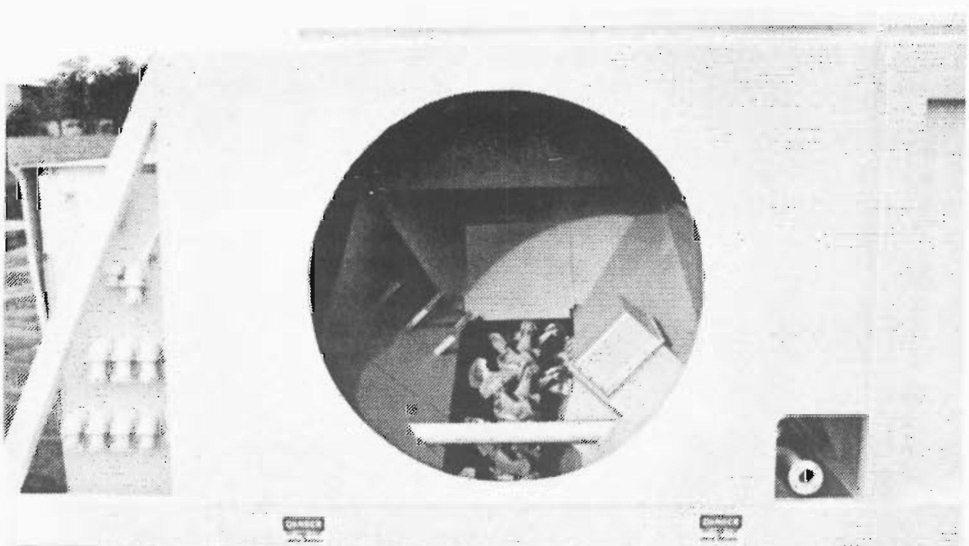


Figure 7.23. Coater auger (Ref 17).

manufacturer's adjustment procedures should be followed. Once the necessary adjustments are made, the mineral filler system should be calibrated again.

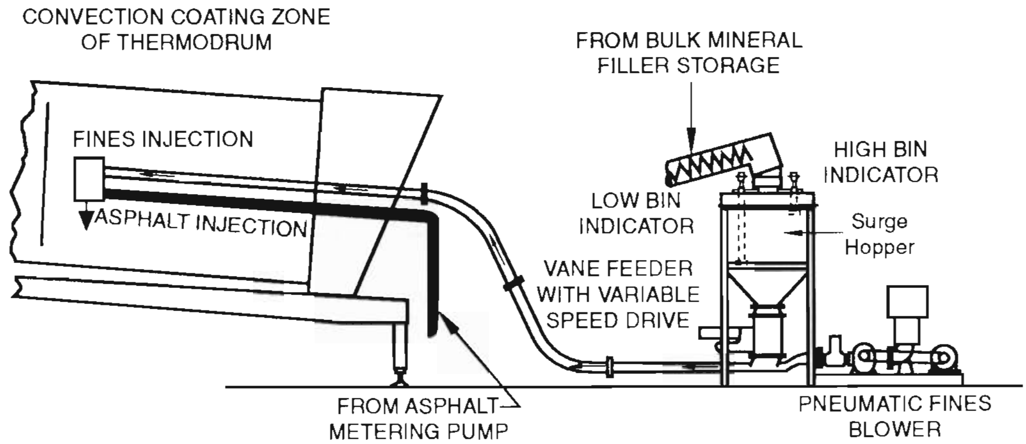


Figure 7.24. Pneumatic mineral filler system for adding filler from bulk storage to thermodrum not equipped with fabric filler collector (Ref 18).

Two items must be remembered. First, the pipe used to carry the mineral filler to the container being used for measurement should be full, both before and after the filler starts to flow. This will provide for a constant volume of material to be delivered each time, without any filler being required to "fill up the pipeline itself." Second, the scale employed to weigh the empty and full container should be properly checked. This scale has a tolerance value around its true reading; that tolerance should be considered when comparing the weighed amount to the value shown on the computer console.

The mineral filler from the vane feeder enters the delivery pipe for transport to the drum mix plant. The material is conveyed pneumatically through the line and into the rear of the drum. Once inside the drum, the filler can be discharged in one of several ways. Sometimes it is merely delivered from the line into the aggregate at the bottom of the drum. Sometimes it is fed into a "mixing box" where it is coated with the asphalt cement before it is dropped into the drum (Fig 7.25).

If the mineral filler is discharged directly into the drum mixer, it can be emptied either upstream or downstream of the asphalt cement entry point. If the filler is placed into the drum upstream of the asphalt cement point, it is usually dropped directly on the aggregate tumbling around in the bottom of the drum. Because the filler is dry and of a very small particle size, it is easy for this material to be caught in the exhaust gas stream. If this occurs, the filler can be carried out of the drum and into the air pollution control system without getting into the asphalt concrete mixture. Some portion of the filler will remain in the mix, but a major portion of the material, depending on drum operating conditions, may be lost from the drum mixer.

If the mineral filler is discharged into the drum after (downstream) the asphalt cement has been injected into the drum mixer, a greater portion of the filler is usually captured in the foaming mass of asphalt cement and aggregate at the bottom of the drum. Because it comes into contact with the asphalt cement very quickly after exiting its delivery pipe, the mineral filler has less chance of becoming airborne and being carried out of the drum. Thus, a greater percentage of the mineral filler material will remain in the mix.

Some drum mix plants are equipped with a device which coats the mineral filler with the asphalt cement before the filler can be exposed to the exhaust gas stream (Fig 7.25). In this case, the mineral filler and asphalt cement are emptied into the drum at the same location inside the drum. The "mixing box" prevents the exhaust gases from coming in contact with the filler until it is covered with the asphalt cement. Several different configurations for the mixing device exist. The most popular version allows the filler to swirl around inside the chamber and be coated with the asphalt cement before the combined materials fall out of the mixing device into the bottom of the drum. Once coated with asphalt cement, the mineral filler will be incorporated into the mix and not carried out of the drum by the exhaust gases.

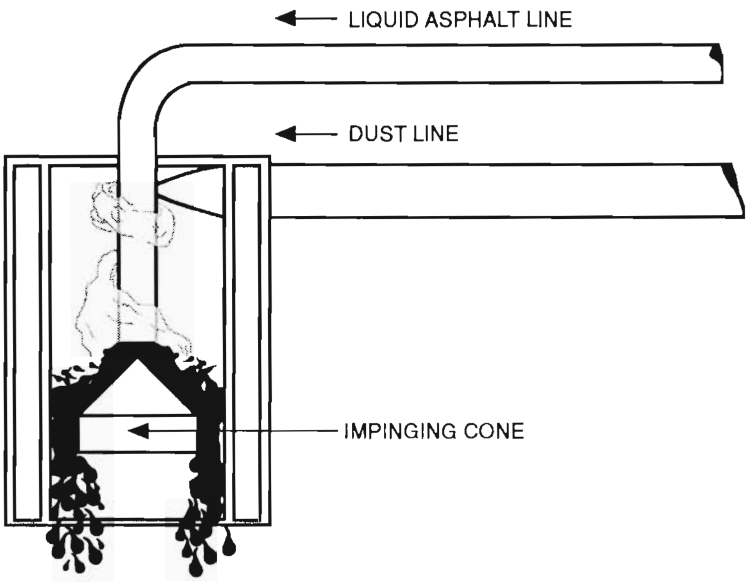


Figure 7.25. Asphalt cement/dust mixing box (Ref 17).

If a baghouse, or fabric filter is used as the air pollution control equipment on the plant, either all or a portion of the material captured in that device can be fed back into the drum mixer. The fines captured in the baghouse drop to the bottom of the house where they are collected in one or more troughs or channels. From the collection points, the baghouse fines are carried, usually by screw conveyor, through an air lock and then fed by air pressure through a pipe into the rear end of the drum mixer (Fig 7.26).

The baghouse fines are typically not metered except as they pass through the air lock as they are returned to the drum. They flow as they are collected, on a continuous basis. Occasionally, a surge of fine material will be carried into the baghouse, captured on the fabric filter bags, and dropped to the bottom of the unit. This slug of material may be carried back to the drum mixer. Typically, this problem is minor and metering of the baghouse fines is not necessary. If, due to the plant operating characteristics, such surges of fines occur regularly, the baghouse fines should be fed into a surge bin for temporary storage. The collected material is then metered back into the plant using a vane feeder system, similar to that for mineral filler.

The line coming from the fabric filter usually enters the rear of the drum mixer and carries the baghouse fines material, under air pressure, into the drum. The material is discharged the same as mineral filler, either upstream or downstream of the asphalt cement entry point, or in conjunction with the asphalt cement through a "mixing box." The incorporation of these fines into the asphalt concrete mixture is the same as for the mineral filler material.

In a few instances, the job mix formula for the mixture being manufactured will require the addition of a mineral filler and the drum mix plant will be equipped with a fabric filter. In some cases, separate feed lines are used for the mineral filler and for the baghouse fines.

Two pipes, in addition to the asphalt cement supply line, enter the rear of the drum mixer. Each empties into the drum, either at the same point or at slightly different positions. In most cases, the baghouse fines are delivered to a surge silo and are metered through a vane feeder into the supply pipe. The mineral filler, also in a silo, is fed through its own vane feeder into the same pipe as the baghouse fines. Thus, a common line is used to feed both the filler and fines to the drum mixer (Fig 7.27).

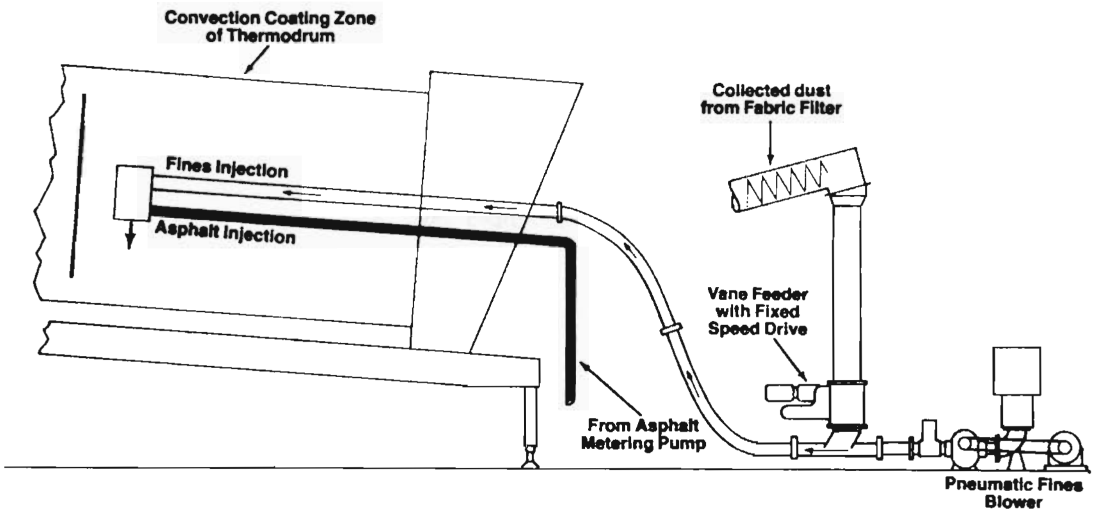


Figure 7.26. Pneumatic dust return from fabric filter collector back into thermodrum (Ref 18).

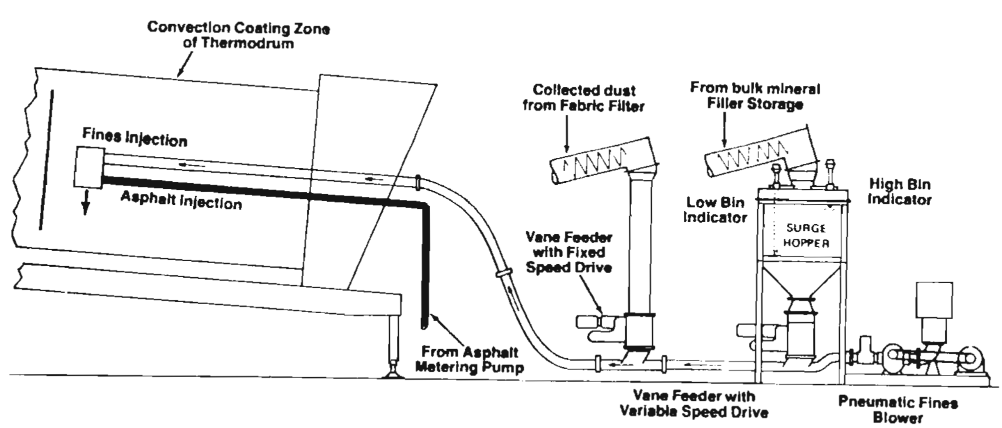


Figure 7.27. Combined pneumatic dust return and mineral filler system for adding filler from bulk storage to thermodrum with fabric filter collector (Ref 18).

If a fabric filter, or baghouse, is used on the drum mix plant, the returned fines must be incorporated into the asphalt concrete mixture or wasted and not be allowed to recirculate back to the baghouse. This can only be accomplished by ensuring that the fines are kept out of direct contact with the high velocity exhaust gases and are coated with asphalt cement. If the fines are carried back to the baghouse, they will be caught and again returned to the drum mixer. Soon the baghouse will be overloaded with excessive fines since new material is continually being generated by the plant. The baghouse will quickly become plugged and cease operating properly. It is essential, therefore, that any mineral filler and/or baghouse fines be coated with asphalt cement and retained in the drum, rather than being recirculated back to the fabric filter.

7.7 RECLAIMED MATERIAL/RECYCLING SYSTEMS

Drum mix plants can be used to efficiently and economically produce recycled asphalt concrete mixtures. In some plants, a single cold feed system delivers both the new aggregate and the reclaimed aggregate into the drum mixer at the same position — at the burner end of the drum. In most plants, however, the feed of the two different materials is separated: the new aggregate is fed into the drum at the upper end, and the reclaimed aggregates are charged into the drum at a midlength entry port. This split feed system keeps the reclaimed material out of direct contact with the burner flame and significantly reduces the opportunity for the hardening of the reclaimed asphalt and the production of blue smoke (hydrocarbon emissions) during the recycling process.

Single Feed

On drum mix plants where a single new aggregate/reclaimed aggregate cold feed system is used, the objective at the burner end of the drum is to protect the asphalt-coated reclaimed material from direct contact with the burner flame and to reduce the volume of blue smoke generated. Several different procedures can be employed, either alone or in combination, to accomplish this task.

One method often used is to spray water on the combined aggregate coming up the cold feed charging conveyor. The water spray, usually 1 to 4 percent, by weight of aggregate, "protects" the aggregate by placing a film of water on the particles. The water film temporarily reduces the exposure of the asphalt-coated particles to the flame and exhaust gases until that film is evaporated from the surface.

The degree of benefit that the water spray provides depends on many factors. The amount of moisture already in and on the reclaimed material is important. The amount of water applied and the location where it is sprayed is also a consideration. If, for example, the reclaimed aggregate is placed first on the conveyor belt, underneath the new aggregate, the water spray cannot reach the asphalt-coated particles. Thus, for the water to have any effect it should be applied directly to the reclaimed material. If, however, the amount of reclaimed material in the mix is high, the water still might not come in contact with much of the reclaimed material.

The type of entry of the aggregate into the drum also plays a part. If the combined material is fed through an inclined chute, a series of flights is needed which are designed to push the aggregates downstream, away from the burner flame. If a slinger conveyor located beneath the burner is employed on the plant, the speed of that device should be set to sling the new and reclaimed aggregate down the drum rather than deposit the materials immediately in the front end of the drum. The farther away the asphalt-coated aggregate is kept from the burner flame, the less hydrocarbon emissions (blue smoke) are generated.

On some plants, a heat shield or a diffuser is used to reduce the contact with the burner flame (Figs 3.4 and 7.28). This device, made of heat-resistant material, spreads the flame out around the circumference of the drum, decreasing the concentration of heat at any one point in the drum. The performance of the heat shield is dependent on its location inside the drum, the amount of reclaimed material in the mix, the moisture content of the new and the reclaimed aggregate, and the required mix discharge temperature.

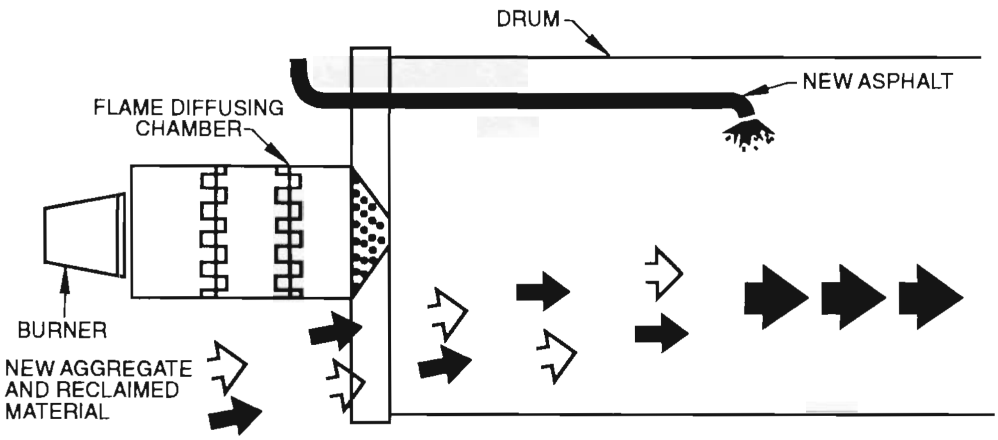


Figure 7.28. Flame-diffused recycling (Ref 28).

When high percentages of reclaimed material are used in a recycled mix produced in a single feed type drum mix plant, generation of blue smoke can be expected. The amount of the hydrocarbon emissions will increase as the volume of the asphalt-coated material increases, as the moisture content in that incoming material decreases, as the mix discharge temperature increases, and if a heat shield is not used inside the drum. Because of the inherent air pollution control problems which exist when producing recycled asphalt concrete mixes using a single aggregate (combined new and reclaimed aggregate) feed entry point, few of this type of drum mix plant remain in operation.

Split Feed

With the vast majority of the drum mix plants currently in use, the reclaimed aggregate is fed separately from the new, uncoated aggregate. The new material is delivered to the burner end of the drum mix plant in a conventional manner. The reclaimed aggregates, however, are usually held in a separate, free-standing cold feed bin or bins.

This latter material is carried up to the plant on its own charging conveyor and weigh bridge system. The cold feed system employed is similar to that for the new aggregates: only the ultimate delivery point of the reclaimed material is different.

Each drum mix plant manufacturer has his own design for the intake system used to introduce the reclaimed material into the drum. In most cases, the inlet is located at the midpoint or just downstream from the center of the drum length (Figs 7.5 and 7.29). The drum has a series of ports or entry chutes cut into the shell to allow the reclaimed material to be introduced into the drum (Fig 7.6). The charging conveyor feeds the material into the rotary inlet and, as the drum turns, the reclaimed aggregate falls through the port holes and into the drum. In some cases, the particles are dragged from near the top of the drum shell through the air to the bottom of the drum. In most cases, however, the reclaimed material enters near the bottom of the drum.

At the point that the reclaimed aggregate actually is placed inside the shell, the flights are often omitted for a short distance permitting the reclaimed material to rest on top of the new, now partially heated and partially dried aggregate, for a short period of time before the combined aggregates are picked up by the flights inside the drum and are tumbled together.

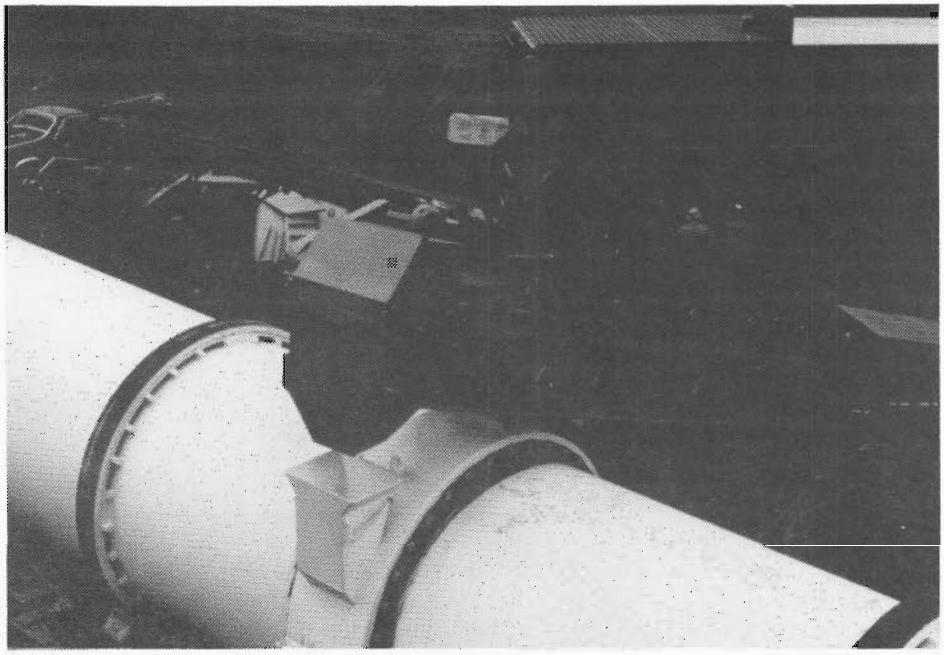


Figure 7.29. Midpoint entry of reclaimed material (Ref 16).

A number of different schemes are employed to try to reduce the temperature of the burner exhaust gases at the point where they come into contact with the asphalt-coated, reclaimed material. It is believed that the asphalt cement coating will "vaporize" from the surface of the aggregate particles at temperatures in the range of 800°F to 1200°F. Thus, in order to prevent the generation of hydrocarbon emissions, the temperature of the burner gases needs to be reduced to something less than 1000°F at the location where the reclaimed aggregate enters the drum. This is accomplished primarily by assuring that a heavy veil of new aggregate is present in the drum immediately upstream of the reclaimed material entry point.

Because a portion of the aggregate used in the recycled asphalt cement mix is introduced at the midlength point on the drum, less aggregate is naturally fed into the drum at the upper or burner end. This means that a less dense veil of aggregate is obtained in the drum since less material is in the upper end of the drum at any time. Less heat transfer therefore takes place between the exhaust gases and the aggregate particles because of the reduced mass of these particles inside the upper end of the drum. The temperature of the gases at the point they come in contact with the reclaimed material is, therefore, higher than it would be if the plant were being run using all new aggregate, at a given ton-per-hour production rate. Some means is needed, then, to transfer as much heat as possible from the exhaust gases to the new aggregate before the reclaimed material entry point is reached.

Most of the methods used involve increasing the density of the new aggregate veil at a location immediately ahead of the center split feed point. In some cases, a dam or donut is secured inside the drum, around its circumference. This ring forms a barrier to the flow of the new aggregate down the drum (Fig 7.5). The new material builds up in front of the dam until enough material is available to spill over the top of the ring and fall into the lower portion of the drum. The "excess" of material in front of the dam or donut becomes part of a heavier veil of material as it is tumbled inside the drum. The increased amount of aggregate allows for more heat transfer to be accomplished and reduces the temperature of the exhaust gases coming in contact with the reclaimed material.

The use of the ring or dam essentially decreases the diameter of the drum at the shell midpoint. This restriction cannot be seen from the outside of the drum. Several plant producers

The use of the ring or dam essentially decreases the diameter of the drum at the shell midpoint. This restriction cannot be seen from the outside of the drum. Several plant producers are making the heat transfer technique more obvious. Drums are available in the marketplace which vary in the diameter of the shell at different points along the drum length (Fig 7.20). The front portion of the drum, at the burner end, is larger in size than the middle part of the shell. At the lower end, the drum diameter flares out again to the same dimension as the upper end. This change in diameter creates a reduction in the drum cross-sectional volume. It thus increases the density of the new aggregate veil upstream of the reclaimed material entry point. Some drums are built without the second change in drum diameter. The upper portion of the drum is larger in diameter than the center part, but the drum diameter then remains constant down to the discharge end of the shell.

Another way to increase the density of the new aggregate veil is to increase the number of flights inside the drum at the burner end of the drum. This greater amount of lifting action causes more aggregate to be tumbled at any particular time, increasing the density of the veil. Finally, the dwell time of the aggregate in the drum can be increased by lowering the slope of the drum. This, in effect, increases the amount of new aggregate in the drum thus causing a heavier aggregate veil and more complete heat transfer.

Some plant producers have gone to the use of longer drum lengths to allow for more time for the heat transfer process to take place. This method basically increases the volume of new aggregate in the upper portion of the drum, densifying the veil of material. Also, by increasing the amount of time it takes for the material to flow through the drum, more complete heating and drying of the new aggregate particles occurs.

Normally, if only small amounts of reclaimed material (less than 20 percent) are being incorporated into a recycled mix, minimal problems in terms of hydrocarbon emissions are usually encountered with the manufacturing process in a drum mix plant. As the percentage of old material increases, however, and as less new aggregate is necessarily fed into the burner end of the plant, the potential for air pollution problems increases. When the amount of reclaimed material used exceeds 50 percent, by weight of mix, the possible production of blue smoke during the recycling process is significant. A combination of procedures, outlined above, is usually needed to assure adequate heat transfer from the exhaust gases to the new aggregate before the burner gases meet the reclaimed material. Except in unusual circumstances, a maximum of 70 percent reclaimed aggregate can be accommodated in the typical drum mix plant.

The reclaimed material is heated and dried in three ways. First, and most obviously, it is directly exposed to the high temperature exhaust gases. If the gases are less than about 1000°F when they come into contact with the asphalt coating on the reclaimed aggregate particles, little of the asphalt cement will be incinerated or vaporized from the aggregate surface. The continued exposure to the gases as the combined new and reclaimed aggregate tumble together down the lower portion of the drum causes these materials to increase in temperature at the same time that the temperature of the exhaust gases is reduced. Thus heat is transferred from the hot air to the aggregate particles.

The second means of heat transfer is from the already partially heated new aggregate to the reclaimed material. When the reclaimed aggregate is placed on top of the new material at the center entry port, the contact between the heated new aggregate and the reclaimed ambient temperature material causes some heat to flow to the reclaimed material. This process continues as both materials travel together down the drum. Finally, the reclaimed material gains in temperature as it touches the heated drum flights and shell wall. As the materials are heated, moisture in the aggregate is driven off and the combined new and reclaimed particles are dried.

In many plants, the reclaimed aggregates enter, using the split feed system, only a short distance upstream of the asphalt cement injection location. This means that the combined materials (new and reclaimed) are coated with asphalt cement before the reclaimed aggregates are heated or dried to any significant degree. This early coating process usually causes some moisture to be trapped on the surface of the reclaimed material, under the new asphalt cement layer. Although much of this moisture is eventually removed as the material flows down the drum, some residual moisture may remain in the recycled mix upon discharge from the drum.

Because of this potential problem, the asphalt cement injection point is pulled back toward the discharge end of the drum in some plants when recycled mix is being produced. This procedure allows more time for the reclaimed material to be heated and dried before the new asphalt binder introduced. Thus, the moisture content in the mixture is reduced. Ideally, the amount of residual moisture in a recycled asphalt concrete mixture should be the same as that in a mix produced using all new coarse and fine aggregate.

7.8 PRODUCTION RATES

Asphalt concrete drum mix plants are typically rated in terms of the number of tons per hour of mix that can be produced. The manufacturing capacity is determined at a moisture content of 5 percent. No mineral filler is assumed to be incorporated in the mix. The calculations are based on an incoming coarse and fine aggregate temperature of 60°F, a mix discharge temperature of 270°F, and an aggregate specific heat value of 0.2 Btu per pound per degree F. In addition, the atmospheric pressure is taken to be the same as at sea level. Any differences in the values of the above factors can cause a variation between the theoretical capacity of a given drum mix plant and its actual output quantity.

Plant capacities are affected by a number of other variables. Differences in operating techniques, atmospheric conditions, fuel type, and fuel Btu content will cause changes in production capacities. In addition, aggregate gradation will be a factor. Mixes containing a large percentage of coarse aggregates being more difficult to heat uniformly than mixes incorporating a balance of coarse and fine aggregate particles.

The moisture content of both the coarse and fine aggregate must be determined in order to calculate the average moisture content of the combined incoming aggregate. Since different amounts of coarse and fine material are used in the mixes, the average moisture is typically between the amount of moisture in each of the two aggregate fractions. The moisture content of the fine aggregate is usually higher than that of the coarse aggregate. The weighted moisture content is thus a function of the amount of moisture in the coarse aggregate multiplied by the percentage of that material in the mix, plus the amount of moisture in the fine aggregate multiplied by the percentage of the latter material in the combined gradation.

If, for example, 60 percent of the asphalt concrete mix consists of coarse aggregate, then 40 percent of the mix is fine aggregate (assuming no mineral filler is used in the mix). If the moisture content of the coarse material is 3.0 percent and that of the fine particles is 8.0 percent, the average moisture content in the combined aggregates is calculated to be: (60 percent x 3.0 percent) + (40 percent x 8.0 percent) = (1.8) + (3.2) = 5.0 percent. If the amount of moisture in the fine aggregates was only 6.0 percent, the combined (average) moisture content of the cold feed materials would be: (60 percent x 3.0 percent) + (40 percent x 6.0 percent) = (1.8) + (2.4) = 4.2 percent.

The production capacity of a drum mix plant, using all new aggregate, is primarily a function of the amount of moisture in the combined aggregate and the diameter of the mixing drum. As the average percentage of moisture in the aggregate increases, the production capacity of a drum mixer of a given diameter decreases. At a constant average incoming moisture content, the production rate increases as the drum diameter increases. The theoretical relationship between average moisture content and drum diameter and the calculated drum mix plant production rate (at a mix discharge temperature of 270°F) is shown in Figure 7.30 for six different Barber-Greene drum mix plant models.

	Nominal Drum Mixer Capacitiesa								
	Normal Operating Range								
	Percent Surface Moisture Removed								
Modal	2	3	4	5	6	7	8	9	10
DM-50 5X22	170 (178)	135 (142)	110 (116)	95 (100)	80 (84)	75 (79)	70 (74)	60 (63)	55 (58)
DM-55 6X24	265 (278)	210 (220)	170 (178)	150 (158)	130 (137)	115 (121)	110 (116)	95 (100)	85 (89)
DM-60 7X30	400 (420)	320 (336)	260 (273)	225 (236)	195 (205)	175 (184)	155 (163)	140 (147)	130 (137)
DM-66 8X32	515 (541)	410 (430)	335 (352)	290 (305)	250 (263)	225 (236)	200 (210)	185 (194)	165 (173)
DM-71 9X36	685 (719)	550 (578)	455 (478)	390 (410)	340 (357)	300 (315)	270 (284)	245 (257)	225 (236)
DM-75 10X40	910 (956)	725 (761)	600 (630)	515 (541)	450 (473)	400 (420)	360 (378)	325 (341)	300 (315)

[a]*Figures with no parentheses are aggregate drying capacities.*

Figures in parentheses are mix production capacities calculated as: aggregate capacity + 5 percent asphalt (no mineral filler added).

Figure 7.30. Examples of effects of moisture content on plant production rate for six Barber-Greene plants (Ref 29).

At an average moisture content of 5 percent, a drum mix plant having a diameter of 5 feet would have a theoretical production capacity of 100 tons per hour. If a drum 7 feet in diameter were employed, that plant's manufacturing rate would be 236 tons per hour. For a drum mixer 10 feet in diameter, the capacity would increase to 541 tons per hour, at 5 percent moisture removal. As the moisture content in the aggregate decreases, say from 5 percent to 3 percent, the production capacity for a drum mixer that was 7 feet in diameter would increase to 336 tons per hour from 236 tons per hour. If the aggregate was wet, with an average moisture content of 8 percent, for example, the same 7 foot diameter plant would only have the capacity to manufacture 163 tons of asphalt concrete mix per hour. As can be readily seen, the moisture content of the aggregates can have a dramatic effect on the production capacity of a given diameter drum mix plant.

In the above illustrations, the mix discharge temperature was held constant at 270°F. This temperature, however, also affects the production rate of the plant. As the mix discharge temperature decreases, for a given aggregate moisture content and drum size, the volume of mix manufactured in the plant increases. In Figure 7.31, a Cedarapids drum mix plant which is 7.33 feet in diameter and 28 feet in length is shown producing mix at five different discharge temperatures. For a value of 5 percent moisture removal, the production rate will increase from 255 tons per hour at 300°F to 300 tons per hour at 250°F to 350 tons per hour at 200°F. When the moisture content on the incoming aggregate is relatively high, the production rate changes are not as great when the mix discharge temperature is lowered. At 8 percent average moisture content, for instance, the production capacity of the plant increases from 175 to 200 to 230 tons per hour as the mix discharge temperature decreases from 300° to 250° to 200°F, respectively.

The production rate for recycled asphalt concrete mixtures is a function of the amount of reclaimed material being fed into the drum mixer. For a split feed plant, as the amount of reclaimed material delivered to the drum becomes greater than 50 percent of the total aggregate feed, the capacity of the plant is decreased (Fig 7.32).

Suppose a recycled mix, for example, is to be made up of 60 percent reclaimed material and 40 percent new aggregate, with the latter consisting of 25 percent coarse aggregate and 15 percent fine aggregate. Further, assume that the moisture contents in the cold feed bins are 5 percent, 3 percent, and 8 percent, for the reclaimed, new coarse, and new fine aggregate, respectively. The weighted (average) moisture content of the combined materials can be calculated as: (60 percent x 5 percent) + (25 percent x 3 percent) + (15 percent x 8 percent) = (3.00) + (0.75) + (1.20) = 4.95 percent. This value is used as an input value into the figure.

The ratio of reclaimed to new aggregate is also an input value. In this example, 60 percent reclaimed material and 40 percent new aggregate is assumed for the recycled mix. For a 60/40 ratio, and at a weighted moisture content of 4.95 percent, the index number of 0.70 is obtained from the chart. This index value means that, in general, a drum mix plant could produce only 70 percent as much mix per hour, based on a 60/40 reclaimed/new aggregate blend, compared to the same plant producing mix using all new aggregate. Thus, if the plant could manufacture 308 tons per hour (at 4.95 percent moisture removal) with 100 percent new material, it would theoretically be rated at 308 x 0.70 = 216 tons per hour using 60 percent reclaimed aggregate.

If the same plant were being operated at a ratio of 70 percent reclaimed to 30 percent new aggregate, and if the same weighted moisture content held for the combined aggregate, the rate of mix production would decrease. The index value for the example is 0.58, meaning that the production rate would only be 58 percent of that using all new aggregate. For the same drum mix plant, the amount of mix manufactured would be decreased from 308 tons per hour to 308 x 0.58 = 179 tons per hour. Thus, as the amount of reclaimed material used in the recycled mix increases above 50 percent, the amount of mix that can be manufactured in a drum mix plant is reduced.

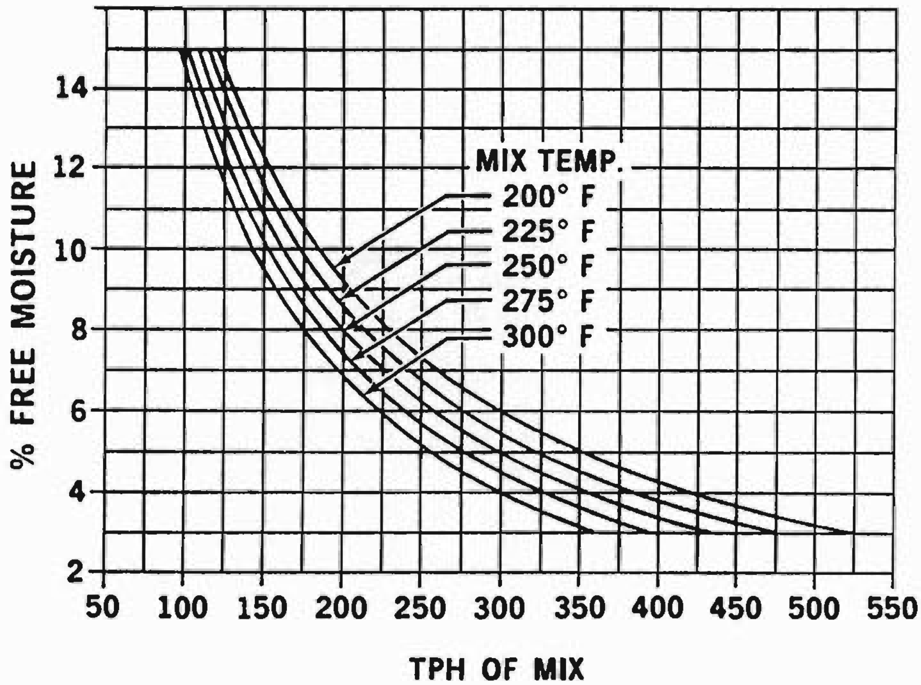


Figure 7.31. Capacity chart for Cedarapids drum mixers (Ref 30).

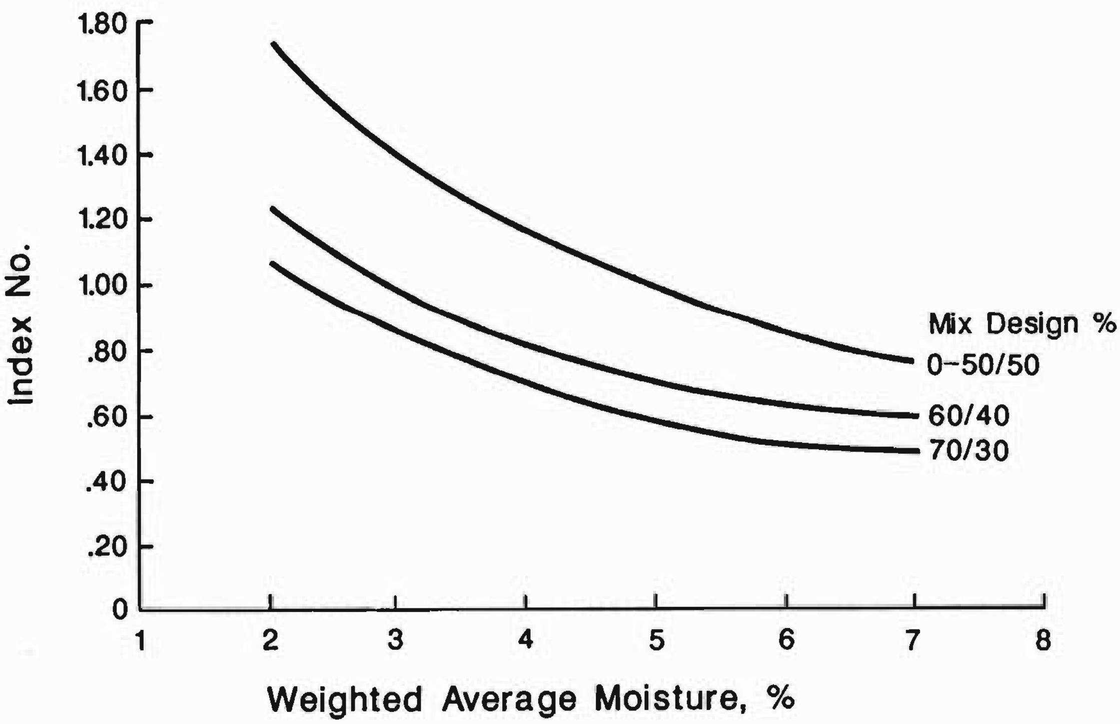


Figure 7.32. Capacity chart for Barber-Greene recycling plants (Ref 31).

7.9 PLANT EFFICIENCY

The main purpose of a drum mix plant is to transfer heat from the burner flame and gases to the aggregate in order to heat and dry it. If perfect heat transfer could take place inside the drum, the temperature of the mix upon discharge from the plant would be equal to the temperature of the exhaust gases at the same point. This equilibrium point would mean that the heat transfer is in balance and that the drum mixer is running at maximum thermal efficiency.

In very few instances, however, does the mix discharge temperature equal the exhaust gas temperature. But if the veil of aggregate inside the drum is of the proper density, the exhaust gas temperature, measured at the point when the exhaust gases enter the plant pollution control system ductwork, should be within 25°F above the temperature of the mix. Thus, if the mixture discharge temperature is 275°F, the exhaust gas temperature should ideally be less than 300°F. This small temperature differential implies that the drum mixer is operating efficiently. If the exhaust gas temperature at the point when the gases enter the plant pollution control system ductwork is found to be more than 25°F above the mix temperature, it generally means that the heat transfer process inside the drum is not as efficient as it should be, primarily due to the lack of a dense, complete veil of aggregate across the circumference of the drum. The degree of inefficiency of the heat transfer is evidenced by the temperature differential between the mix upon exiting the drum and the exhaust gases upon entering the plant ductwork.

During the production of a recycled asphalt concrete mixture, the heat transfer between the burner gases and the new and reclaimed aggregate should be similar to that for a mixture using all new material if all materials are introduced into the burner end of the drum mixer. Thus, for this system, the exhaust gas temperature should be within the 25°F temperature difference if the plant is operating properly. If a split feed type plant is being employed, the difference in the two temperatures will typically be greater than 25°F, depending on the proportion of reclaimed material being introduced at the center inlet point. As a higher percentage of reclaimed aggregate is employed in the recycled mix, the temperature differential increases.

As the ratio of reclaimed material to new material becomes greater, from 20/80 to 40/60 to 60/40 (reclaimed/new), there is less and less new aggregate being delivered to the burner end of the drum mixer. This means less material inside the drum, for a given production rate, and a less dense veil of aggregate to intercept the exhaust gases moving down the drum. Thus, the heat transfer process is not as efficient inside the drum as when a greater volume of new aggregate is being used. In some instances, when more than 50 percent of the recycled mix consists of reclaimed material, the temperature of the exhaust gases entering the ductwork can be more than 50°F above the mix discharge temperature.

The efficiency of the mixing operation, therefore, can be judged in part by observing the temperature differential which exists between the mix upon leaving the drum and the burner gases exiting the ductwork. Since both temperatures are recorded continuously and are usually displayed on the plant control console, this method of monitoring the plant production process is easy to accomplish. If the temperature differential is greater than it should be, an effort should be made to increase the density of the aggregate veil inside the drum, upstream of the reclaimed material entry port and upstream of the asphalt cement delivery point.

A second way to judge the efficiency of the drum mix plant operation is to observe the asphalt concrete mixture as it exits the drum and enters the delivery system to carry the material up to the surge silo. The appearance of the asphalt concrete material, whether it consists of all new aggregate or a blend of new and reclaimed aggregate, should be uniform across the width of the discharge chute. The color of the aggregate particles should be consistent and the larger aggregate pieces should be evenly distributed throughout the mixture.

If the drum mixer is not running efficiently, the veil of aggregate inside the drum will not be complete. On one side of the drum, depending on which direction the drum is turning, there will not be enough aggregate available to fully intercept the burner gases. In this area, the velocity of the gases remains high, allowing fine, dust-sized particles to be picked up in the gas stream and carried to the rear of the drum. As the exhaust gases change direction to enter the air pollution control system ductwork, the larger dust particles drop out of the gas stream and are deposited on one side of the drum. These uncoated particles are discharged on one side of the mixture as it exits the drum. A steady stream of light brown, uncoated, fine aggregate particles on one side of the asphalt concrete mix discharge chute thus provides an indication that the veil of aggregate inside the drum is incomplete.

If a dry, powdered additive such as hydrated lime is being added to the incoming cold aggregate at the burner end of the drum mixer, it is possible for that very fine material to be picked up in the exhaust gases shortly after it is entered into the plant. As long as the aggregate veil is proper, the powdered material or additive will be trapped in the tumbling mass of aggregate and incorporated into the mix. If the aggregate veil is incomplete, however, the powdered material can be carried down one side of the rotating drum shell and then either transported into the air pollution control equipment or dropped into the bottom of the drum at the mix discharge point. The material will then be visible on one side of the asphalt concrete mixture as it exits the drum.

Typically a high exhaust gas temperature (as the gas enter the ductwork) compared to the mix discharge temperature will be accompanied by a stream of light-colored fines on one side of the mix discharge chute. Both of these phenomena are indications that the drum mixer is not operating as efficiently as it could and should be. The plant personnel should alter the production process to achieve a denser veil of aggregate in the drum. This can be accomplished in a variety of ways — by increasing the number of flights inside the drum, by installing a dam or ring inside the drum, by using "kicker" flights to retain the material in the drum longer, and by lowering the slope of the drum, to increase the aggregate's dwell time.

CHAPTER 8. SURGE BINS

8.1 BIN GEOMETRY

A drum mix plant operates on a continuous basis: aggregate is steadily withdrawn from the cold feed bins, continually carried up the charging conveyor, and constantly fed into the rotating drum. The aggregate moves down the drum and exits from the drum in a continuous stream. The hauling vehicle, however, can only accept the manufactured mix on a batch basis, truckload by truckload. Thus, a means is needed to convert the steady flow of material into a discontinuous flow. That piece of equipment is a surge bin or silo.

Surge bins come in a variety of shapes. The majority of the silos currently employed are circular in cross section. Bins which are oval, elliptical, rectangular, and even square, are in use. The shape of the bin does not seem to have any significant effect on the ability of the silo to deliver mix to the haul truck uniformly, although there is some concern that mix can sometimes "hang up" in the corners of a square or rectangular bin. In addition, the diameter of the bin does not seem to be a major factor in the amount of segregation of an asphalt concrete mix which can occur. The manner in which the bin is operated has a great affect on the uniformity of the mix delivered — greater than the geometry of the surge bin itself.

8.2 CONVEYING DEVICES

A variety of conveying devices are used to carry the asphalt concrete mix from the discharge chute on the drum mixer to the surge bin. The most popular equipment is the drag slat conveyor (Fig 8.1). In this system, a continuous set of flights, connected together by a chain, pull the mix up an inclined metal chute. The amount of mix that can be carried by the drag slat depends on both the spacing between the slats and the height (or depth) of the individual flights themselves. On some drag slat conveyors, the speed of the conveyor can be altered to allow the capacity of the device to be more evenly matched to the output of the drum mixer.

Belt conveyors can be used to deliver the mix to the surge silo (Fig 8.2). The belts are essentially the same as those that carry the incoming aggregate into the drum, except they are able to withstand the increased temperature of the hot-mixed material. Bucket elevators are also found on some plants (Fig 8.3). These devices are similar to the equipment used on batch type plants to carry the hot aggregate from the discharge end of the dryer to the top of the mixing tower.

The type of conveying equipment employed is not a major factor in the uniformity of the mix delivered to the surge bin. What makes a significant difference is the manner in which the mix exits from the device and enters the top of the surge bin.

8.3 TOP OF THE SILO

The asphalt concrete needs to be placed into the silo in a manner which minimizes the segregation of the material. Segregation most typically occurs in mixes which contain a high proportion of large aggregate and/or are gap graded. The actual separation of the large and small particles occurs when the asphalt concrete is placed in a conical pile, and the bigger particles run down the side of the pile, collecting at the bottom edge. Segregation can also occur when all the mix is delivered to one side of the silo, allowing the coarser pieces to run all the way across the surge bin to the opposite wall. Prevention of segregation begins at the top of the silo.

Figure 8.1. Drag slat conveyor.

In some of the early surge bins, the asphalt concrete material was transported to the top of the silo either by slat conveyor, belt conveyor, or bucket elevator, and discharged into the silo. This method of delivery caused the large particles to be flung the farthest — against the far wall — and the smaller particles to be dropped with a shorter trajectory. To combat this problem, some manufacturers developed a series of baffles to capture and contain the asphalt concrete, dropping it into the center of the bin. Still other suppliers used a splitter system to divide the mix that was delivered to the device, thereby pushing a portion of the mix to each section of the silo. In general, the baffle and splitter systems reduced the segregation problem but did not always eliminate it.

Most surge silos currently in use employ some form of temporary holding hopper or batcher at the top of the silo to momentarily store the mix being transported up the conveyor (Fig 8.4). This "gob" hopper collects the continuous flow of mix and then, when the hopper is nearly full and the hopper gates are opened, deposits the mix, in a mass, into the main part of the silo. The mass of mix hits the bottom of the silo (when empty) or the top of mix already in the silo. Upon contact, the mix spatters in all directions, uniformly, thereby minimizing segregation. The system functions well unless the surge bin is almost full. In the latter case, the mix, when released from the hopper, does not fall very far. When it quickly hits the mix already in the silo beneath the hopper, the falling mix lacks the momentum to spread out over the width of the bin. Thus, a conical pile can be formed. This pile may be the beginning of a segregation problem as more mix is deposited on top of it. Most surge silos are equipped with high bin indicator warning systems which alert the plant operator to cut off the flow of incoming mix when the bin becomes too full.

Figure 8.2. Belt conveyor.

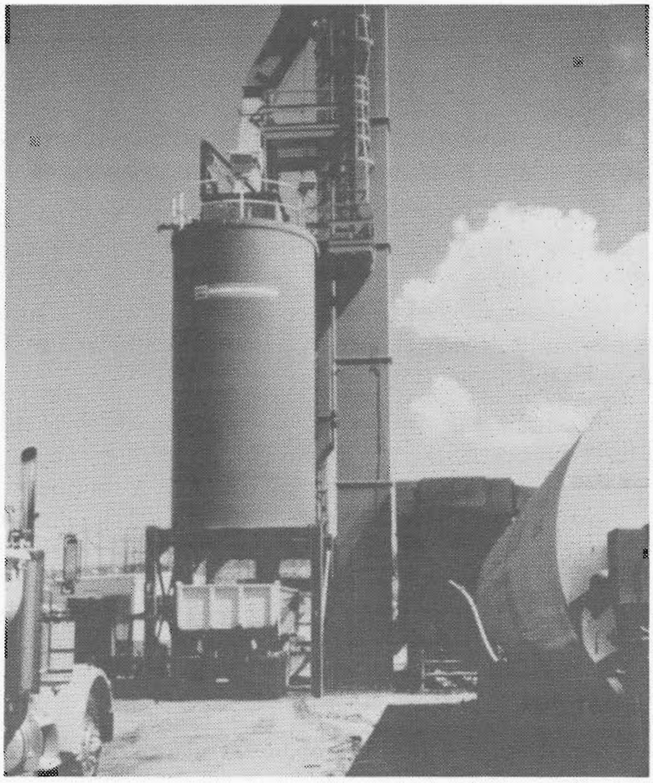


Figure 8.3. Bucket elevator.

with high bin indicator warning systems which alert the plant operator to cut off the flow of incoming mix when the bin becomes too full.

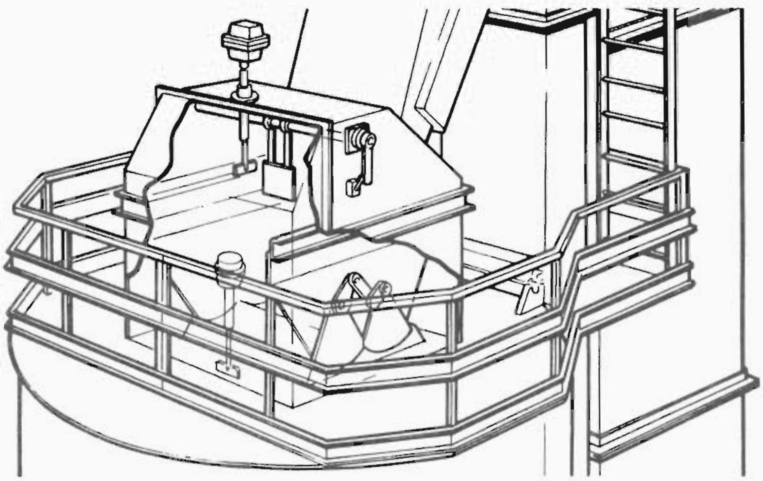


Figure 8.4. Silo-loading batcher at top of silo (Ref 18).

The temporary batcher may not prevent a segregation problem if the asphalt concrete mix is delivered to it improperly. In many cases, the transporting devices place the mix all on one side of the hopper. This causes a small amount of rolling of the coarse aggregate in the batcher itself. It also causes the mix to be dropped off-center into the silo. Thus, even though the surge bin may be equipped with a batcher, the mix must be deposited uniformly into the center of the batcher, and the mix must be delivered from the batcher into the center of the bin to prevent segregation of large stone size mixes or gap graded mixes.

Sometimes, the plant operator may leave the gates on the bottom of the batcher wide open. This completely defeats the purpose of the holding hopper, allowing the asphalt concrete mix to dribble into the silo in a continuous stream. In some cases, the batcher may be emptied more often than necessary, before it is completely full. This continual dumping of the hopper reduces the amount of material dropped into the silo in a mass and can increase the amount of segregation which may develop.

Another means of introducing the mix into the silo is with a rotating spreader chute (Fig 8.5). 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 extensive 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.

8.4 HEAT AND INSULATION

Most surge bins are insulated. The purpose of the insulation is to reduce the loss of heat from the mix as it temporarily resides in the bin. The type of insulating material and its thickness vary among the various manufacturers.

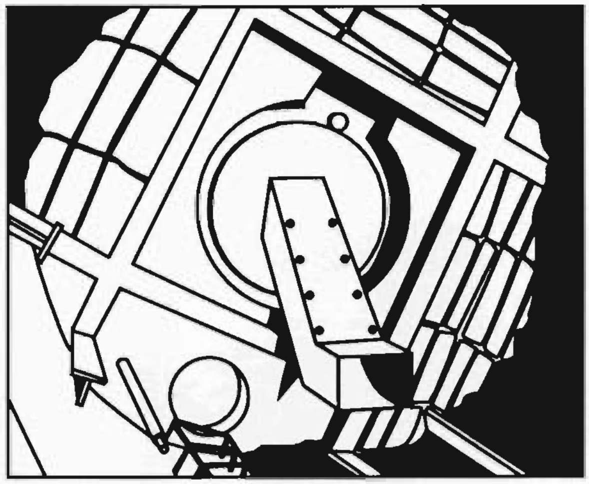


Figure 8.5. Rotating chute inside silo (Ref 32).

The cone on the surge bin is usually heated. This is done to prevent the mix from sticking to and building up on the wall of the cone. The heat can be provided by electrical or hot oil systems. In some cases, the vertical walls on the silo are also heated. The heating is done to allow the mix to retain the desired temperature for an extended period of time. If the silo is to be used strictly as a surge bin and emptied of mix at the end of each production cycle, heating of the bin walls is usually unnecessary.

Occasionally it is necessary to retain an asphalt concrete mixture in the silo for a longer time period, such as overnight or over a weekend. In most cases, this can be quite successfully accomplished without undue hardening or temperature loss in the mix. A well-insulated silo, however, is required. There is no strong evidence, on the other hand, that heating of the bin vertical walls is necessary. Mixes stored for several days in silos equipped with heated cones only have shown only minimal oxidation and temperature loss. The amount of hardening which occurs is related to the amount of mix in the silo. The large mass of mix in a full silo will age less than will a small volume of mix in a nearly empty silo. In addition, the amount of temperature loss in the stored mix will depend on a number of factors, including the initial mix temperature, the gradation of the material, and environmental conditions.

Asphalt concrete mixes may be stored for as long as two weeks when kept in a heated, airtight silo. In this case, an inert gas system is employed to purge the silo of oxygen. The silo must be well sealed, both at the bottom gates and the top, to prevent the movement of air into and through the mix. The bin, moreover, must be completely heated and very well insulated. If mix is to be stored more than a day or two, it is usually good practice to pull a small amount of mix from the silo every day to prevent the mix from setting up in the silo. Although mix can be stored for relatively long periods of time, it is rarely necessary to do so. Most silos, therefore, are used either as surge bins or periodically for overnight storage of the asphalt concrete material.

The mix held in a surge or storage bin should be tested to assure that it meets all the normal requirements for asphalt concrete materials delivered directly to the paving site. This testing should include measurement of the mix temperature upon discharge from the silo and the viscosity of the asphalt cement recovered from the mix. As long as the mixture meets these specifications, the length of time the material is held in the silo should not be restricted.

8.5 THE CONE AND LOADOUT

The bottom of the surge bin is shaped like a funnel (Fig 8.6). 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.

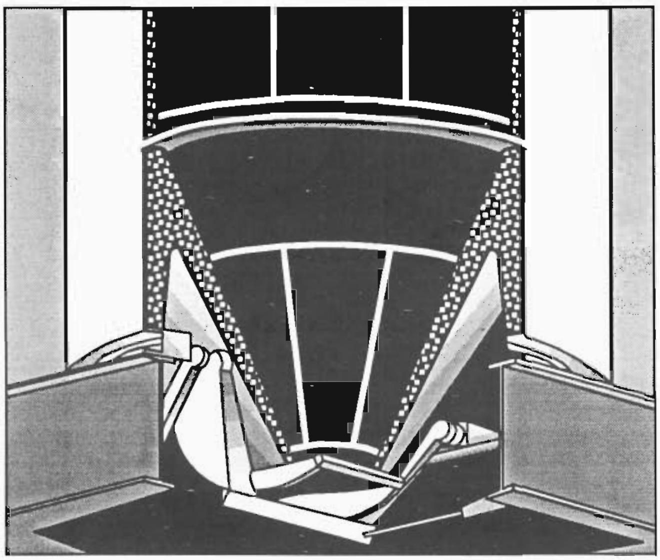


Figure 8.6. Cone at bottom of silo (Ref 33).

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.

Just as it is important to deliver mix into the silo in a mass, it is also important to deposit the asphalt concrete in one mass into the haul truck. In this operation, it is necessary for the gates on the bottom of the silo, at the bottom of the cone, to be opened and closed quickly (Fig 8.7). It is also necessary for the gates to open completely so that the flow of mix is unrestricted.

If all the asphalt concrete is placed in the hauling vehicle in one drop from the silo, segregation of the larger aggregate particles can occur. If the mix is deposited into the center of the truckbed, the material will build up into a conical shaped pile. Because the growth of the pile will be restricted by the sides of the truck, the bigger aggregate particles will roll toward the front of the truckbed and also toward the rear of the truck. These pieces accumulate in both ends of the load and are later delivered into the hopper on the paver from the truckbed. The pockets of coarse material then appear in the mat behind the laydown machine at the end of every truckload of mix. In reality, some of the large aggregate pieces come from the end of one truckload and some from the beginning of the next truckload of mix.

This segregation problem can be eliminated by dividing the delivery of the asphalt concrete from the silo into multiple drops, each delivered to a different section of the bed of the hauling vehicle. If a tandem axle or triaxle dump truck is being used, about 40 percent of the total weight of the mix should be loaded into the center of the front half of the truck (at the quarter point of the truck length). The truck should then be pulled forward so that the next 40 percent or so of the total load can be deposited into the center of the back half of the bed (at the three-quarter point of the truck length). The vehicle should then be moved again so that the remaining 20 percent of the mix can be dropped into the center of the bed, between the first two piles. If a semitrailer is used to deliver the mix, the number of drops of material from the silo should be increased so as to distribute the mix along the length of the truckbed.

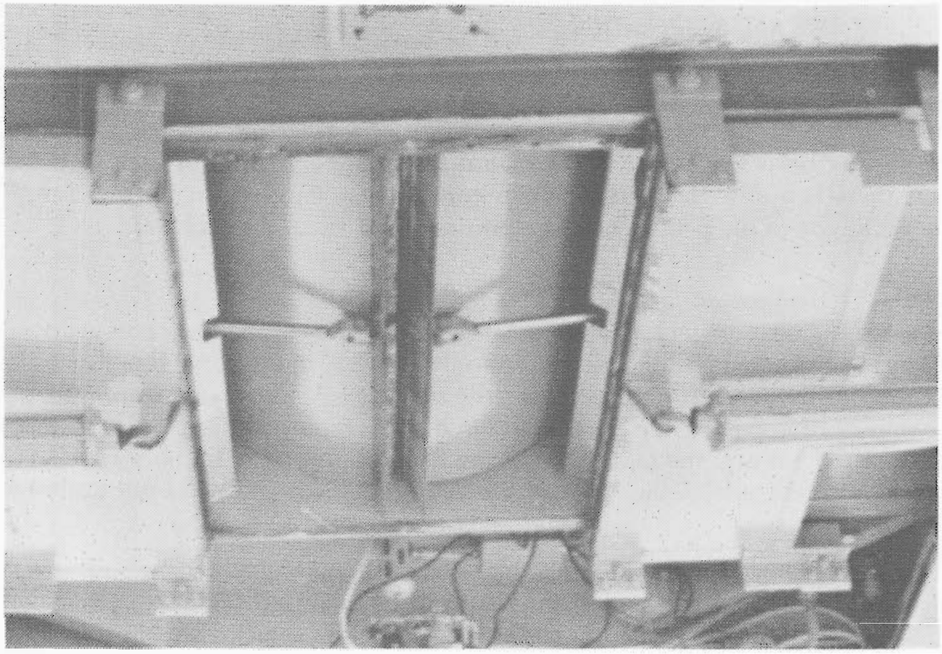


Figure 8.7. Silo gates at bottom of cone (Ref 34).

The objective of this delivery method is to minimize the distance that the coarser aggregate pieces can roll. This significantly reduces the chance for segregation in the mix. This procedure, however, requires that the truck driver remain in his vehicle during loading and that he reposition his truck under the silo periodically so that the asphalt concrete mix is spread more evenly on the truckbed. In any case, the truck should NOT be loaded in one drop of mix from the silo, even if the mix does not have a tendency to segregate. Multiple discharges are very beneficial in keeping the mix uniform for delivery to the paver. Further, a truck should never be loaded by continually discharging mix from the surge bin while the truck moves slowly forward.

The plant operator should quickly be able to determine the time it takes to deliver the proper amount of mix, per drop, into the haul vehicle. This can be done by timing the discharge of the mix and comparing the time to the weight of mix delivered. Because trucks are a variety of sizes, the time per drop of mix may well be different from truck to truck. But, after a little practice, the operator should be able to accurately judge, by time, the amount of material to be placed in each truckbed. This amount can also be confirmed visually by watching the height of each growing pile of mix in the truck as the loading continues.

In any case, the loading operator should not be allowed to dribble mix into the haul vehicle. The gates on the silo should not be continually opened and closed to deliver only small amounts of mix to the truck. This problem occurs most frequently in plants where the surge bins are placed directly over the truck scales. Because the operator can quickly determine the bins are placed directly over the truck scales. Because the operator can quickly determine the amount of mix actually in the truckbed by observing the scale readout on his control console, the tendency is to load the vehicle right up to the legal limit. This is done by using multiple drops of small quantities of mix at the end of the mix main delivery. If the discharge of mix from the silo is timed, however, this procedure is unnecessary. By eliminating the practice, the potential for mix segregation is also greatly reduced. In addition, a batching weigh hopper can be used under the silo to determine the amount of mix being loaded into the haul truck (Fig 8.8). This equipment eliminates the need for a truck scale.

8.6 SURGE BINS AND SEGREGATION

Two types of segregation occur in an asphalt concrete mixture placed by an asphalt paver. The first is side-to-side segregation. In this instance, the larger aggregate pieces all appear on one side of the mix on the roadway. The second type of segregation is truckload-to-truckload. Here the coarser particles appear in the mat at the end (beginning) of each load of mix. In each case, there is a definite pattern, either continuous or intermittent, to the segregation problem. Definition of the pattern helps determine the cause of the problem.

Side-to-Side

Side-to-side segregation generally occurs at the top of the silo. This pattern is an indication that the larger aggregate is being delivered to only one side of the surge bin. Instead of entering the center of the bin through a batcher, the mix is being separated during its discharge from the transporting device into the bin. In some cases, the smaller aggregate is deposited in the middle of the bin and the bigger pieces are flung to one side. In other instances, all the mix is thrown to one side of the silo and the larger aggregate particles roll downhill to the opposite side of the silo.

If side-to-side segregation occurs in the mat, the direction of loading the haul trucks under the silo should be reversed for several truckloads of mix. Thus, if the trucks are usually filled when heading in an easterly direction under the silo, a few vehicles should be loaded when facing west. When these reversed truckloads are dumped into the paver, the pattern of segregation on one side of the lane should switch to the other side of the mat. This procedure will confirm that the segregation problem has its origin in the silo caused by the way the mix is being delivered into the bin by the drag slat conveyor, belt conveyor, or bucket elevator. Correction of the problem entails redirecting the flow of mix as it is deposited in the bin.

Truckload-to-Truckload

This type of segregation can be continuous (between every truckload) or discontinuous (occurring periodically in the mat at the end or beginning of some loads of mix). The causes of each pattern can be the same or different. Asphalt concrete mixtures which contain a large amount of big aggregate will tend to segregate more readily than mixes which are made using a smaller top size material. Mixes which are gap or skip graded will separate more easily than mixes which are uniformly graded from coarse to fine.

Mixes which are dribbled into the center of the silo in a continuous flow will form conical piles inside the bin, causing the larger particles to roll to the sides of the bin. As these pockets of coarse material are drawn down into the cone of the silo, they are funnelled into a narrow space and are more concentrated. However, as long as the level of mix in the silo remains above the low bin indicator point, most of these particles are redistributed and segregation is not a major problem.

When the mix is drawn below the top of the cone on the silo, the larger pieces on the side roll into the center of the cone and are concentrated in one point. These pockets of large aggregate are then present as the mix is discharged into the haul truck. If the pattern of segregation is not constant on the roadway, one possible cause of the problem is that the plant op-

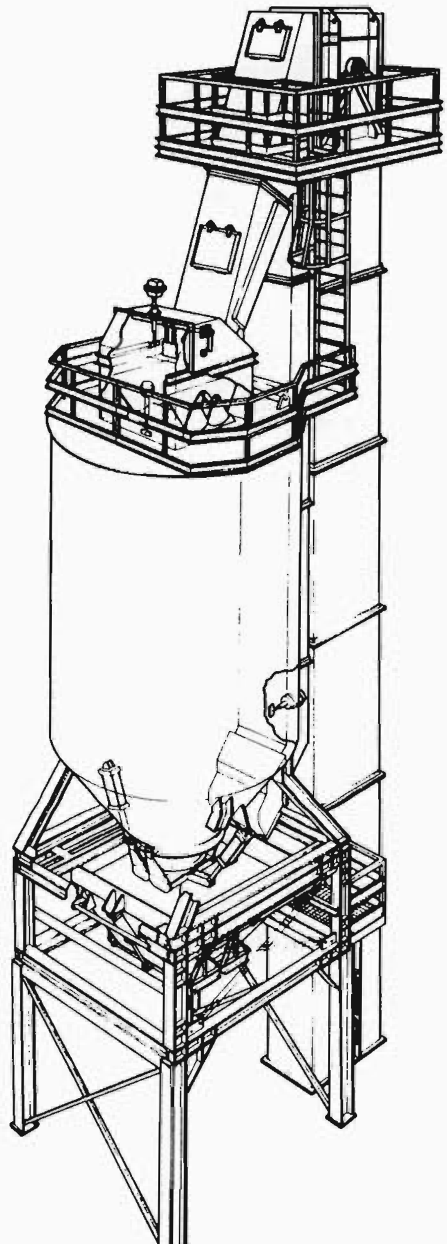


Figure 8.8. Silo weigh batcher (Ref 18).

erator is periodically ignoring the low bin indicator point in the bin and delivering mix to the hauling vehicle even when the level of material in the silo is below the top of the cone. This situation is even more aggravated when the silo is run completely empty. If the pattern is consistent, the operator may be completely disregarding the low level warning point (it may be broken or turned off) and always loading the trucks with the level of mix in the silo beneath the top of the cone.

Even this cause of segregation can be reduced as a potential problem by loading the haul vehicle in at least three drops of mix from the silo to the truck. This lessens the distance that the large particles will roll in the bed, as explained above. Again, it is pointed out that the segregation problem which is started inside the silo can be significantly enhanced by discharging the mix into the truck in only one drop from the surge bin. The larger aggregate pieces roll to the front of the bed and to the tailgate. The segregation that appears on the roadway, therefore, comes in part from the end of one load of material, but also in part from the beginning of the next load.

Even though the mix is segregated in the hauling vehicle, the degree of segregation which appears in the asphalt concrete mat on the roadway can be reduced through a number of actions. First, the tailgate on the haul vehicle should not be pulled until the bed of the truck is raised enough to allow some of the mix in the bed to shift and slide against the tailgate. This permits a greater mass of material to be delivered at one time into the paver hopper, lessening the local percentage of coarse pieces initially discharged into the hopper. Second, the hopper on the paver should be kept partially full between trucks. The mix should not be pulled out of the hopper to the point that the drag slats at the bottom of the hopper are visible. If the hopper is emptied between truckloads, the large aggregate particles will be deposited into the bottom of the hopper and will be pulled first through the paver and spread across the augers and then the mat. If some mix is left in the paver, the new load of material will be combined with this mix, and the percentage of coarser particles in one spot in the mix reduced. Finally, the wings on the paver hopper should not be dumped between every truckload and should never be dumped into an empty hopper. The bigger aggregate tends to collect in the wings of the hopper. When the wings are dumped into the empty hopper, the segregation problem is enhanced.

Although mix segregation starts in the silo, it can be aggravated by the method in which the material is discharged into the haul truck and also by the way the asphalt concrete is delivered to the paver. Attention to the pattern of the segregation, and to its continuity, provides an indication as to the cause of the problem.

CHAPTER 9. AIR POLLUTION CONTROL SYSTEMS

9.1 AIR POLLUTION CONTROL

All drum mix plants have a small amount of dust carryout associated with their operation. Typically, less dust becomes airborne inside a drum mixer than inside a conventional aggregate dryer on a batch plant. It is still necessary, in order to meet the various federal and state air pollution codes, to provide control equipment to capture any particulate emissions which might otherwise be discharged from the drum mixer.

Inside the drum, the aggregate particles are tumbled as the material is transported down the drum by the various types of flights. Some of this aggregate is very small in size, passing the number 50, 100, and 200 sieves (or 40, 80, and 200 sieves). Many of this very fine aggregate is initially free flowing. Others are attached by moisture to larger aggregate particles. As these latter particles move down the drum and are dried, some of this very fine aggregate drop off and become free flowing itself. This very fine aggregate is then susceptible, because of its small size and light weight, to becoming entrapped in the exhaust gas stream inside the drum. The small particles are thus carried into the plant ductwork and to the plant stack. The gas flow inside a drum mixer is a function of the diameter of the drum and the size and speed of the exhaust fan.

A minimum volume of gas must move inside the drum mixer in order for the plant burner to operate properly. This volume is measured in CFM, or cubic feet per minute. For a small diameter drum mixer, the required gas flow might be about 20,000 CFM. For a higher capacity plant, the needed gas flow could range as great as 100,000 CFM. The velocity of the gas, in terms of feet per second, varies with the diameter of the drum and with the amount of aggregate inside the drum. The amount of dust carryout generally increases with the square of the exhaust gas velocity.

The more aggregate that exists inside the drum, the less the amount of particulate carryout. A complete veil of aggregate, across the whole top of the drum area, greatly reduces the amount of dust particles which can be captured in the burner exhaust gases. This is because the airborne dust collides with the larger aggregate particles as the dust is carried down the drum by the gases. The more aggregate in the drum, the less dust that is initially picked up in the gas stream and the more fine particles which are knocked out of the gas by coming in contact with the coarser aggregate.

The amount of dust carryout also can be significantly reduced in many cases by encapsulating the aggregate in the asphalt cement binder early in the heating-drying-heating cycle. In plants where the asphalt cement discharge point is well up toward the burner end of the drum, the coarse and fine aggregate is coated with the binder material while some of the very fine aggregate is still damp. Thus many of the fine particles, which might easily become airborne if they were drier and therefore lighter, can be covered with the asphalt cement before they become caught in the exhaust gases. Typically, with some minor exceptions, the amount of dust carryout increases as the asphalt cement injection line is positioned farther down the drum toward the discharge end of the drum.

The amount of dust carried into the plant air pollution control equipment is a function of the amount of very fine material in the incoming new aggregate, the size, weight, and moisture content of the very fine aggregate, and the type and amount of the very fine particles present in the reclaimed aggregate if a recycled asphalt concrete mix is being manufactured. The operation of the plant is a major consideration, including the production rate (amount of material inside the drum) and location of the asphalt cement discharge pipe. The amount of dust carryout from a drum mix plant can vary widely, but can be altered with a change in the incoming aggregate characteristics and the production process.

Since some dust particles will always escape from the asphalt concrete mix and be caught in the burner exhaust gas stream, air pollution control equipment is needed on a drum mix asphalt plant. Three primary types of collectors can be employed, either singly or in combination with one another. These are: (a) dry collectors, (b) wet collectors, and (c) fabric filters.

In many air pollution control systems used on modern drum mix plants, a dry collector is used in conjunction with either a wet scrubber or a fabric filter (baghouse). The dry collector is sometimes referred to as the primary collector. The wet collector on the fabric filter is then called the secondary collector. The dry collector is used to remove the larger dust particles from the exhaust gas stream. The wet scrubber or baghouse is then used to capture the very fine dust particles. In essence, the dry collector functions to decrease the dust loading on the secondary collector.

9.2 DRY COLLECTORS

Dry collectors, are essentially expansion chambers. The dust-laden exhaust gases exit the rear of the drum mixer and are carried into the ductwork between the drum and the stack. For a given set of plant-operating criteria (aggregate moisture content, production rate, drum slope, etc.), a given volume of gas is pulled through the drum, from the burner end to the discharge end, by the exhaust fan (Figs 9.1 and 9.2). The velocity of that gas varies with the amount of area through which it is moving. As the given volume of gas, in terms of cubic feet per minute, is drawn out of the drum and into the ductwork, the velocity of the dust-laden gas increases. This is due simply to the fact that the cross-sectional area of the duct is considerably less than the area across the drum diameter. Thus, the speed of gas increases in the restricted space for a given volume of gas.

A dry collector is employed to significantly and quickly reduce the velocity of the exhaust gases after they exit the ductwork. It is essentially an expansion chamber with a greater cross-sectional area than the ductwork.

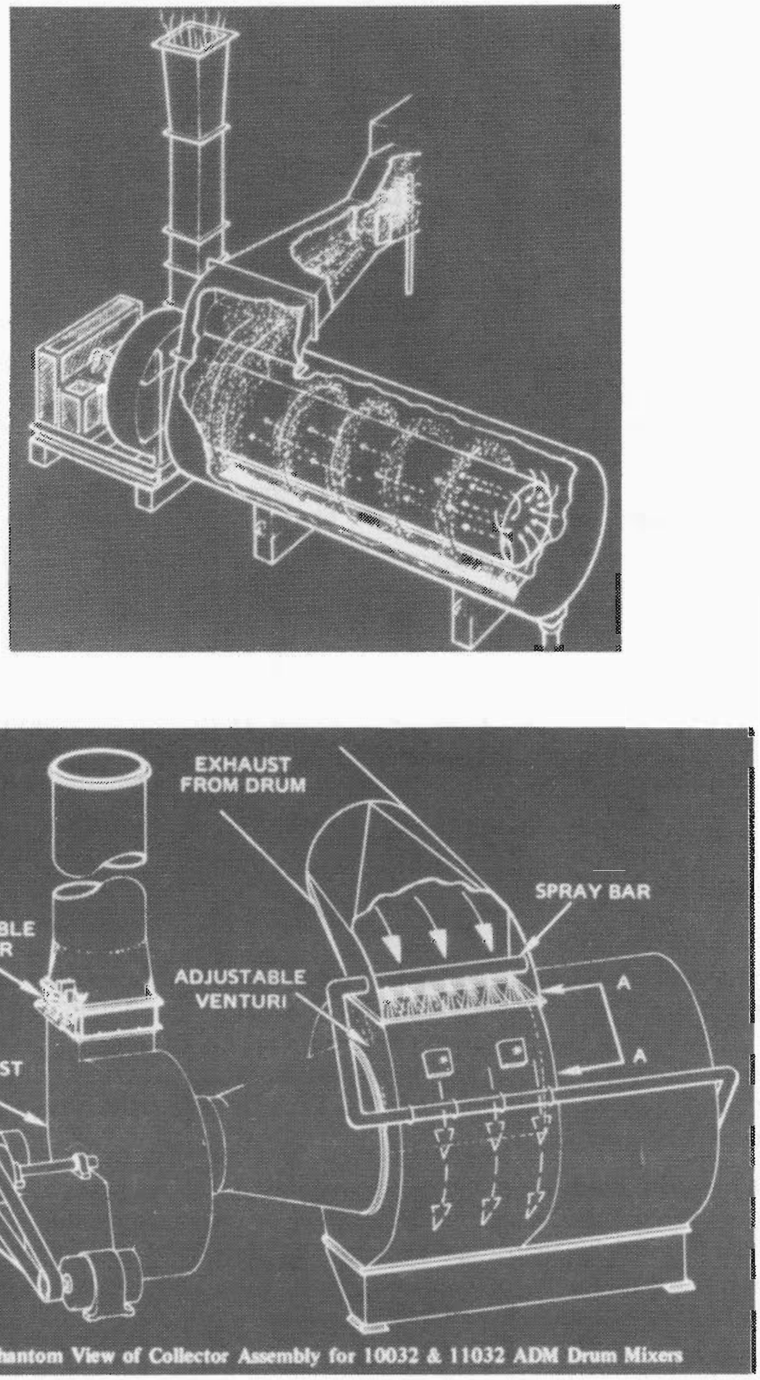
The chamber, also sometimes called a knockout box, allows the speed of the gases to decrease, causing in turn the largest and heaviest of the dust particles to fall out of the gas stream. The size and amount of the dust which leaves the exhaust gases depends on the relative reduction in velocity of the gas as it enters and passes through the dry collector.

The larger, heavier dust particles slow down more quickly than do the smaller, lighter pieces. As these particles leave the gas stream, they fall to the bottom of the dry collector which is typically sloped to allow the material to be concentrated at a central point or along a trough. The dust particles which are caught can then either be wasted or returned uniformly to the drum mix plant.

Dry collectors can have an efficiency of 70 to 90 percent. This means that a dry collector can be used to remove a significant portion, but not all, of the dust found in the exhaust gases. When used in front of a wet collector, the dry collector reduces the amount of dust entering the wet scrubber. This decreases the volume of the sludge produced in the secondary collector. When used in conjunction with a fabric filter, the dry collector makes the baghouse more efficient by eliminating a major portion of the dust which would otherwise enter that equipment. In this case, the dry collector, or knockout box, is often built into the front of the housing of the bag house.

9.3 WET COLLECTORS

Wet collectors work on the principle of wetting the dust particles which are entrapped in the exhaust gases (Fig 9.3). The water droplets hit the dust specks, increase their weight, and cause them to fall out of the exhaust gas stream. The combination of water and dust is then removed from the collector in the form of a watery sludge.



Phantom View of Collector Assembly for 10032 & 11032 ADM Drum Mixers

Figure 9.1. Exhaust fan for wet collector system (Ref 25).

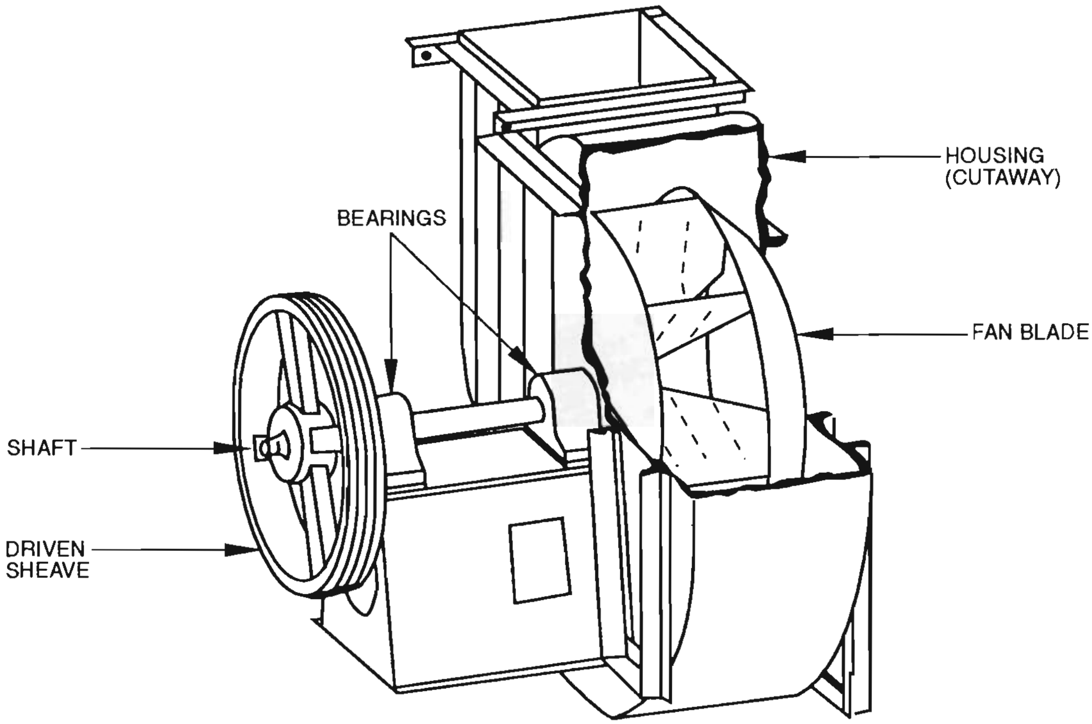


Figure 9.2. Cutaway view of exhaust fan assembly (Ref 35).

The dust-laden burner gases are drawn from the drum mixer by the exhaust fan. After passing through the dry collector (if any) the gases are pulled into the wet collector ductwork. At one point, the gases pass through a narrowed opening, or venturi (Fig 9.4). As the gas flow is concentrated in a small area, it is sprayed with water from multiple nozzles. The water spray wets the dust particles. The exhaust gas and wet dust then move into the separator section of the collector.

In this latter part, the exhaust gases are sent into a circular motion around the circumference of the unit (Fig 9.5). The wetted dust particles, which are relatively heavy, are removed from the exhaust gases by centrifugal force and fall into the bottom of the collector. The clean gas continues to swirl around the collector until it reaches the end, and the cleansed gases are then passed to the plant stack and to the atmosphere.

A wet scrubber system is usually 90 to 97 percent efficient in removing dust particles from the exhaust gas stream. The efficiency rating is a function of the size and amount of the dust in the gases. It is also affected by the volume of water used to spray the particles. If all the nozzles in the scrubber are open and functioning, the wet collector will remove almost all of the dust particles drawn into it. If, however, some of the water spray nozzles are plugged, the efficiency of the wet collector will be reduced.

Another variable which affects the scrubber operation is the cleanliness of the water being used in the system. If the water being sprayed is free from sediment, the wet scrubber will function better than if the spray water is dirty. The amount of dirt in the water depends on the size of the settling pond and water recirculation system used on the drum mix plant.

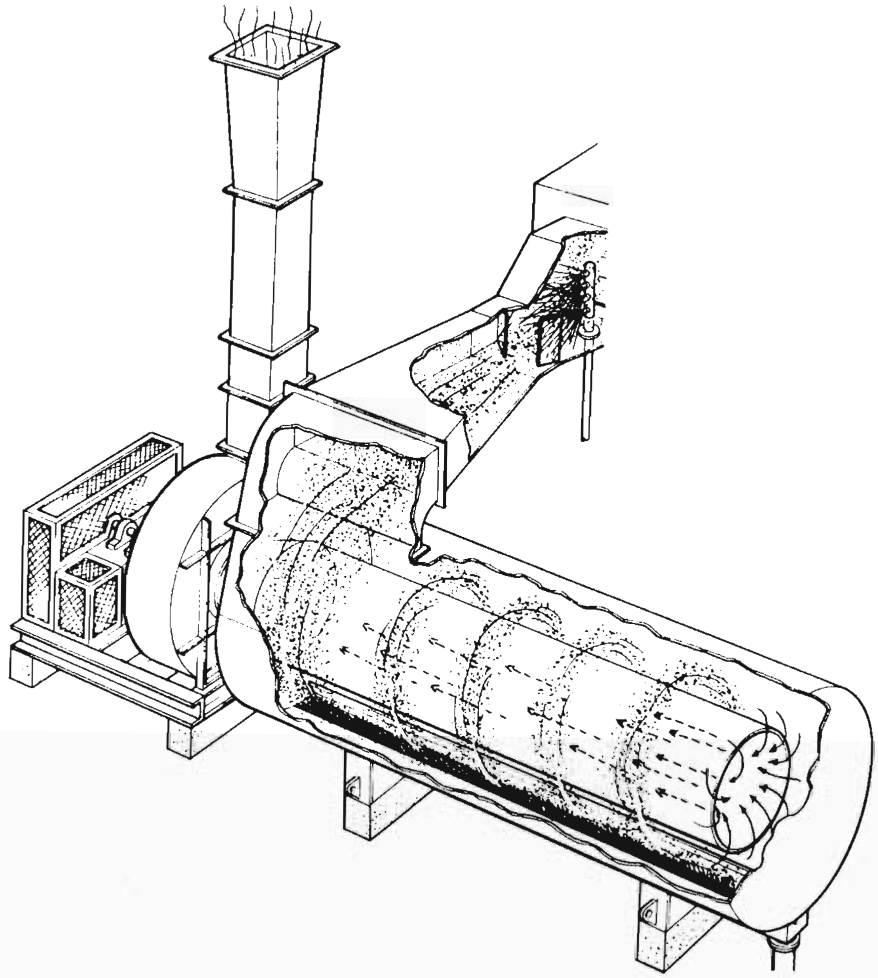


Figure 9.3. Wet collector (Ref 35).

A settling pond is used with most wet collectors in order to decrease the volume of water needed to operate the wet scrubber. The water and dust, in the form of a sludge, is sent from the bottom of the collector, through a pipe, to the pond. Typically the settling pond is divided into several sections, with the dirty water entering the first section continually. Primary separation of the dust from the water occurs in this part of the pond. The heaviest dust particles settle to the bottom of the pond. The cleaner water is drawn off the top of this section through an outlet on the opposite side of the pond from the wet collector inlet pipe. This water continues to lose its dust content, through settlement, as the water passes through one or more additional sections of the pond. In each section, the dirty water enters one side and the cleaner water is drawn off from the far side. The efficiency of the settlement process is directly related to the size of the settling pond: the bigger and deeper the pond, the more water contained in the pond, and the more time available for the dust to settle out of the sludge before the water is circulated back to the scrubber unit.

Settling ponds fill up with sludge. As the pond gets more shallow, the volume of water that can be contained in the pond decreases. This, in turn, reduces the time the water can re-

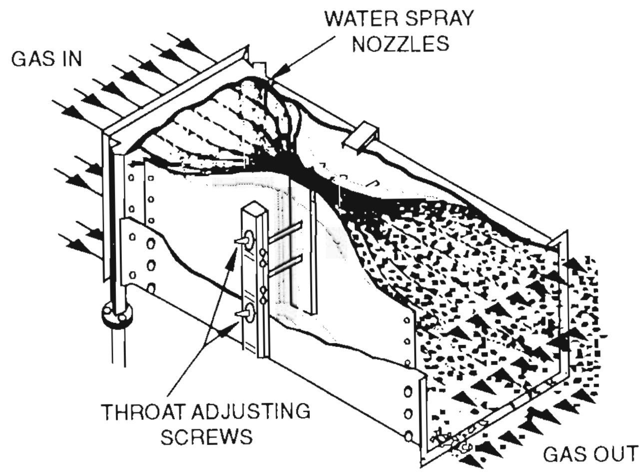


Figure 9.4. Venturi throat (Ref 25).

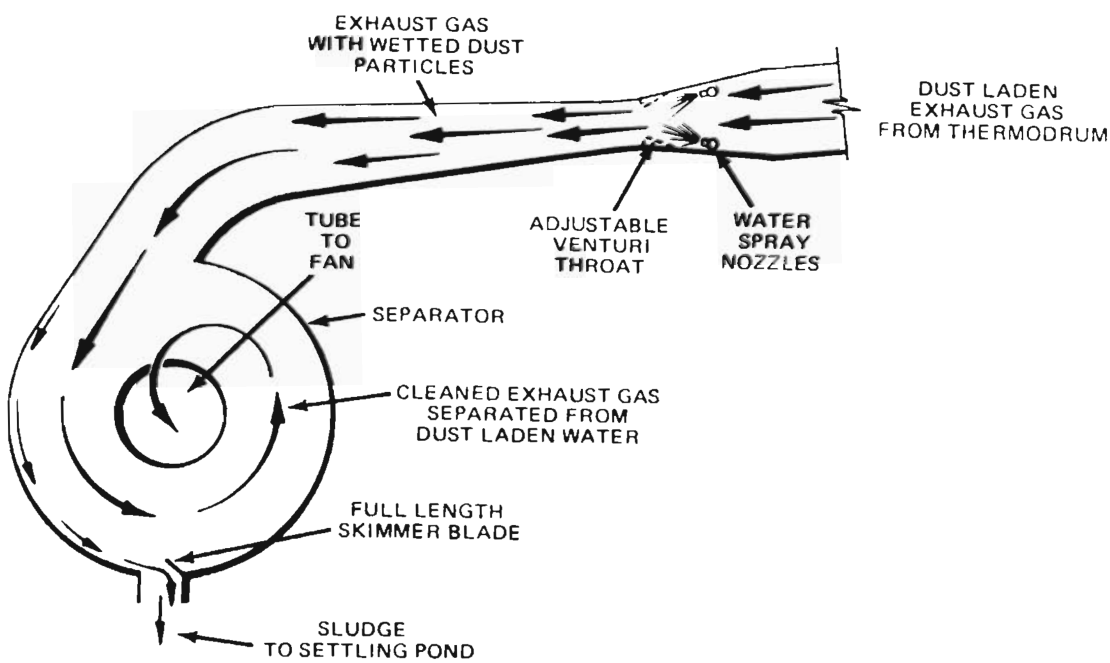


Figure 9.5. Circular motion of exhaust gases in a wet collector (Ref 35).

main in the pond prior to being recirculated. When a pond becomes too shallow, dirty water will be sent back to the wet collector. Thus, it is necessary to periodically remove the sediment from the pond bottom in order to maintain the cleanliness of the scrubber water and the efficiency of the collector. In addition, ponds lose water over time, both through evaporation to the air and through leaks in the piping system. This reduction in the amount of water being used in the system should be corrected periodically in order to maintain the efficiency of the scrubber.

It is obvious that the dust particles carried into the wet collector are lost to the asphalt concrete mix. The material which ends up on the settling pond bottom must be wasted. Thus the gradation of the mix produced in the plant is not the same as the gradation of the incoming new and/or reclaimed aggregate. In some cases, where the amount of dust carryout is not great, the change in gradation will be minimal. If there is a large volume of dust captured in the exhaust gas stream, a significant change can occur in the mix gradation, primarily in the very fine aggregate sizes.

9.4 FABRIC FILTERS

The fabric filter, or bag collector, operates on a simple method. Dust-laden gas from the drum mixer is pulled through a fabric (Fig 9.6). The small openings in the fabric allow the exhaust gases to pass through, but capture the dust particles. The dust is removed from the fabric in one of several ways and falls to the bottom of the baghouse. There it is collected, ready to be wasted or returned to the drum mixer.

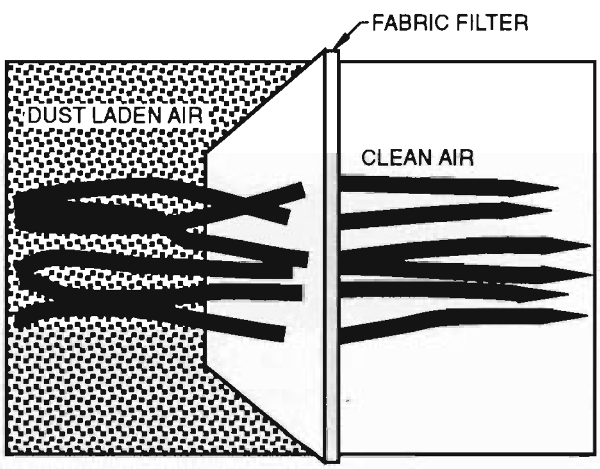


Figure 9.6. Fabric filter (Ref 36).

The dirty exhaust gases coming from the drum mixer are pulled into the ductwork and into the baghouse by the fan (Fig 9.7). In many cases, a primary dry collector (expansion chamber) may be used in front of the first sets of filter bags. In this initial expansion chamber, the heaviest and largest dust particles drop out of the airstream as the gas velocity is decreased.

The material used in the filter cloth is usually a high temperature resistant nylon. This material is able to withstand not only gas temperatures up to 450°F, but also is resistant to high dust loadings, high humidity, and multiple bending and flexing. The fabric is dense enough to catch the dust particles while still permitting the air to pass through. The nylon material will disintegrate, char, or even burn, however, if subjected to exhaust gas temperatures above 450°F.

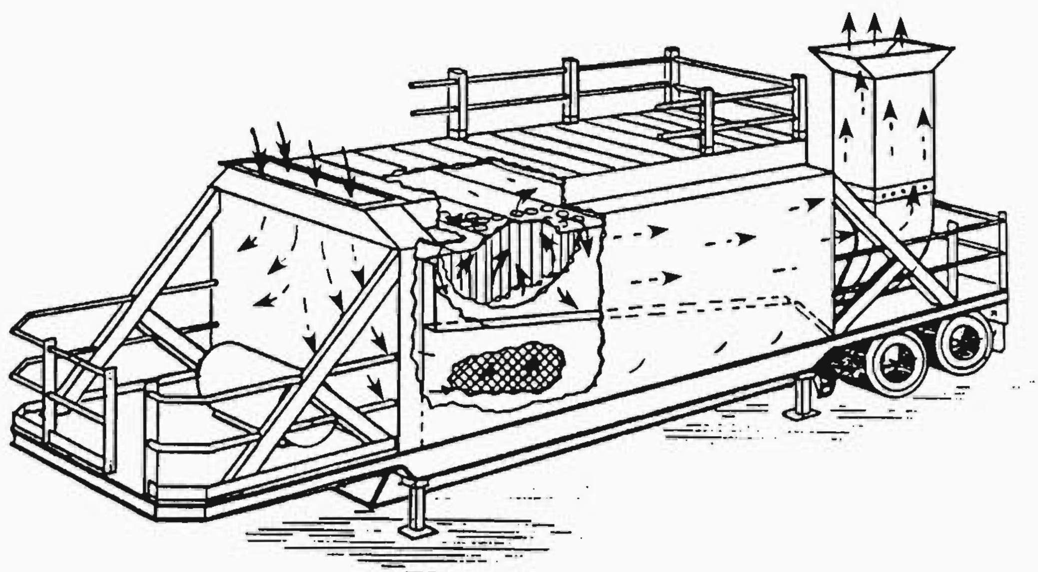


Figure 9.7. Baghouse (Ref 25).

The filter fabric is formed around a circular metal framework or cage. This bag is closed on the bottom but open on the top (Fig 9.8). In order to remove the dust from the plant, multiple bags are employed. These are arranged in rows inside the baghouse. Depending on the volume of air being cleaned, a fabric filter unit can contain from 200 to 800 separate bags (Fig 9.9). The number of bags used also depends on the diameter and length of each individual bag. The filter area of each bag is calculated from the amount of fabric around each bag. In general, one square foot of filter cloth area is needed to clean from 5 to 7 cubic feet per minute (CFM) of exhaust gas. This air to cloth ratio, 5 to 7 CFM per square foot of filter area, can vary with a number of operating conditions. A typical air-to-filter-cloth ratio, however, is 6:1. The number of bags needed in the baghouse (for a given diameter and length of bag) is determined by taking the air-to-cloth ratio value (CFM per square foot of filter area) divided into the total CFM of the burner exhaust gases.

There are two sections to any baghouse, the dirty gas side and the clean gas side (Fig 9.10). The exhaust fan pulls the dirty gas from outside of the circular fabric filter through the material. The dust particles are caught on the outside surface of the bag. The exhaust gases, relieved of their dust, are carried out the top of the bag and to the stack. The dust particles, stopped on the outside of the bag, build up with time and form a dust cake or coating on each bag. This coating is important to the efficiency of the baghouse. If the bags are clean, only the coarser dust particles will be captured and the finer specks will pass through the fabric. If the bags are completely blinded, however, the gas will be unable to go through the dust cake, and the baghouse will stop functioning. Thus, for maximum efficiency, the dust cake must be periodically removed from the filter fabric surface. This is accomplished by cleaning the bags.

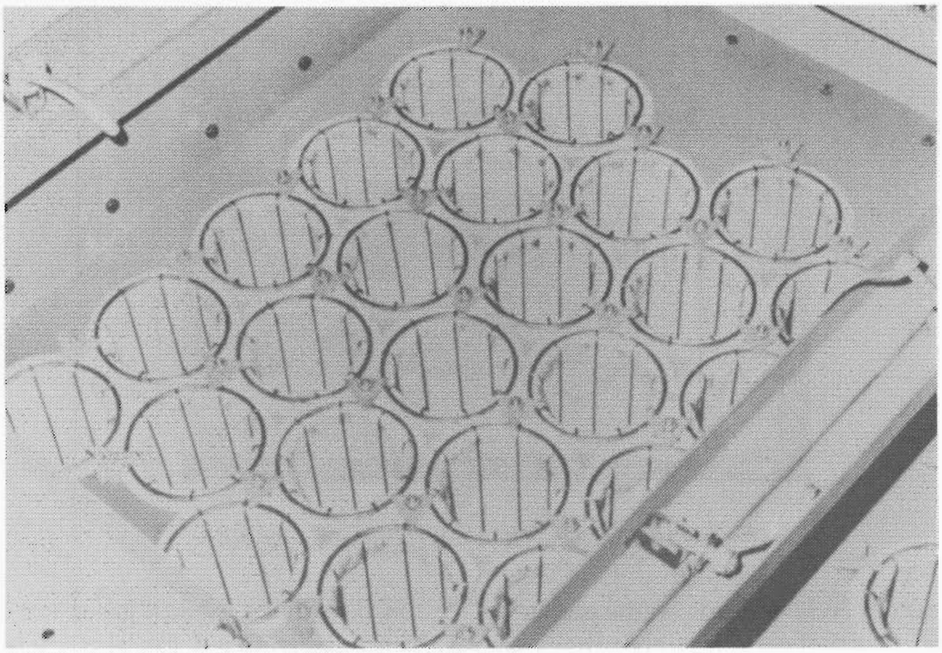


Figure 9.8. Bags and wire cages (Ref 37).

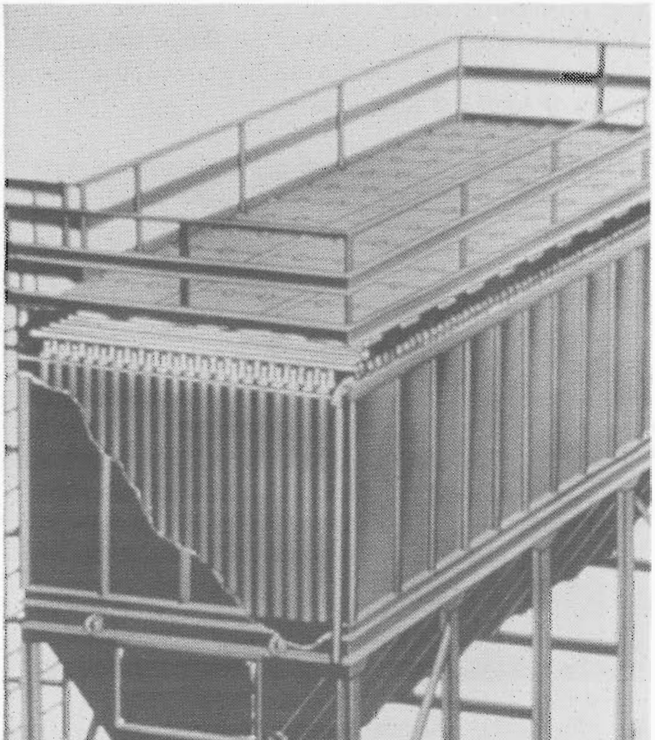


Figure 9.9. Typical baghouse (Ref 37).

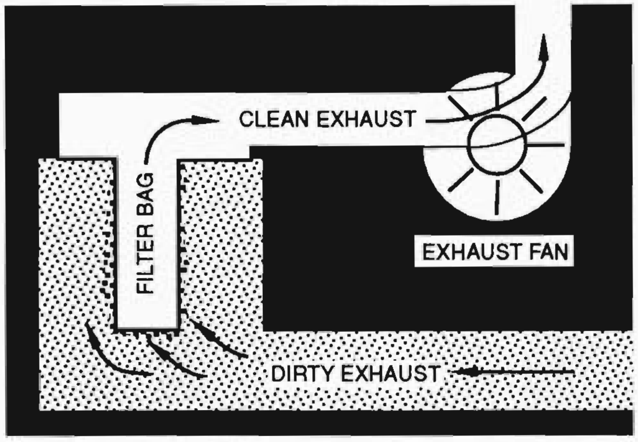


Figure 9.10. Dirty and clean side of baghouse (Ref 36).

The cleaning cycle depends on the amount of dust loading in the exhaust gases and on the size of the dust particles. Bags are usually cleaned in groups so that some bags are heavily coated with dust while some are only partially covered and some are being cleaned. The cleaning occurs by flexing or shaking the bags, backflushing them with a pulse of clean air, or a combination of both procedures (Fig 9.11). In most cases, the reverse air pulse is used. The dust cake on the bag is blown free as the jet of air flexes the bag from the inside. The dust particles then fall to the bottom of the baghouse. In general, the cleaning cycle occurs for a few seconds every minute or so of gas flow time.

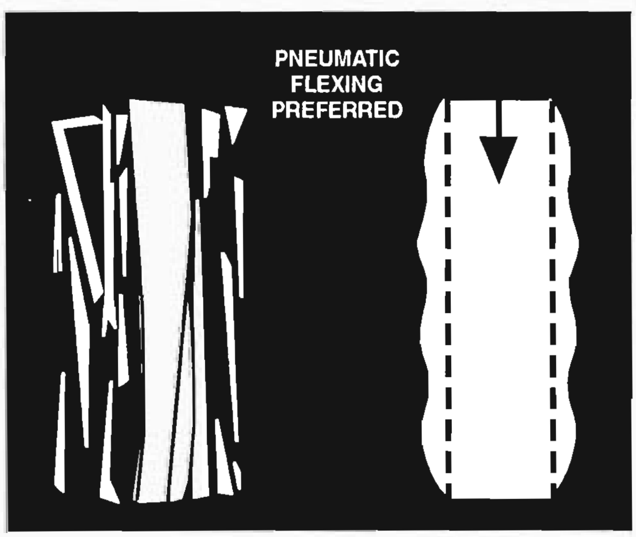


Figure 9.11. Method of cleaning bags (Ref 36).

A baghouse can remove up to 99.9 percent of the dust particles in the exhaust gas stream. This efficiency, however, is dependent on several factors. The flow of the gas into and through the bags is restricted by the filter fabric itself and by the dust coating on the bags. This degree of resistance is measured as a pressure drop between the dirty side and the clean side of the bags. The pressure drop, given in inches of water, is typically between 2 and 6 inches (Fig 9.12). A low pressure drop, 1 to 2 inches, indicates that the bags are quite clean. This means that some very fine dust particles are probably passing through the filter cloth. A high pressure drop (over 6 inches), on the other hand, shows that the dust buildup on the bags is excessive and that the gas cannot be effectively pulled through the drum and the baghouse. This can result in a substantial reduction in the capacity of the drum mixer.

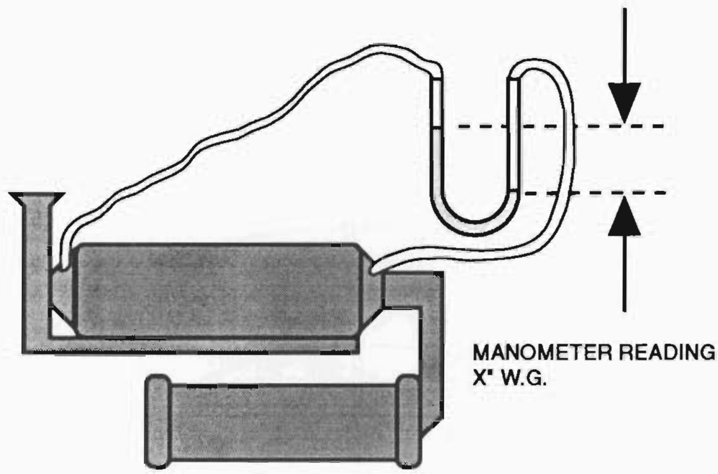


Figure 9.12. Pressure drop across bags (Ref 36).

The efficiency of the baghouse can also be decreased if the dust coating becomes a mud coating, thereby blinding the bags. This problem occurs when the temperature of exhaust gases entering the baghouse is below the dew point — the temperature to which air must be cooled for dew (condensed moisture) to form. The moisture, combined with the dust in the air, forms a mud on the surface of the bag. This heavy, wet coating cannot be easily removed during the bag cleaning cycle. If this happens, the pressure drop across the bags increases significantly, reducing the efficiency of the baghouse and even choking off the burner flame in extreme cases.

To prevent mud from collecting on the bags, the fabric filter system must be preheated before mix production is commenced each day. This is accomplished by operating the plant burner in the low fire position for a period of time, with no aggregate in the drum. The heated air, pulled into the dust collector by the exhaust fan, will in turn raise the temperature inside the baghouse above 200°F. This preheating operation will reduce the possibility of water from the aggregate (turned into water vapor inside the drum during the drying process) condensing on the fabric filter surface.

The nylon bags, when subjected to temperatures above 450°F, can char, disintegrate, and burn. The baghouse thus should be protected from high temperatures by automatic shutdown devices (Fig 9.13). In this regard, one or more temperature sensors are usually located upstream of the baghouse, in the ductwork at the end of the drum mixer. The sensor is typically set at a temperature of 400°F. If the temperature of the exhaust gases entering the ductwork exceeds this value, the sensor immediately shuts off the burner by stopping the fuel flow. This prevents damage to the bags and the housing.

The dust collected in a fabric filter is deposited at the bottom of the baghouse. The sloping sides of the housing near the bottom funnel the dust particles to collection troughs. Screw conveyors remove the collected dust from the baghouse. The material is carried through an air lock system to a transfer point and is either wasted or fed back into the drum mix plant.

The gradation of the asphalt concrete mixture produced in the drum mix plant will be different depending on whether or not the baghouse fines are returned to the plant. If the collected dust is wasted, the mix will be somewhat coarser than if the material is fed back into the drum. If the dust is returned to the plant, the mix gradation will more nearly equal the gradation of the incoming new and/or reclaimed aggregate. It is very important, however, for the baghouse fines to be delivered to the drum mixer continuously and uniformly rather than in slugs. This is usually accomplished in one of two ways: either by pneumatically conveying the dust particles directly from the baghouse to the rear of the drum or by first placing the baghouse material in a fines storage silo and then metering the material back into the drum through the fines feed system.

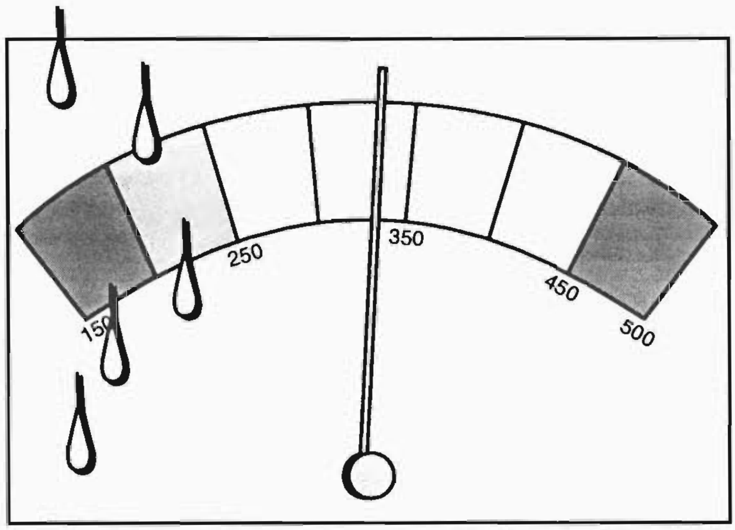


Figure 9.13. Temperature range for baghouse operations (Ref 36).

CHAPTER 10. BATCH PLANTS

Batch plants produce asphalt mixtures in distinct batches, rather than as a continuous flow or stream of material. The maximum size of a batch is controlled by the capacity of the pugmill mixing chamber. Typically, batch sizes are about 6000 pounds, but generally can range from 3,000 to 12,000 pounds.

Batch plants originated around 1870 (Ref 12) when the basic asphalt plant operations of drying, screening, proportioning, and mixing were combined. Since that time, they have been improved significantly by means of new components, automated and computerized control systems, and improved noise and dust control. Nevertheless, the basic equipment for drying, screening, proportioning, and mixing has not changed much during the past 40 or 50 years.

With the exception of the limited use of continuous asphalt plants (Chapter 1), the batch plant has been the mainstay of the hot-mixed asphalt concrete paving industry until the widespread use of drum mix plants began in the early 1970's. In the late 1980's, approximately 70 percent of all asphalt plants in operation were batch plants; however, batch plants produced only an estimated 40 percent of the hot-mixed asphalt concrete used for paving. In addition, about 95 percent of the plants being manufactured and sold at that time were drum mix plants. Thus, while a large number of batch plants were used, most of the production was from drum mix plants. It is also apparent that the percentage of batch plants will decrease as many existing batch plants are retired and replaced with drum mix plants. Nevertheless, there are, and probably will be in the near future, a large number of batch plants in operation.

10.1 BATCH PLANT OPERATIONS

An asphalt batch plant, whether portable or stationary, must perform the following basic operations (Fig 10.1): (a) aggregate storage and cold feeding, (b) aggregate drying and heating, (c) screening and storage of hot aggregate, (d) storage and heating of asphalt cement, (e) measuring and mixing of asphalt and aggregate, and (f) loading of finished asphalt mixture (Ref 12). The major components of a typical batch plant are illustrated in Figure 10.2.

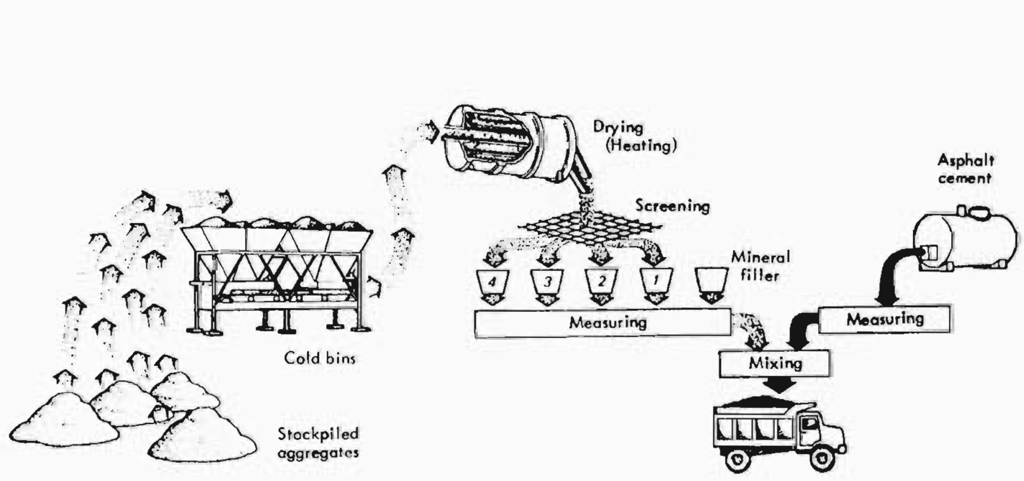


Figure 10.1. Schematic of batch plant operations (Ref 12).

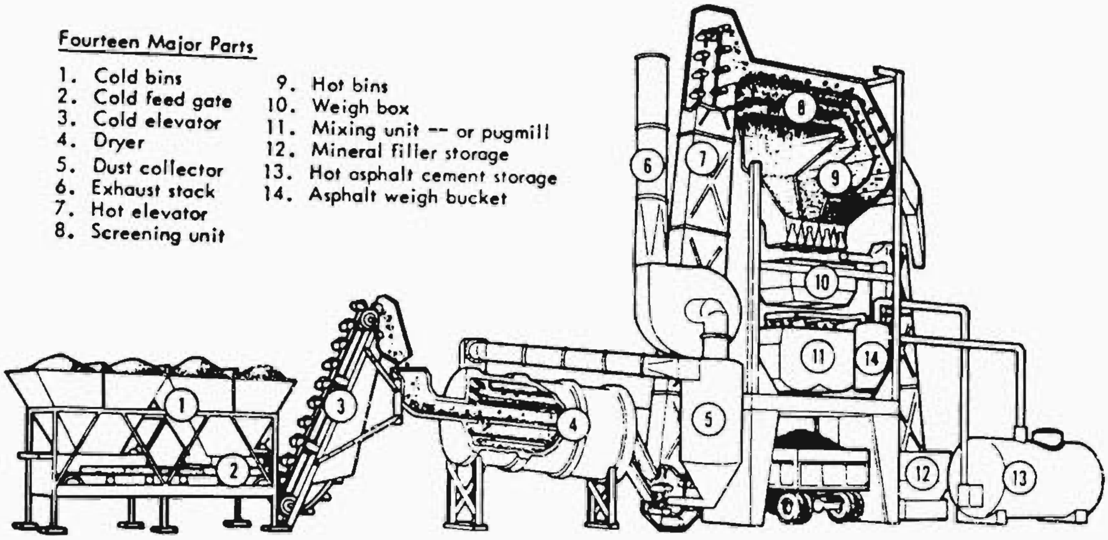


Figure 10.2. Major components of a batch plant (Ref 12).

Unheated aggregate is obtained from the stockpile and placed in the cold feed bins (1) [Note: numbers in parentheses refer to components shown in Fig 10.2]. The aggregate is proportioned by cold feed gates (2) onto a belt conveyor or bucket elevator (3), which transports the material to the upper end of the dryer (4) where it is dried and heated.

Undesirable dust in the dryer exhaust is removed by a dust collector (5), which consist of a dry collector, a wet collector, a fabric filler (baghouse), or a combination of devices. The fines collected are either wasted or returned to the plant for incorporation into the mixture. The gases are then exhausted to the atmosphere (6).

The dry heated aggregates are delivered by a hot elevator (7) to the screening unit (8). The aggregate is passed through the screens and separated into normally four different sizes and deposited into separate hot bins (9) for storage. As needed, the heated aggregate is measured by weight into the weigh box (10). The aggregate, along with mineral filler from storage (12), are then deposited into the mix chamber or pugmill (11). Generally, the aggregate is dry mixed for a second or two. Then heated asphalt cement, which has been pumped into the asphalt weigh bucket (14) from storage (13), is sprayed into the pugmill where it is mixed thoroughly with the aggregate and mineral filler. The asphalt mixture is then loaded into trucks or stored.

If a reclaimed asphalt mixture is being used, the reclaimed material can be introduced into the plant at the following points: (a) into the bottom of the hot elevator (7), (b) into the hot bins (9), or (c) into the weigh hopper (10). Regardless of the method, the reclaimed material, which is unheated, is added to superheated new aggregate.

Batch plants operations can be manual, semiautomatic, or automatic. In the semiautomatic plants, all operations from the weigh box discharge to the pugmill discharge are automatically controlled. In the fully automatic plant, all operations are controlled and will repeat themselves once the mix proportions and timers are set.

The various components and processes are discussed in the following sections. However, because many of these processes are the same or very similar to those used by drum mix plants, the reader will be directed to the appropriate section of the manual, and only the differences between the operation of the two types of plants will be highlighted.

10.2 AGGREGATE STOCKPILING

While stockpiling techniques are not quite as critical for batch plants as for drum mix plants, it is recommended that the procedures described in Chapter 2 be followed. These techniques will minimize the variation and corrections required by the batch plant and will improve the quality and uniformity of the final mix product.

10.3 COLD FEED SYSTEM

The cold feed system includes cold feed bins, feeder conveyor, gathering conveyer, scalping screen, charging conveyor, and reclaimed material bins and conveyor. Most of the equipment and processes are essentially the same as for drum mix plants and have been discussed in detail in Chapter 3.

As with drum mix plants, the course and fine aggregate of different sizes are placed into separate cold feed bins (Fig 4.2). Each bin should be kept filled to insure a uniform flow of material with no interruptions. This uniform flow from each bin is necessary for the following reasons: (a) an erratic or incorrect proportioning of aggregate could cause an overfilling of hot bins while starving others; (b) an excessive amount of a specific aggregate at the cold feed can overload the dryer or the hot screens; and (c) a wide variation in the quantity of aggregate at the cold feed bin can cause a considerable change in the temperature of the aggregate leaving the dryer and a variation in the temperature of the asphalt concrete mixture.

While in theory, a batch plant can correct for minor variations in aggregate feed rate and proportions, it is recommended that the cold feed system be operated with the same care required for drum mix plants.

Newer model batch plants operate with semifixed gate openings and variable speed feeder belts. On older plants, however, the feeder belt ran at a fixed speed and the gate openings had to be changed in order to vary the production rate.

Since the cold feed system for a batch plant does not contain a weigh system, it is extremely important that the aggregates being delivered to the dryer be monitored both visually and by means of a sieve analysis to insure a correct, uniform flow of aggregate. Gate opening indicators should be checked periodically to insure that the gate openings are correct. In addition, variations can be caused by roots or other debris clogging the gates, by aggregate bridging over the gates, or by nonuniform flow resulting from moisture in the aggregate.

10.4 AGGREGATE DRYING AND HEATING

The batch plant dryer is a revolving cylinder or drum with a diameter of 5 to 10 feet and a length of 20 to 40 feet. The function of the dryer is to remove moisture from the aggregate and to heat the aggregate to a specified temperature.

Aggregate is introduced into the dryer at the upper end and flows through the dryer by gravity as it rotates. Simultaneously, a burner at the lower end heats the air which is pulled toward the upper end of the dryer by the fan. This flow is in the opposite direction to the aggregate flow. Thus, batch plant dryers involve a counterflow process (Fig 10.3), as opposed to a parallel flow process (Fig 10.4) used in most drum mix plants.

Another major difference between dryers and drum mixers is the shape of the flame. The burner flame on a dryer is generally long, thin, and extends well into the dryer. The flame on a drum mixer is generally short and bushy (Figures 10.5 and 10.6).

The dryer is also equipped with flights which lift the aggregate and cascades it through the burner exhaust gases (Fig 10.7). As with drum mixers, this action forms a veil which is important to the drying and heating of the aggregate as previously discussed.

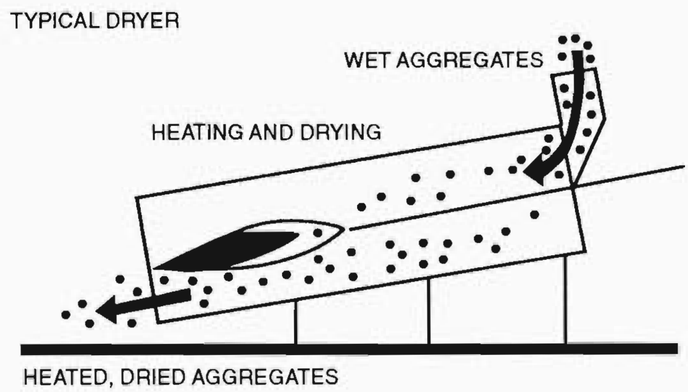


Figure 10.3. Counterflow process of a dryer (Ref 9).

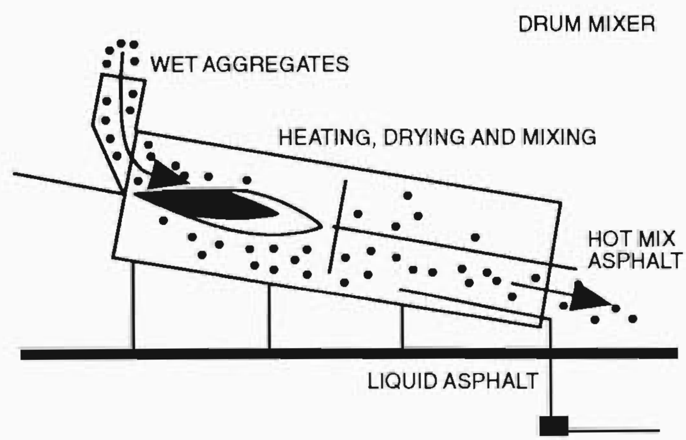


Figure 10.4. Parallel flow process of a drum mixer (Ref 9).

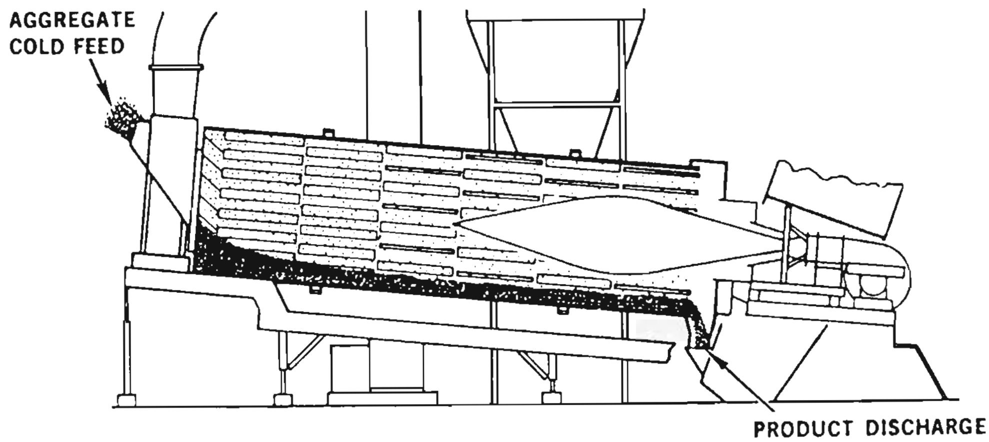


Figure 10.5. Aggregate dryer with long, slim flame (Ref 23).

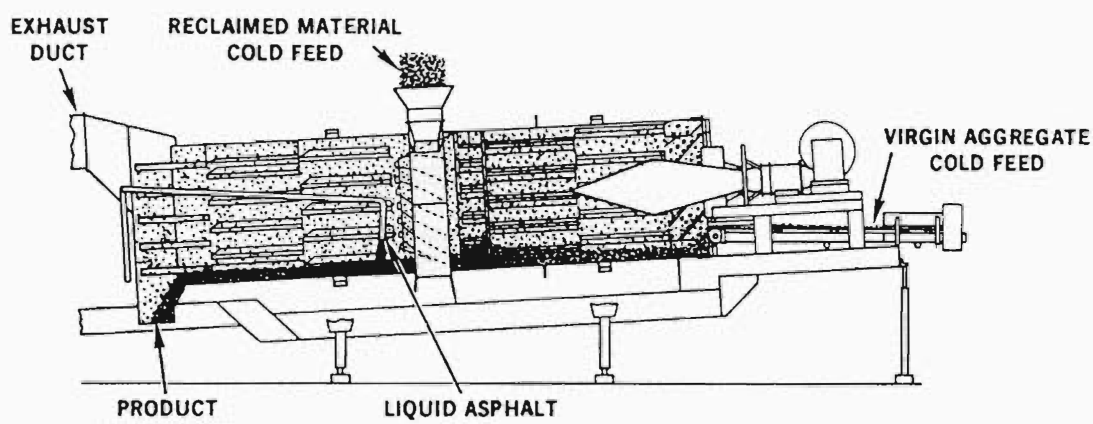


Figure 10.6. Drum mixer with short, bushy flame (Ref 23).

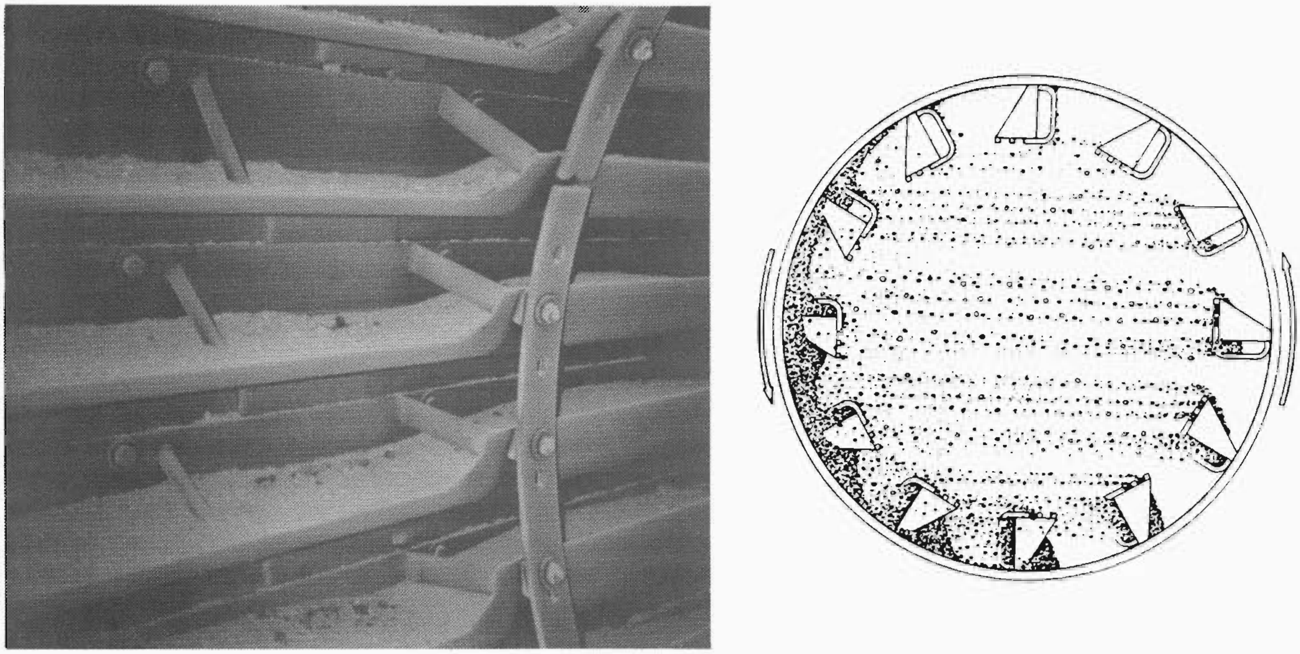


Figure 10.7. Typical flights and function (Ref 12).

The temperature of the final mixture is, for the most part, dependent on the aggregate temperature. Thus, excessive heating of the aggregate can cause excessive hardening of the asphalt cement. Insufficient heating of the aggregate, on the other hand, will make it difficult to coat the aggregate with asphalt cement.

10.5 SCREENING AND STORAGE OF HOT AGGREGATE

The heated aggregate is transported by a hot elevator to the screen deck to separate the aggregate into various specified sizes and to deposit these fractions in hot bins.

Hot Screens

The screen unit contains a set of different sized vibrating screens. As shown in Fig 10.8, there are four screens. The first is a scalping screen which intercepts oversized material. Normally, there will be three additional screens which will separate the aggregate into four size ranges and deposit these materials into four hot storage bins. The number of bins used will vary from 2 to 4 depending on the type of mix being produced.

To be efficient, the screen area must be balanced with the dryer production, the aggregate proportions supplied from the cold feed bins, and the capacity of the pugmill. If an excessive amount of aggregate is delivered to the screens, or if the screens are plugged, material which should have passed through the screens and into one particular bin will ride over the screens and drop into a larger size bin. If the screens are worn or torn, oversized material will go into hot bins designated for smaller size particles. This will cause a change in the gradation of the aggregate incorporated in the mix and may cause a change in mix properties.

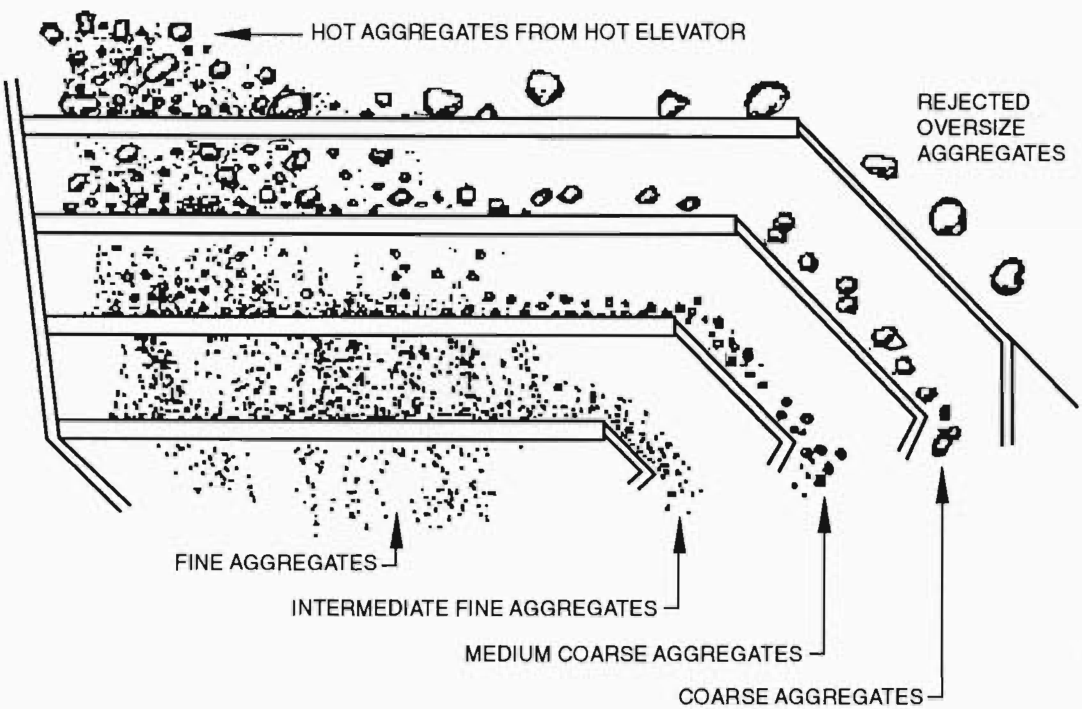


Figure 10.8. Hot screening unit (Ref 12).

Hot Bins

The heated aggregate is stored temporarily by size in the hot bins. The bins should be large enough to store enough material to allow the pugmill and plant to operate at capacity. The number one bin contains the fine aggregate and is the largest of the four bins.

The partitions between bins must prevent intermingling of the different sized aggregates and, therefore, should be periodically inspected for holes. Hot bins should have mechanical or electronic detectors to indicate when the aggregate is below a specified level. In addition, each bin should have an overflow pipe to prevent buildup of an excessive amount of aggregate which could result in overflow into the adjacent bin. Such an aggregate buildup can blind the screen avbove the hot bin, resulting in excessive carryover of one size aggregate into the adjacent hot bin. If an excess or shortage of aggregate occurs in the hot bins, appropriate adjustments at the cold feed bins should be made immediately.

Fines often build up in the corners of the fine aggregate bin. When the bin levels are low these collected fines can break loose producing excessive fines in the mix. Fillets welded in the corners of the sand bin will help minimize this problem. In addition, moisture vapor from the air or aggregate can condense on the hot bin walls. This moisture can accumulate fines which will later be deposited in a surge into the weigh hopper and into the pugmill. Thus, dust from the baghouse or mineral filler should be placed in the weigh hopper directly and not placed in the fines bin.

Another potential problem is worn gates at the bottom of the hot bins which will allow material to leak into the weigh hopper and alter the aggregate gradation in the asphalt concrete mixture.

Proportioning from the Hot Bins

When the plant is operating, it is necessary to check the gradation of the aggregate in each bin and determine the amount of material which must be withdrawn from each hot bin to meet the job mix formula. This is essentially a trial and error procedure which can be done manually or with the aid of a desktop computer or programmable calculator. The following example is taken from "Construction Bulletin, C-14," of the Texas State Department of Highways and Public Transportation. It should be noted that all other states operate on the basis of percent passing or retained.

Example. The design mixture contains 6.8 percent asphalt and 93.2 percent aggregate by weight of total mixture. The specified gradation of the aggregate is as follows:

Passing-Retained Sieve Size	Grading Analysis Total Aggregate (% by Weight)
1/2"-3/8"	1.4
3/8"-4	39.6
4-10	23.9
10-40	14.0
40-80	10.8
80-200	6.9
Pass 200	3.4
	100.0

The aggregate is proportioned from the cold feed bins to meet the specified gradation and is subsequently passed through the dryer, separated by the screens and placed in at least two to four hot bins depending on the type of asphalt mixture being produced. In this example 3 bins are used.

A sieve analysis produced the results shown in Figure 10.9. Trial and error is used to determine the percentage of aggregate needed from each bin. Bins No. 2 and 3 have one dominant size that will satisfy the percentage required in the completed mixture. Begin with Bin No. 3 and try a percentage that, when multiplied by the dominant size in that bin, will give a percentage a little below that of the trial design. It is assumed that a small percentage of that size will be obtained from Bin No. 2. Use the same procedure for Bin No. 2.

Most of the plus 10 material is obtained from Bins No. 2 and 3, and thus the total plus 10 material should be reasonably close to the specified mixture design by establishing the percentages for Bins No. 2 and 3. It generally can be expected that the percentage obtained from Bin No. 1 (minus 10 material) will be close to the trial mixture design.

Revised: April, 1984

State Department of Highways &
Public Transportation
Construction Form No. 544 Rev. (2)

STATE DEPARTMENT OF HIGHWAYS & PUBLIC TRANSPORTATION
ASPHALTIC CONCRETE SIEVE ANALYSIS WORK SHEET

County: Monroe Highway: S. H. 2000 Project: F 1(234) Control: 5 6-7

Date: 9-4-67 Time: ______ Station: ______ Sampled By: ______

Spec. Item: 3 4 0 Type: D Design No.: Selection of Grading

Sieve Size	Aggregate A Bin No. 1 (a) Weight (grams)	Total % ×	60.0 %	Aggregate B Bin No. 2 (b) Weight (grams)	Total % ×	30.0%	Aggregate C Bin No. 3 (c) Weight (grams)	Total % ×	10.0 %	Bin No. 4 (d) Weight (grams)	Total % ×	%	Combined Analysis % (a + b + c + d)	Spec
~~[illegible]~~														
~~[illegible]~~														
~~[illegible]~~														
1/2"-3/8"	33	2.3	1.4	0	0.0	0.0	0	0.0	0.0				1.4	0-15
3/8"-4	952	66.0	39.6	0	0.0	0.0	0	0.0	0.0				39.6	21-53
~~[illegible]~~														
4-10	440	30.5	18.3	151	18.6	5.6	0	0.0	0.0				23.9	11-32
+ 10			59.3			5.6			0.0				64.9	54-74
10-40	9	0.6	0.4	365	45.0	13.5	3	0.8	0.1				14.0	6-32
40-80	6	0.4	0.2	136	16.8	5.0	225	56.2	5.6				10.8	4-27
80-200	3	0.2	0.1	72	8.9	2.7	163	40.7	4.1				6.9	3-27
Pass 200	0	0.0	0.0	87	10.7	3.2	9	2.3	0.2				3.4	1-8
Total	1443 gm	100.0%	60.0 %	811 gm	100.0%	30.0 %	400 gm	100.0%	10.0 %	gm	100.0%	%	100.0 %	

PER CENT MOISTURE IN AGGREGATES IN HOT BINS

Bin No.	(a) Tare Wt. (gms.)	(b) Gross Wet Wt. (gms.)	(c) Gross Dry Wt. (gms.)	(d) Wt. Moist. (gms.) b-c	(e) Dry Wt. Aggr. (gms.) c-a	% Moist. $\frac{d}{e} \times 100\%$
1						
2						
3						
4						

Asphaltic Binder = ______ %

Total = 100.0%

John Doe

Inspector

Figure 10.9. A sample sieve analysis work sheet.

If the figures based on the first sieve analysis are unrealistic, the values should be discarded and, if necessary, the cold feed gates should be adjusted, the hot bins should be emptied, and new samples secured. Sieve analyses should be conducted of the aggregate from each bin and the procedure repeated.

After one or more trials it is determined that by using 33.1 percent from Bin No.1, 24.0 percent from Bin No. 2, and 42.9 percent from Bin No. 3, the mixture will satisfy the specification. Then the calculation of bin weights can be made.

The batch weights for a 3,000-pound batch will be:

Bin No. 1	33.1% X 0.932 X 3000	=	925 pounds
Bin No. 2	24.0% X 0.932 X 3000	=	671 pounds
Bin No. 3	42.9% X 0.932 X 3000	=	1200 pounds
Asphalt	6.8% X 3000	=	204 pounds
			3000 pounds

10.6 WEIGH HOPPER/WEIGH BUCKET

In contrast with drum mix plants where the individual aggregates are controlled at the cold feed bins and the total aggregate being introduced in the mix is measured by the weigh bridge on the charging conveyor, a batch plant weighs the aggregate taken from the hot bins by means of a weigh hopper. The weigh hopper is suspended from a scale and cumulatively weighs the various aggregates. The coarse aggregate is usually placed first into the weigh hopper followed by finer and finer material. This sequence minimizes the loss of fines through the discharge gates allowing the fines to fill the voids in the coarser aggregate and partially mixes the aggregate together.

At the same time, the asphalt cement is pumped into a weigh bucket prior to being sprayed into the pugmill.

Calibration

The weigh hopper and weigh bucket should be checked with standard weights. Normally ten 50-pound standard weights are used. Prior to checking, the hot bins should be loaded to capacity. Then the test weights should be attached to the weigh hopper or weigh hopper scale beam while the screens are running. The exact dial reading for 500 pounds of weight should be recorded. The weights are removed and aggregate is placed in the weigh hopper until the same dial reading is achieved. The procedure is then repeated until the total batch weight is achieved.

The asphalt cement scale is calibrated in a similar manner. The standard weights are placed on, or are attached to, the weigh bucket and the dial readings are recorded as each weight is added.

10.7 PUG MILL MIXING

From the weigh hopper, the aggregate is deposited into the pugmill which is a twin-shaft mixer. The mixer consists of a mixing chamber with two horizontal shafts that have paddle shanks mounted on each. Each shank has two paddle tips which are adjustable and easily replaced (Fig 10.10).

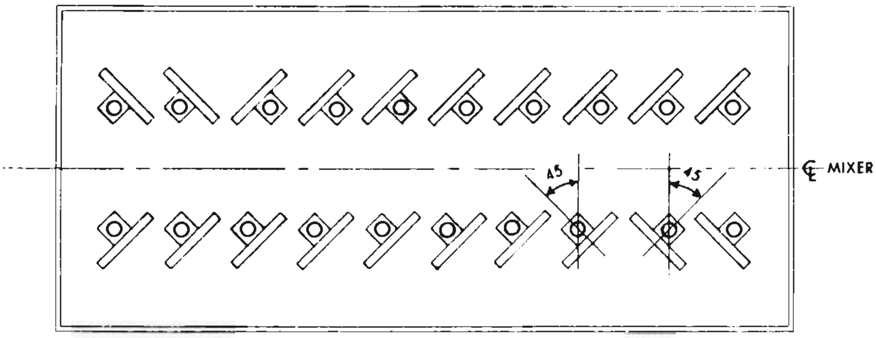


Figure 10.10. Typical paddle arrangement for pugmill (Ref 12).

Paddles should be set to move the mixture around the mixing chamber and to prevent dead areas. Generally, the distance between paddle tips and liner should be less than half the maximum aggregate size. If the distance is greater than this, a dead area can develop where material will not be adequately mixed and coated with asphalt. Dead spots can also develop when two or more adjacent paddles are missing.

The pugmill should be operated with batches that are equal to the recommended batch rating for the plant, which is based on the capacity of the live zone (Fig 10.11). If too much material is introduced into the pugmill, the material above the paddle tips will tend to stay at the top and not be mixed (Fig 10.12). Similarly, if a small batch is placed in the pugmill, the material will not be mixed because there is not enough material to be carried and moved by the paddles (Fig 10.13).

After the aggregate is introduced into the pugmill, the aggregate generally is mixed for a very short time (dry mixing) prior to introducing the asphalt cement. The asphalt cement is then sprayed uniformly over the aggregate and mixing continues (wet mixing). The mixing time should be as short as possible and still obtain a uniform coating of all aggregate particles and a uniform distribution of all aggregate sizes. An excessive mixing time significantly affects production and exposes the asphalt cement to oxygen which results in hardening (aging). It is questionable whether dry mixing produces any significant benefits and should be minimized (usually limited to one second).

Mixing total times can be established by the procedure described in AASHTO T195 or ASTM D2489 (Ross Count). To determine a Ross Count, or degree of partial coating, take a sample of hot asphalt mixture screened to obtain particles larger than 3/8 inch. Each particle should be visually examined and classified as partially uncoated or completely coated. The Ross Count is computed as follows:

$$\text{Ross Count} = \frac{\text{Number of Completely Coated Particles}}{\text{Total Number of Particles}} \times 100$$

The minimum wet mixing time is typically equal to the time required to coat 95 percent of the coarse aggregate (Ref 12).

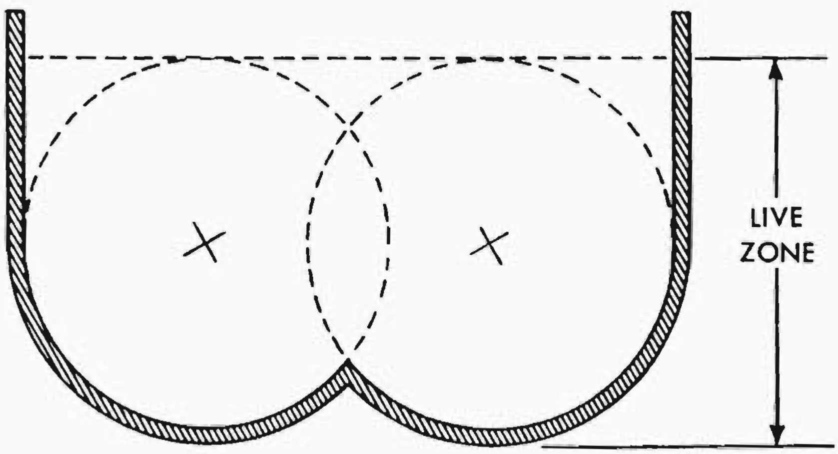


Figure 10.11. Live zone of pugmill in a batch plant (Ref 12).

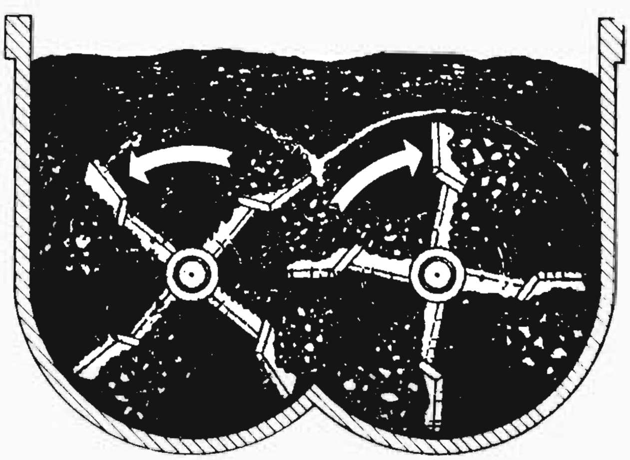


Figure 10.12. Overfilled pugmill (Ref 12).

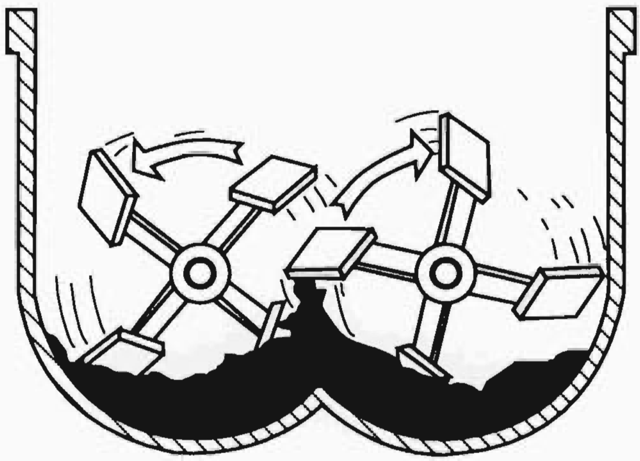


Figure 10.13. Underfilled pugmill (Ref 12).

SECTION 2
ASPHALT CONCRETE LAYDOWN OPERATIONS

CHAPTER 11. HAUL VEHICLES

11.1 TYPES OF TRUCKS

The various type of haul vehicles and the procedures involved in transporting asphalt concrete mixtures from the asphalt plant to the paver are critical to the construction of a quality pavement. Regardless of the type, all haul vehicles used should have metal beds which are clean, smooth, and free of holes. In addition, the vehicle bodies should be insulated. The three most common haul vehicles are: (a) end-dump trucks, (b) bottom dump trucks, and (c) live bottom (conveyor) trucks.

End-dump Trucks

An end-dump truck should be capable of discharging the mixture into the hopper of the paver without pressing down or riding on the paver. If the truck cannot deposit the mixture into the hopper without spillage, the truck should not be used or should be modified to increase the length of the bed overhang.

Bottom Dump Trucks

Bottom dump trucks unload by dumping the mix directly on the roadway or through a spreader box beneath the truck. In the first method, the discharge gate openings must be controlled in order to place the proper amount of material in a windrow. In the second method the amount of material is controlled by the width of the opening of the spreader box. It it is essential that the mixture be placed as uniformly as possible in order to insure an adequate supply of mixture to the paver.

The asphalt concrete material is then picked up by a windrow elevator (Fig 11.1) and placed in the hopper of the paver. The equipment shown involves a pickup machine which is rigidly and permanently attached to the paver. In this case, the paver does not have wings in the hopper.

Live Bottom Trucks

Unloading this type of truck is accomplished by a slat conveyor in the bottom of the truck bed which moves the material to the rear of the truck and empties it into the paver or deposits it on the roadway in a windrow.

11.2 HANDLING, LOADING, AND UNLOADING PROCEDURES

Various procedures related to haul vehicles can have a significant effect on the quality of the asphalt cement mixture placed and on the ultimate durability of the pavement.

Oiling the Bed

Truck beds should be coated with a lubricant to keep the asphalt cement mixture from sticking to the bed. Excess lubricant, however, regardless of type, should be drained prior to loading the truck.

It is recommended that nonpetroleum agents such as lime water or soapy water be used as a lubricant. Petroleum-based agents, such as diesel fuel, are often allowed and used. Diesel fuel, however, can be absorbed into the mixture resulting in a significant softening of the asphalt cement, an increase in fluid content, and, as a result, bleeding and a loss of stability. Thus, diesel fuel should not be permitted.

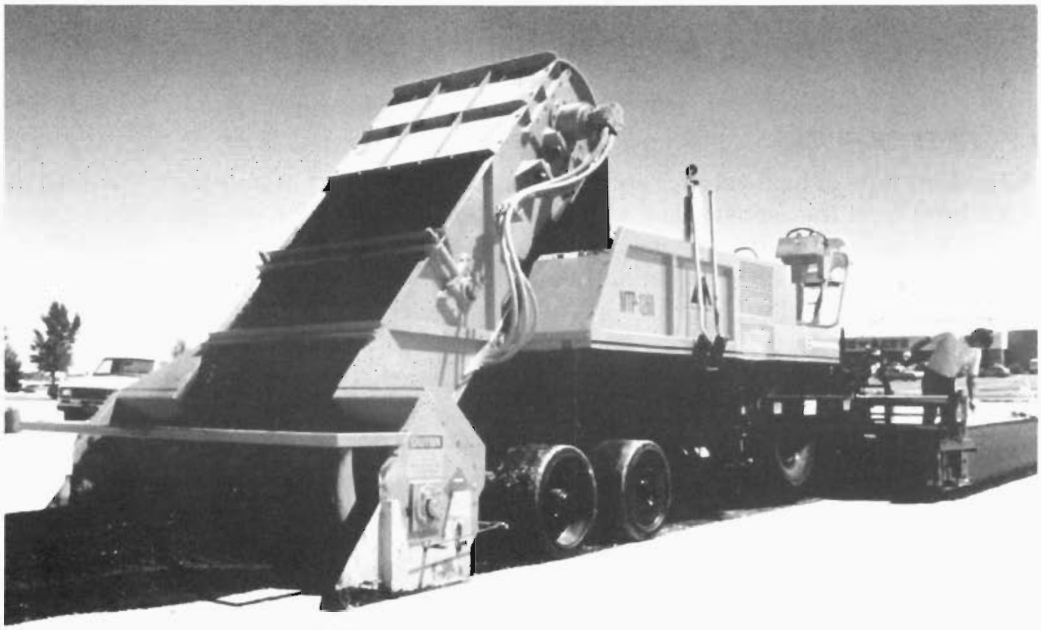


Figure 11.1. Windrow pickup machine and paver.

Truck Loading

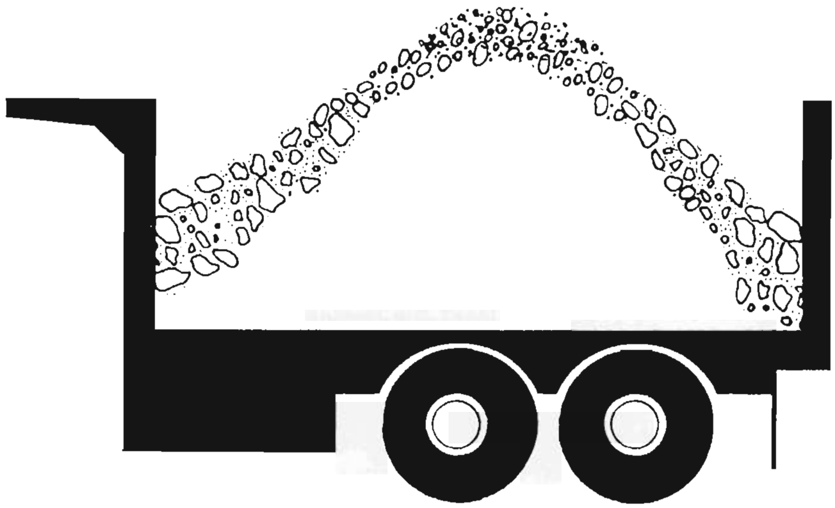
When loading trucks, there is a tendency for the mix to be discharged into a single pile in the truck bed (Fig 11.2a). When a large truck is loaded in a single drop, coarse material will roll down the pile and accumulate in the front, back, and, to a lesser extent, the sides of the truck. When this truckload of mix is deposited in the paver hopper, the coarse material is both the first and last to be discharged. The coarse mix on the sides of the truck bed will be deposited in the hopper wings. This segregated material can subsequently appear as coarse spots in the finished surface between each truckload of mix.

Trucks with a relatively large capacity should be loaded in a minimum of three drops (Figure 11.2b). The sequence of drops should be front, back, and middle. This sequence reduces the distance coarse aggregate particles can roll and reduces segregation. Further, the first and second drop should be made as close as practical to the front and rear (tailgate) of the truck bed.

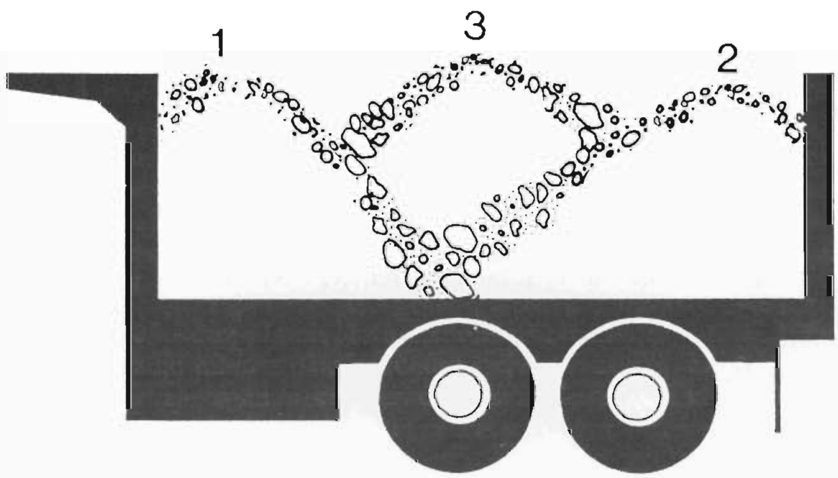
The asphalt concrete mixture should be dropped into the truck bed in a large mass. Thus, large, elongated gates on the silo or surge bin are desirable since they allow a large mass of mix to be discharged which minimizes coning. The least desirable situation is to have a small stream of material deposited slowly into the truck bed. This enhances rolling of coarse aggregate to the outside corners of the truck bed and increases segregation. Further, small drops of mix, used to "top off" a load of mix to the legal weight limit, should not be permitted.

Tarpaulins

In cool weather or on long hauls, tarpaulins should be used to minimize temperature loss of the mix since excessive cooling can result in lumps and formation of a crust, especially



a. Incorrect loading procedure.



b. Correct loading procedure.

Figure 11.2. Truck loading (Ref 39).

when hydrated lime is incorporated in the mix. These tarps should extend at least one foot over the side and tailgate of the truck bed and must be tied down to prevent air being forced under the tarp causing a more rapid cooling of the mix. It would be better to eliminate the tarpaulin than to allow air to enter between the tarpaulin and the asphalt concrete mixture.

Truck Unloading

As previously noted, there is a tendency during loading for mixtures to segregate in the truck beds because of the loading procedure. Although the best method of eliminating this source of segregation is use of the correct loading operation, there are several procedures which can be used to minimize the segregation when unloading.

The best end-dump truck unloading technique involves flooding the paver hopper with mix. Often when the truck is backed into the paver the tailgate is released and coarse aggregate particles trickle into the hopper. To eliminate this effect, the bed of the truck should be raised slightly without the tailgate being opened until some mix slides against the tailgate. 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 into the hopper, it also causes the segregated coarse material to be reincorporated into the mix.

The coarser material on the sides of the truck bed tends to roll directly into the wings of the hopper (Fig 11.3). If the hopper wings are dumped after each truckload of mix, 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 truckload or whenever the wings are emptied (Fig 11.4). Such patterns can occur as two spots on either side of the mat (Fig 11.5) or can extend entirely across the mat (Fig 11.6).

Bumps in the road between each truckload can be produced if the truck bumps into the paver or if the truck driver rides the brakes while the truck is being pushed by the paver. During unloading, the truck should be stopped a short distance from the paver, before contact is made with the push rollers on the paver. The paver should then move forward and "pickup" the truck. The truck driver should not hold his brakes except when the paving operation is moving downhill.

General

Trucks with very long beds have a lesser tendency to produce segregation because these trucks, out of necessity, are usually moved during loading. Bottom dump trucks tend to minimize segregation because the material is somewhat remixed when it is deposited on the pavement. In addition, live bottom trucks are probably less prone to producing segregation because of their length, their shallow side boards which prevents large piles of mix from being deposited in the beds, and the method of unloading which minimizes rolling of the coarse aggregate.

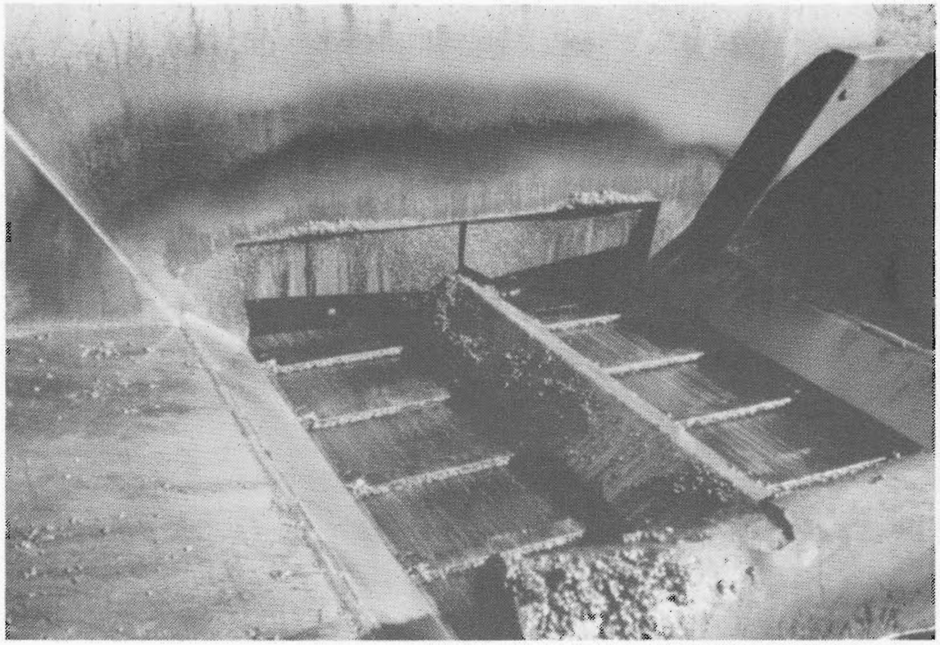


Figure 11.3. Paver hopper.

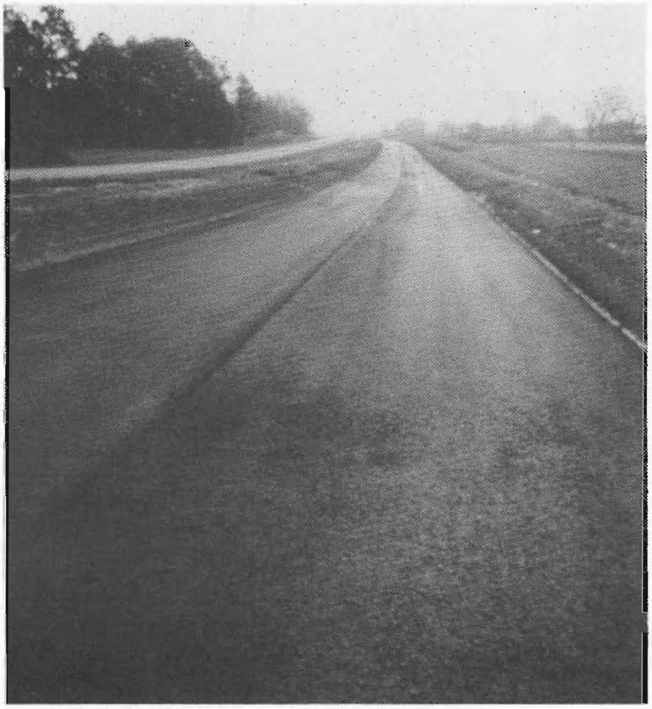


Figure 11.4. Systematic spot segregation between truckloads.

Figure 11.5. Spot segregation due to emptying hopper wings.

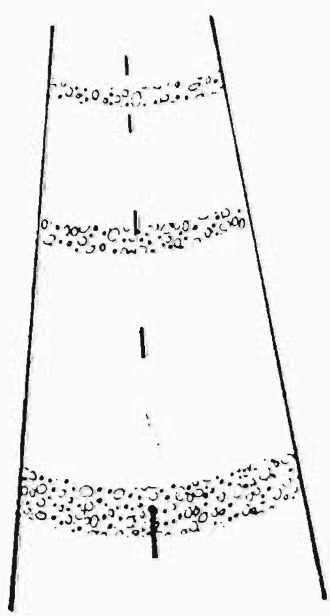


Figure 11.6. Spot segregation extended across the mat.

CHAPTER 12. ASPHALT PAVERS

12.1 ASPHALT PAVER HISTORY

Prior to the 1930's, asphalt concrete mixtures were spread across a roadway primarily by hand methods. Machinery was then developed by several different equipment manufacturers to partially automate the placing process. The earliest paving equipment operated on steel rails (side forms) and employed a bucket loading machine to pick up and deliver a windrow of aggregate to an on-board pugmill where that aggregate was mixed with asphalt cement, as shown in Figure 12.1. A screw conveyor was used to spread the material across the roadway width and a screed, riding on the forms, was used to strike off the mixture to an elevation equal to the height of the rails (Ref 1).

Improvements in this type of equipment lead to the development of a paver that eliminated the necessity for the rails and allowed the spreader to operate as a self-propelled machine by mounting it on crawler tracks. The screed was towed by the spreader. It was equipped with elongated outrigger-type leveling arms projecting fore and aft from each side of the screed. This allowed the device to control the depth and the smoothness of the mix being placed. These leveling arms, which actually supported the screed, permitted the machine to average out the variations in the surface being overlaid and therefore to place a smoother asphalt concrete mat.

By 1933, equipment was being manufactured which operated on the same principles as today's modern pavers. The machinery had a hopper into which haul vehicles could deliver premixed asphalt concrete. The equipment also employed a spreading auger to distribute the mixture across the width of the roadway being paved. Further, the paver had a floating screed, with a tow point for the screed, supported on sledlike runners that ran on top of the existing pavement surface (Ref 1). One of these early pavers is shown in Figure 12.2.

Continued changes in the pavers in the late 1930's lead to the use of a flight feeder to more efficiently transport the asphalt concrete mix from the paver hopper to the spreading screws. In In addition, the tow or pull point of the floating screed was changed to place it on the tractor frame. This alteration permitted the paver itself to be used as the reference for the leveling action of the floating screed. The principle of the floating screed has basically remained unchanged since that time.

Over the years, however, a number of major modifications have been made in the operation of the asphalt paver. One of the most significant changes has been in the use of power transmission machinery (2). The evolution in this type of equipment modified the paver operation in three ways: (a) by improving the capability of handling larger trucks and placing greater tonnages of mix, (b) by providing improved mat quality and smoothness through more consistent control of the operating variables, and (c) by reducing the need for the operator to constantly control the machine's distribution and placing functions.

A second major change has been the development of automatic grade and slope control devices (Refs 3, 4, and 5). The use of erected references (stringlines) and mobile references (towed skis and joint-matching shoes) has allowed the paver screed to average out differences in the elevation of the existing roadway over longer distances, permitting the placement of a smoother asphalt concrete mat. Employment of the mobile grade control device allows the tow point of the screed to follow the longer reference line rather than the short reference of the wheelbase of the paver itself. Thus, through use of grade and slope controls, vertical movement of the paver tractor unit was isolated from the free-floating action of the paver screed.

A more recent development is the use of the hydraulically powered extendable paver screed (Refs 6, 7, and 8). Previously, in order to increase the width of the mix being placed

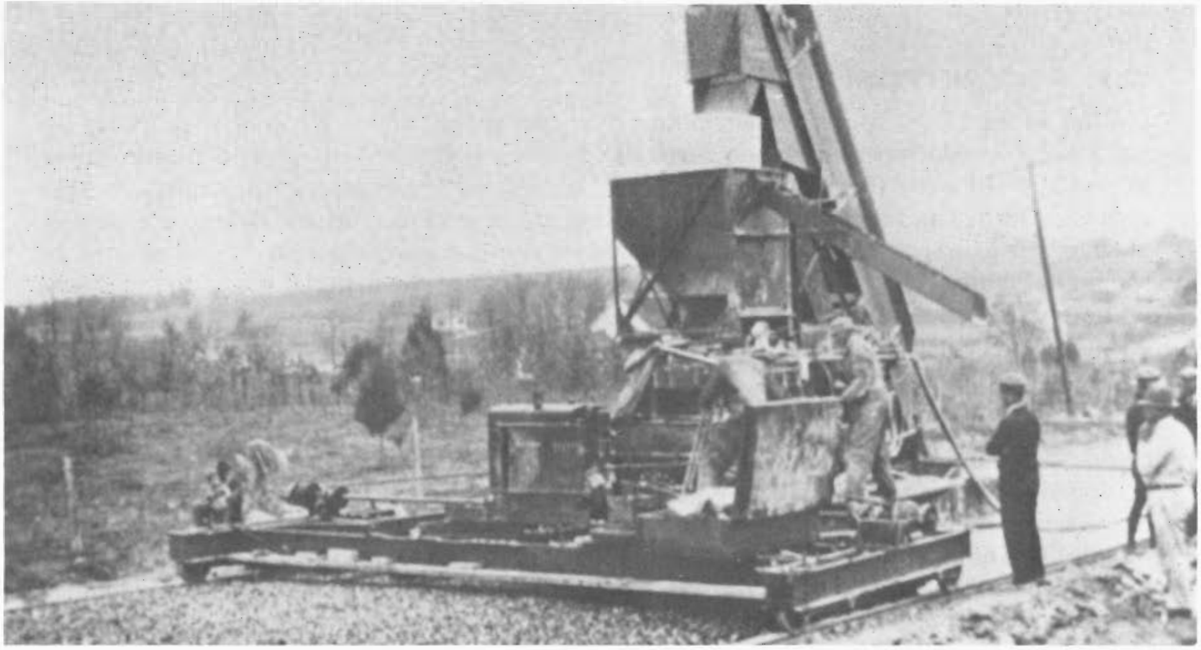


Figure 12.1. Paver operating on side forms.

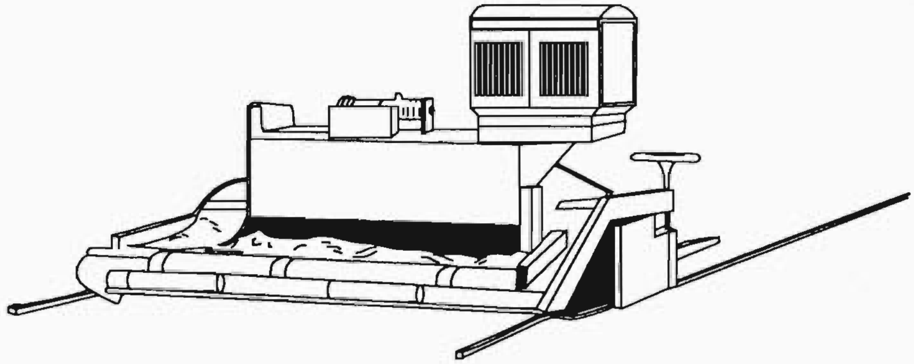


Figure 12.2. Paver with screed supported on runners.

beyond that of the basic paver screed, rigid extensions were bolted to the end of the basic screed. Using the self-widening screed, the width of the mat being placed can be altered in seconds, greatly improving the operating efficiency and productivity of the paver. Depending on the manufacturer of the paver, the extendable screeds are located either in front of or behind the main paver screed.

Throughout all the changes to the mechanical operation of the paver tractor unit, the basic principles of the floating paver screed have remained unchanged. The self-leveling action of the screed still allows this piece of equipment to reduce the amount of mix placed on the high spots and increase the amount of material placed in the low spots in the existing pavement surface. The parts of the asphalt paver and the operation of this machine are described below.

12.2 PARTS OF THE ASPHALT PAVER: THE TRACTOR UNIT

The asphalt paver consists of two primary parts. The first is the tractor unit and the second is the screed unit. The tractor unit fulfills all the functions necessary to receive the asphalt concrete mix from the haul trucks, carry that material back to the spreading screws, and distribute the mix across the width of the roadway being paved. The tractor unit is the prime mover section of the paver. It is powered by its own engine and provides the required propulsion energy to move the machine forward, either on rubber tires or crawler tracks. It is composed of a number of major components including truck push rollers, mix-receiving hopper, material flow gates, twin slat conveyors, and a pair of screw conveyors or augers. The parts of the tractor unit and the screed unit, are shown in Figure 12.3.

Push Rollers

The push rollers, located on the front of the paver hopper, are used to contact the tires of the haul truck and to push that truck ahead of the paver. The rollers must be clean and free to rotate properly in order to reduce the weight of the truck on the paver.

Paver Hopper

The paver hopper is used to receive the asphalt concrete mix from the haul vehicle. As such, it is merely a temporary holding bin for that material. The width of the hopper must be great enough to allow the body of the haul truck to fit inside of it. In addition, the vertical position of the hopper must be low enough to permit the truck bed to be raised in the air without the bed riding on the front of the hopper. Finally, means must be provided at the front of the hopper to minimize the spillage of the mix out of the hopper during the dumping of the hopper wings.

The sides, or wings, of the hopper are movable. The paver operator is able to raise the wings in order to remove all the mix that has accumulated along the sides and in the corners of the hopper. This mix, if left to stand for a long period of time, will cool and will be very difficult to remove from the metal hopper sides. Thus, the mix is moved from the sides of the hopper into the middle of the hopper by raising the wings (sides) and allowing the mix to be deposited into the area of the slat conveyors. The dumping of the hopper wings is accomplished between the arrival of truckloads of mix to the paver hopper. It is not done at the same time that the mix is being emptied from the truck into the paver. Figure 12.4 illustrates the movement of the sides or wings of the paver hopper. To reduce segregation, however, it is strongly recommended that the wings on the paver not be dumped more than twice a day.

Slat Conveyors

At the bottom of the paver hopper is a twin set of slat conveyors. As shown in Figure 12.3, these devices are used to carry the asphalt concrete mix from the hopper through the tunnel on the paver and back to the spreading screws. The slat conveyor on one side of the paver operates independently from the movement of the slat conveyor on the other side of the ma-

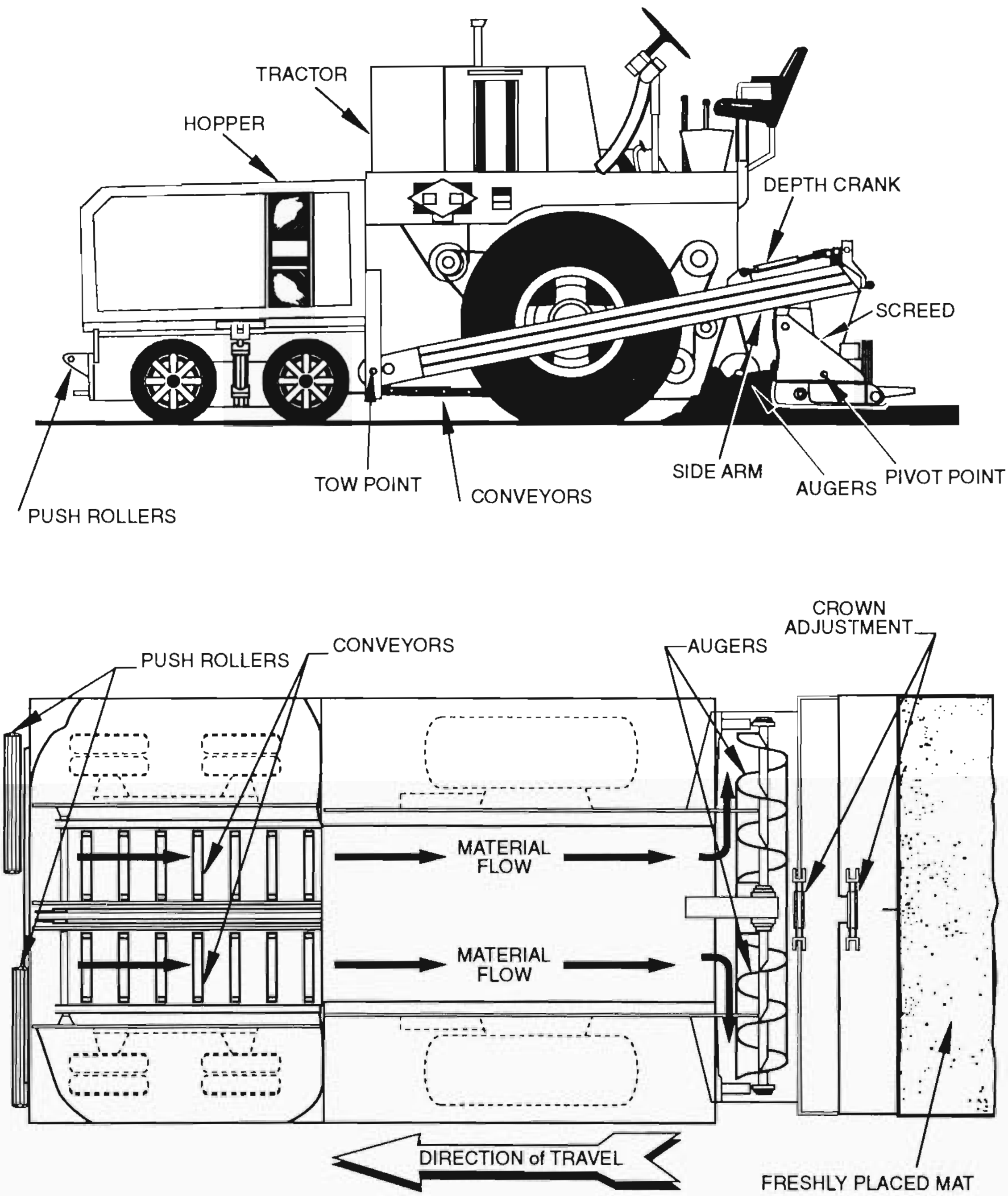


Figure 12.3. Parts of a modern asphalt paver.

chine. Thus, the amount of mix that can be carried back through the paver on one side can be different from the volume of material that is being delivered on the other side. The slat conveyors are a continuous system, with the slats being rotated back to the bottom of the hopper underneath the paver itself.

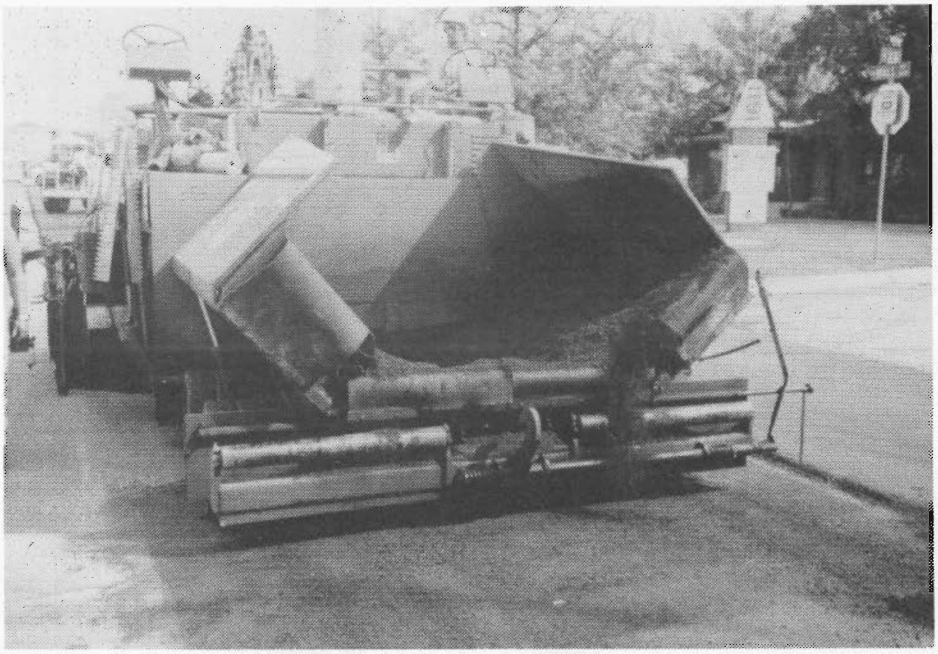


Figure 12.4. Dumping the hopper wings.

Flow Gates

At the back of the paver hopper is a set of flow gates. These gates, one over each of the two slat conveyors, are used to regulate the amount of mix that can be delivered by the conveyors to the augers. The gates move vertically, either by manual manipulation or mechanically, and regulate the amount of mix that can enter the paver tunnel by the vertical setting of the gates. The location of the flow gates is shown in Figures 12.5 and 12.6.

If the flow gates are set too high when the slat conveyors are operating, there will be a large volume of asphalt concrete material pulled back through the paver tunnel by the slat conveyors and placed on the augers. This material will flood (overload) the augers and provide too great a head of material against the paver screed, causing the screed to rise and the mat thickness to be increased. If the flow gates are set too low, there will not be enough mix delivered to the augers by the slat conveyors. The head of material will be insufficient in front of the screed and the screed will sink, causing a reduction in the thickness of the mat being placed. The flow gates should be adjusted so as to provide a proper head of material in front of the screed. Figure 12.7 shows three possible positions of the flow gates — too high, too low, and correct — in relation to the head of material in front of the paver screed.

Augers

The mix that is carried to the back of the tractor unit by the slat conveyors is deposited in front of the screw conveyors or augers (Figures 12.3 and 12.8). Just as the slat conveyors operate, independently on each other, the augers on each side of the paver are run separately from one another. The mix placed in the auger chamber from the slat conveyors is distributed

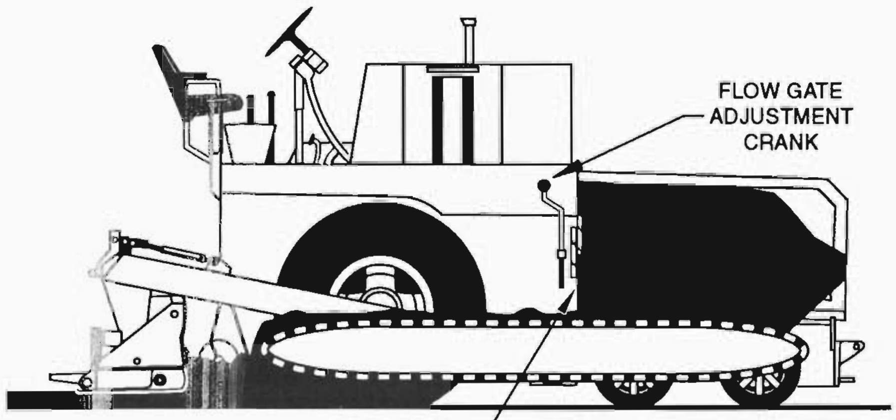


Figure 12.5. Paver flow gate location.

Figure 12.6. Flow gates in lowered position.

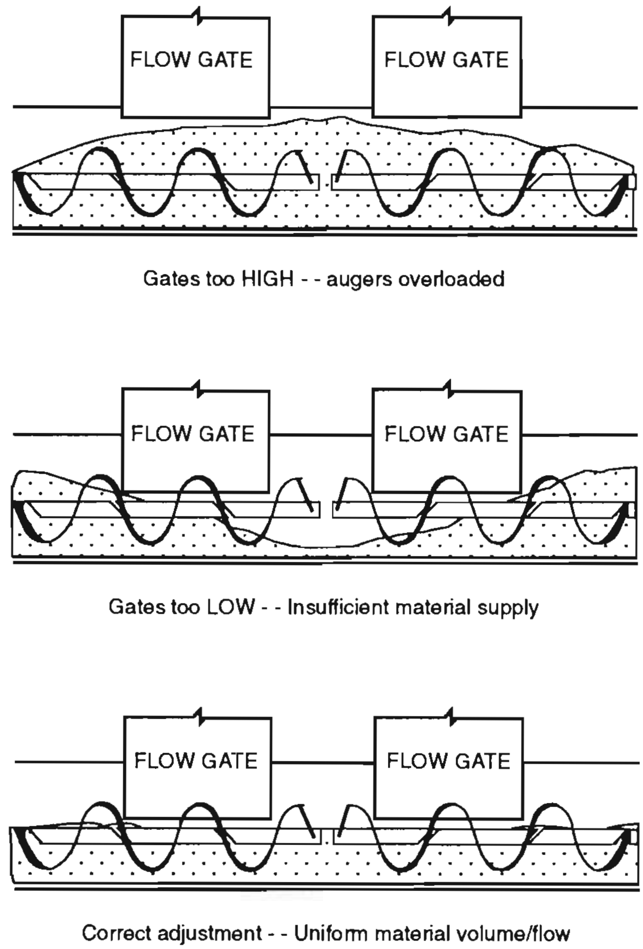


Figure 12.7. Flow gate setting and head of material on the augers.

across the width of the paver screed by the movement of the augers. At the junction of the two augers in the center of the paver, adjacent to the auger gear box, there is typically a different shaped auger (reverse auger or paddles) to tuck mix under the gear box and assure that the mix placement at this location is the same as that across the rest of the width of the screed. This reverse auger (paddle) is shown at the upper left side of the main screw auger in Figure 12.8. It is important that the augers carry a consistent amount of mix across the front of the screed so that the force on the screed is constant and the angle of attack of the screed is stable.

Material Feed System

As shown in Figure 12.9, the slat conveyor and auger on one side of the paver act independently from the slat conveyor and auger on the other side of the paver. In the manual mode, the paver operator can usually select one of several speeds for the slat conveyor, each essentially a percentage of the maximum speed of the conveyor. Once the conveyor speed is selected, the speed of the spreading screw conveyor (auger) is proportioned to the speed of the slat conveyor. The operator is responsible for controlling the slat conveyor and augers in order to keep a constant supply of asphalt concrete mix in front of the paver screed. The flow of material to the screed is essentially regulated by the height of the hopper flow gates and the starting and stopping of the slat conveyor and auger on each side of the paver. With this

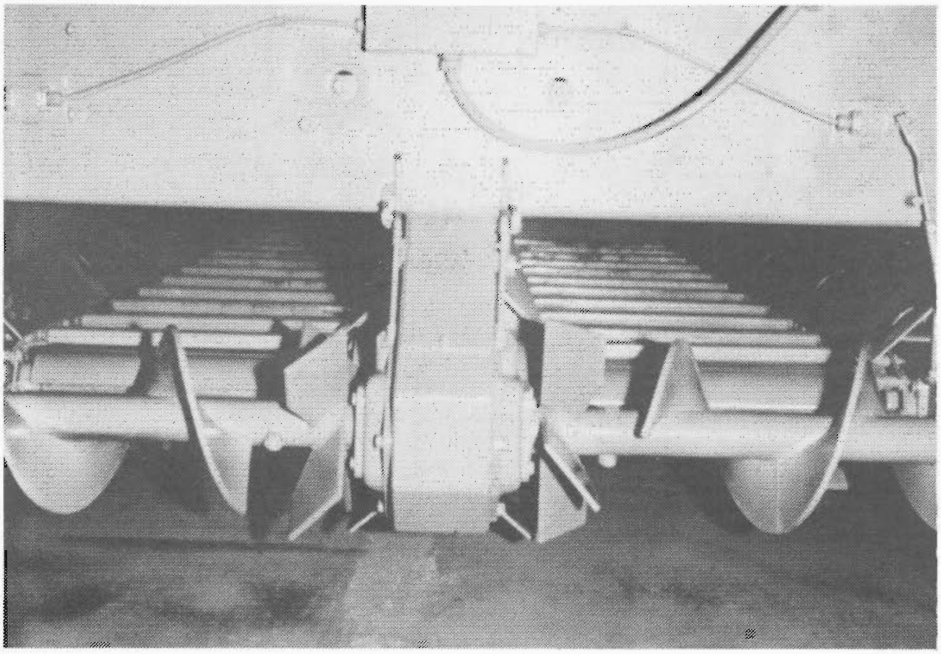


Figure 12.8. Paver augers (without screed in place).

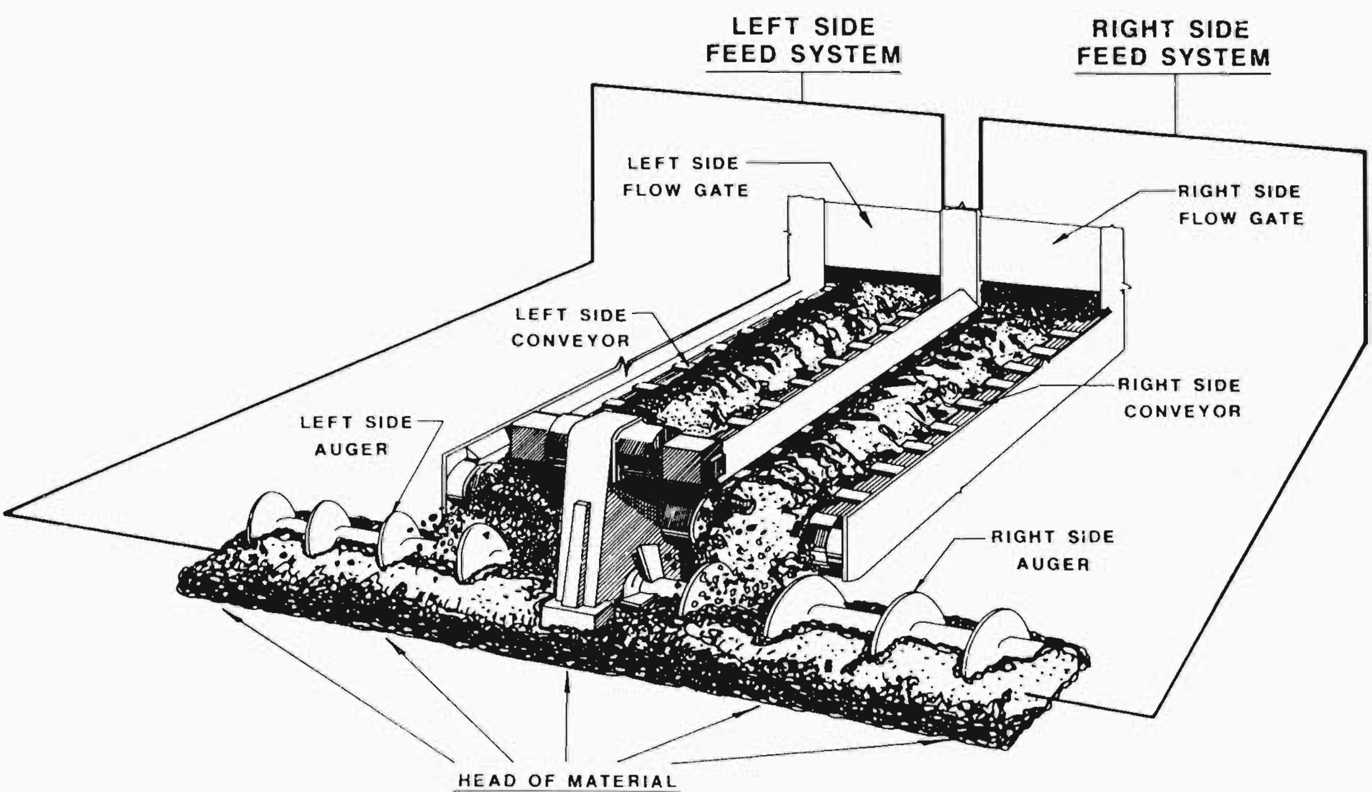


Figure 12.9. Material feed system.

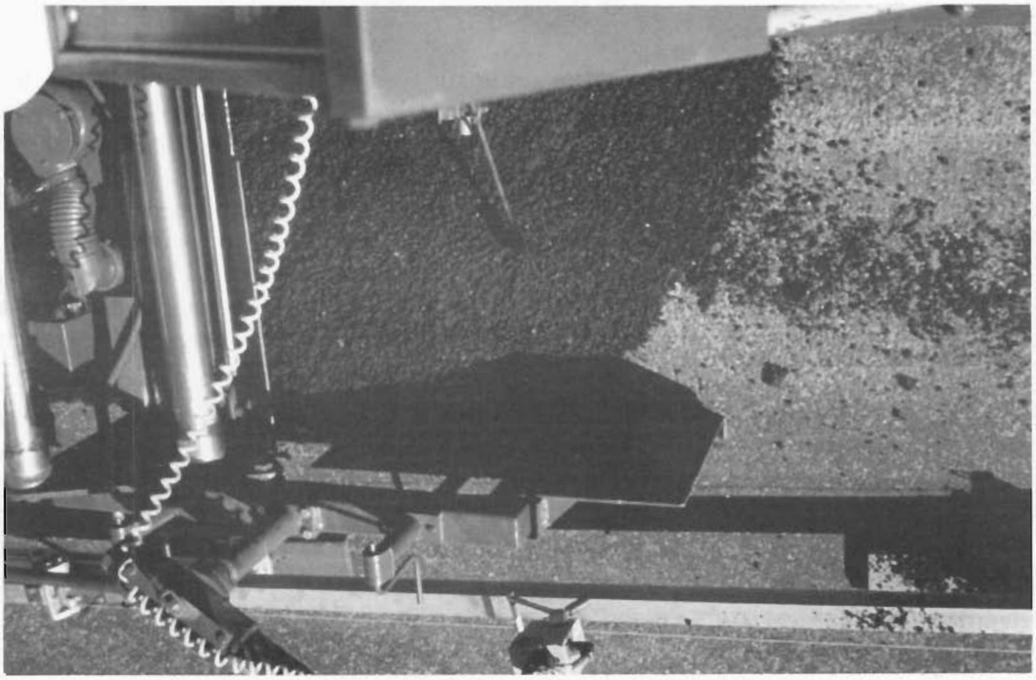


Figure 12.10. Feed control sensor.

manual system, the amount of mix sent to the augers does not change with a change in the speed of the laydown machine unless the speed of the whole material delivery system is changed by the paver operator.

Most pavers today are equipped with an automatic feed system which supplies mix to the paver screed in proportion to the need for the material. For this system, a feed control sensor is used to determine the amount of mix in the auger chamber, as shown in Figure 12.10. If the volume of mix available in front of the screed is too little, the feed sensor control arm will hang down almost vertically, causing the slat conveyor-auger system to turn on. As mix is delivered to the screed, the feed sensor control arm will rise. When too much mix is in the auger chamber, the feeder control paddles will cause the slat conveyor and augers to shut off, stopping the supply of mix to the screed. When the level of mix in the auger chamber falls, the control arm will also fall, causing, in turn, the slat conveyor and auger feed system to start again.

The purpose of the automatic feed control system is to monitor and regulate the head of material in front of the paver screed. For the system to function properly, the feed sensor control arm should be located as close to the outside end of the augers as possible. If rigid paver screed extensions are used, as discussed below, the control arm should be mounted beyond the end of the augers, just inside the end gate on the paver screed, as illustrated in Figures 12.11 and 12.12.

The amount of mix carried in the auger chamber should be as constant as possible. The proper depth of material on the augers should be at the center of the auger shaft (Fig 12.13). The level of material carried in front of the screed should not be so little so as to expose the lower half of the screw conveyor flights (Fig 12.14). Further, the level of mix delivered to the screed should never be so great as to cover the upper portion of the auger (Fig 12.15). Thus, for the correct head of material to be carried in front of the screed, the mix in the auger chamber should be at a level equal to the center of the shaft of the augers.

If the feed system is set and operating properly, the slat conveyor and augers on each side of the paver will rarely shut off. This continuous action of the conveyors and augers is accomplished by obtaining the proper position for the hopper flow gates and determining the correct speed setting for the slat and screw conveyors. The ultimate key to the placement of a smooth pavement layer is the use of the material feed system to keep the head of material in front of the screed constant, primarily by keeping the slat conveyor and augers running as close to one hundred percent of the time as possible.

12.3 PARTS OF THE ASPHALT PAVER: THE SCREED UNIT

The screed unit, which is towed by the tractor unit, is employed to establish the thickness of the asphalt concrete layer and to provide the initial smoothness to the new surface. In addition, the screed imparts some degree of density to the material being placed through the vibratory or combination tamping and vibratory action of the screed. A diagram showing the parts of the screed for one particular make and model of paver is shown in Figure 12.16.

Tow Point

The screed unit is attached to the tractor unit at only one point on each side of the paver. This point, shown in Figure 12.17, is called the tow point or the pull point by the different paver manufacturers. The tow point is really a pin-type connection which allows the leveling arms (also called side arms or pull arms) of the screed to rotate or pivot around that point. This pin connection reduces the ability of the tractor unit to transmit torque to the screed unit.

The concept of the pull point allows the tractor unit to provide the wheelbase for the screed unit. The screed then pivots around the pull or tow point and responds to the average grade being spanned by the tractor wheelbase. For the floating screed principle to work

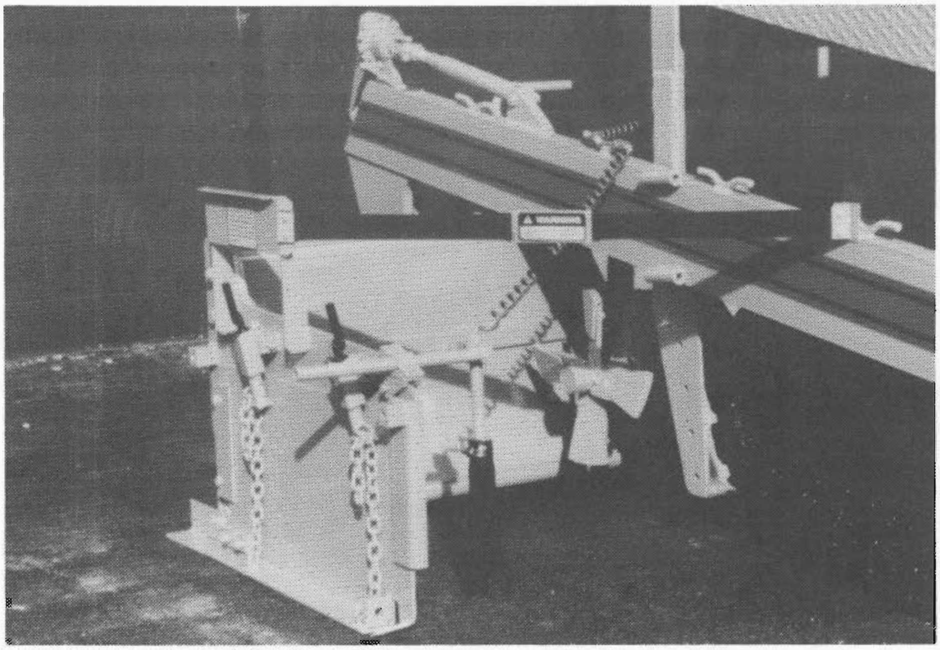


Figure 12.11. Feed control sensor attached to end gate, with kick-out paddles on end of auger.

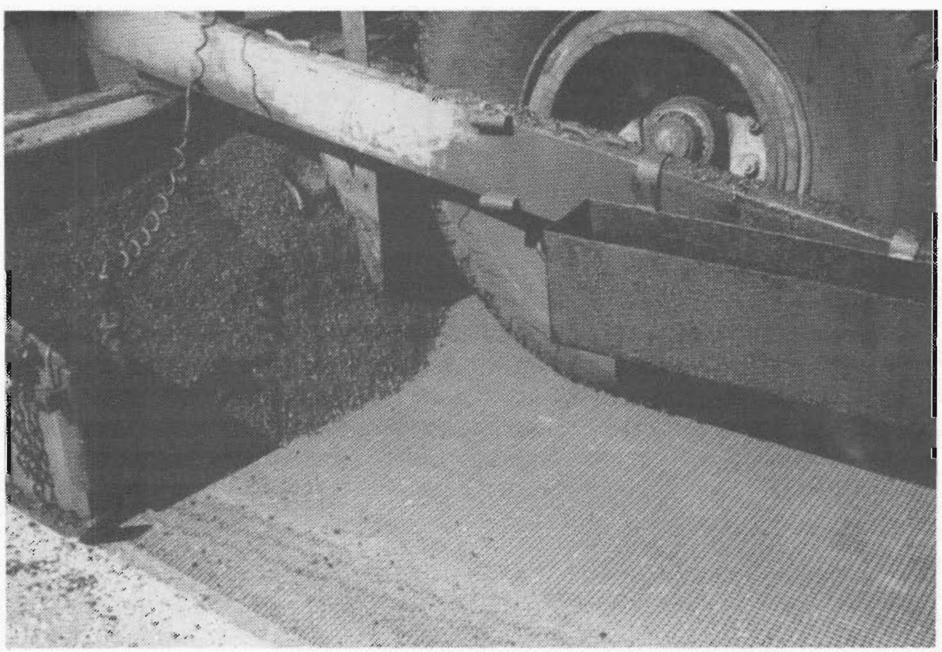


Figure 12.12. Feed control sensor location.

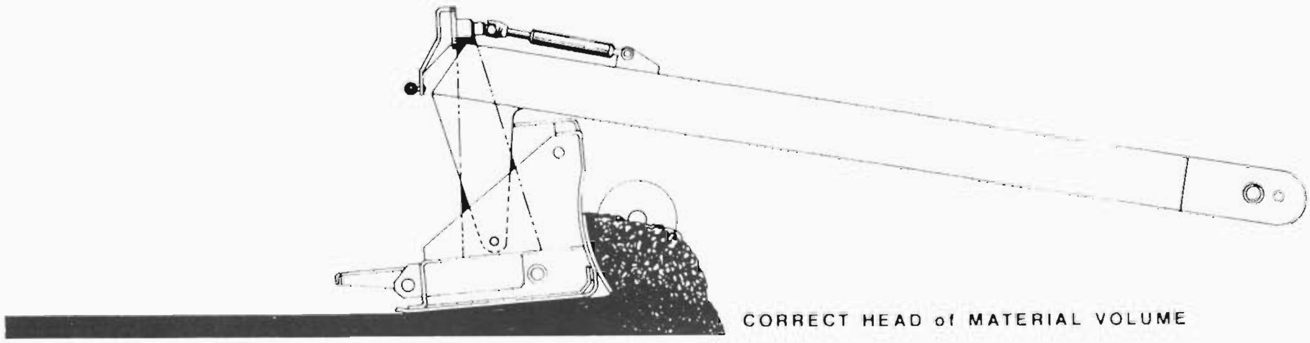


Figure 12.13. Correct head of material in auger chamber.

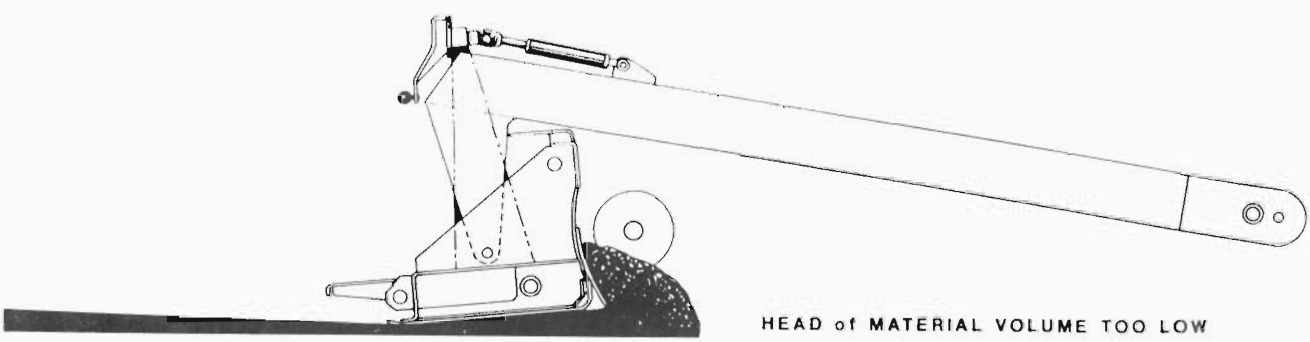


Figure 12.14. Lack of head of material in auger chamber.

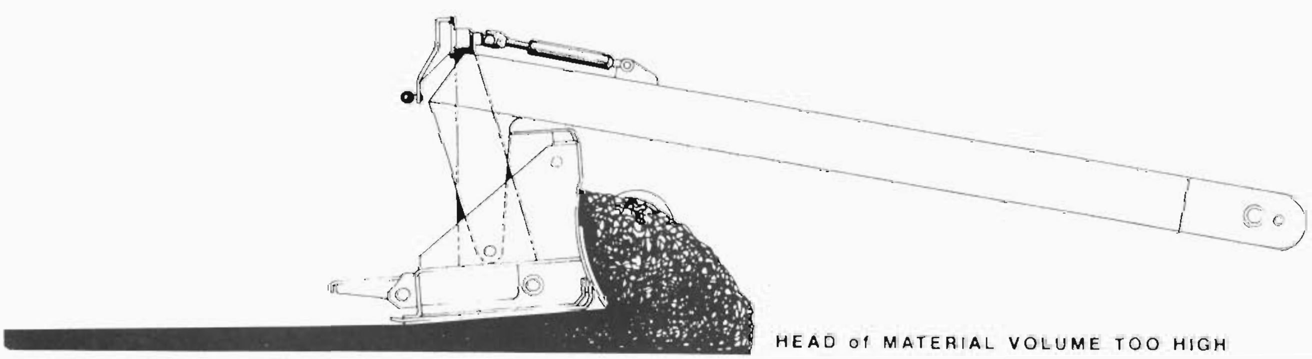


Figure 12.15. Excess of head of material in auger chamber.

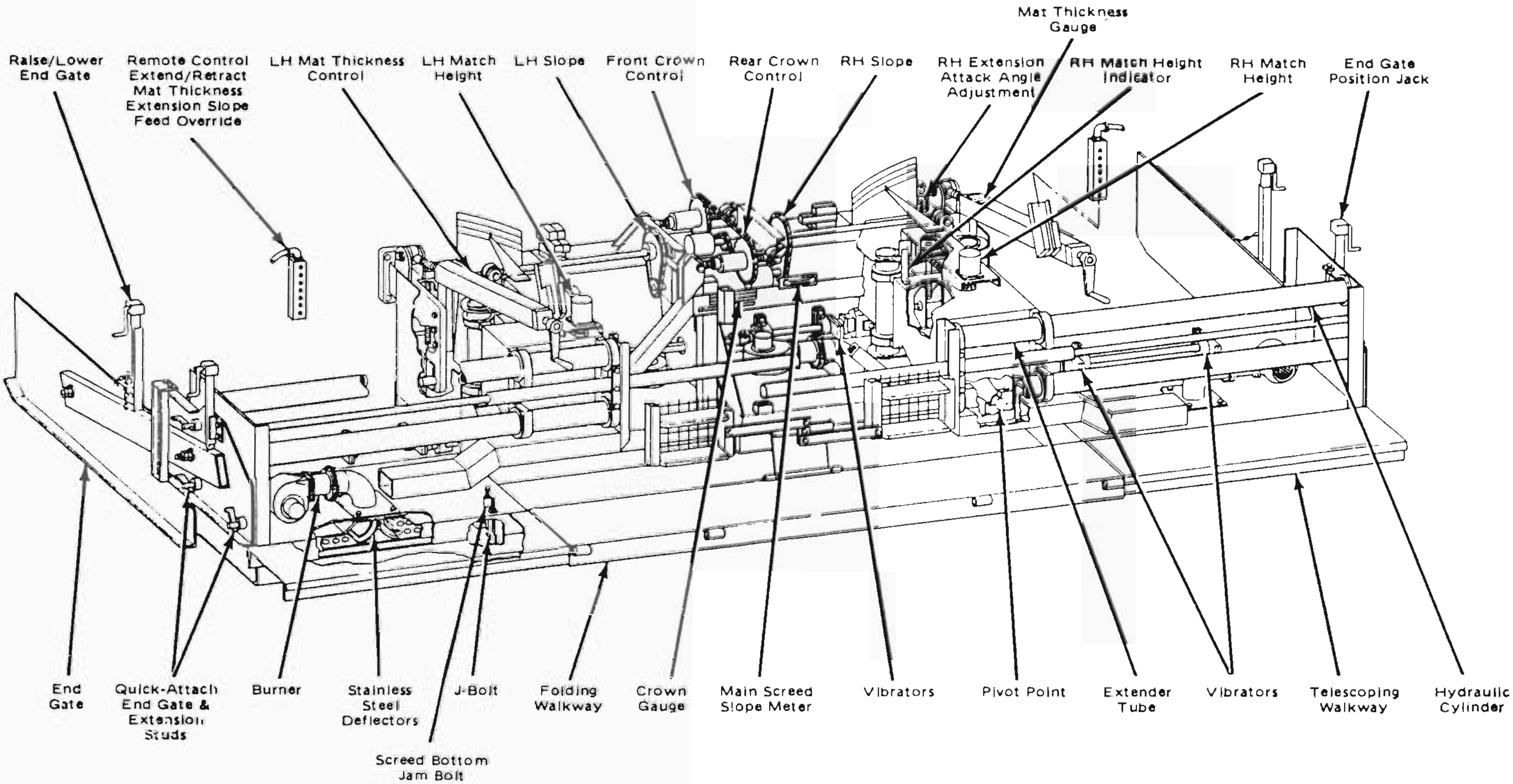


Figure 12.16. Parts of a paver screed.

properly, it is important that the pull points on both sides of the tractor be at the same level above the ground. The position of the screed pull points can be altered by raising or lowering the cylinder rods on which the pull points are mounted. For most asphalt concrete mixtures, the pull or tow point is positioned in the center of the cylinder stroke. For some asphalt concrete mixtures being placed, however, it is advantageous to change the elevation of the pull points — raise or lower the elevation of the pull point to improve the texture of the mat being placed.

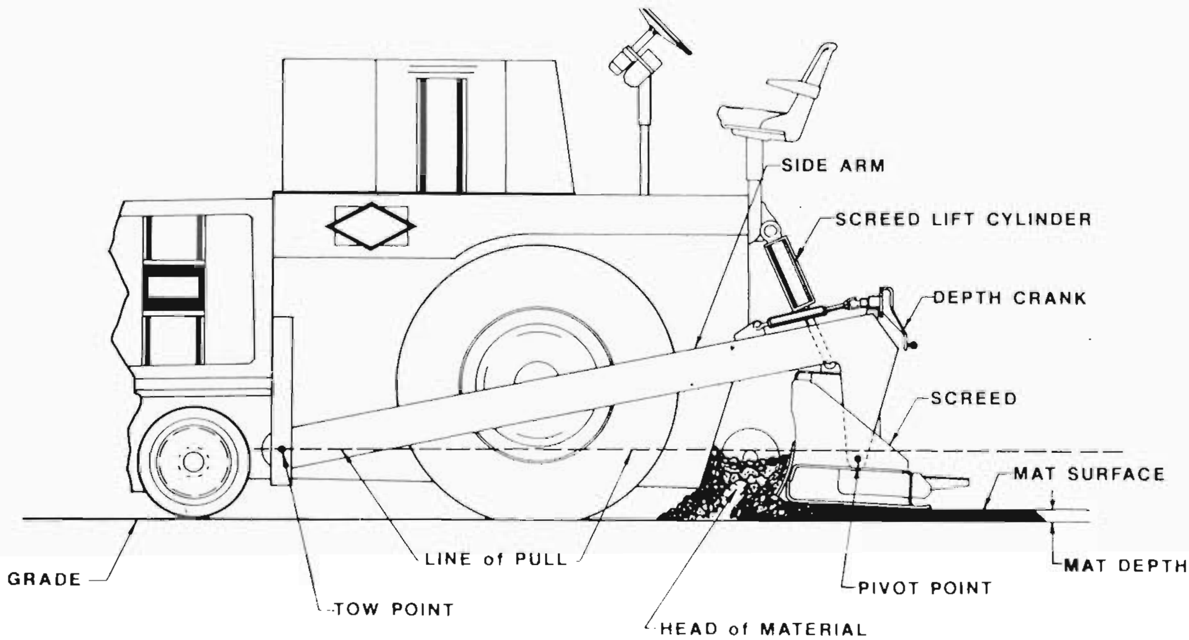


Figure 12.17. Relation of the screed unit to the tractor unit.

When the pull points are too high, however, the front of the screed is tilted down in order to maintain the proper mat thickness. Premature wear on the strikeoff and the leading edge of the screed can be experienced, as shown in Figure 12.18, the smoothness of the mat can be reduced, and the degree of compaction imparted to the mix will be lessened. When the pull points are too low, on the other hand, the front of the screed is tilted up in order to maintain the correct thickness of the asphalt concrete mix being placed. Premature wear can occur on the trailing edge of the screed as shown in Figure 12.18.

The relationship between a change in the elevation of the tow point on one end of the leveling arm and the movement of the screed on the opposite end of the leveling arm is shown in Figure 12.19. An eight-to-one ratio exists between the movement of the tow point and the change in the angle of attack of the front edge of the paver screed. This means that if the tow point is moved vertically upward 1 inch, the angle of attack of the screed will be increased by 1/8 inch. As discussed in detail below, the paver must move forward approximately five lengths of the leveling arm before the screed will move up to the new level of the tow point, and the forces on the screed will again be in equilibrium.

The combination of the screed pivot point at the end of the leveling arm attached to the tractor and the thickness control device at the screed provides for adjustments to be made to the angle of attack of the screed unit. The angle of attack is shown in Figure 12.20. Because of

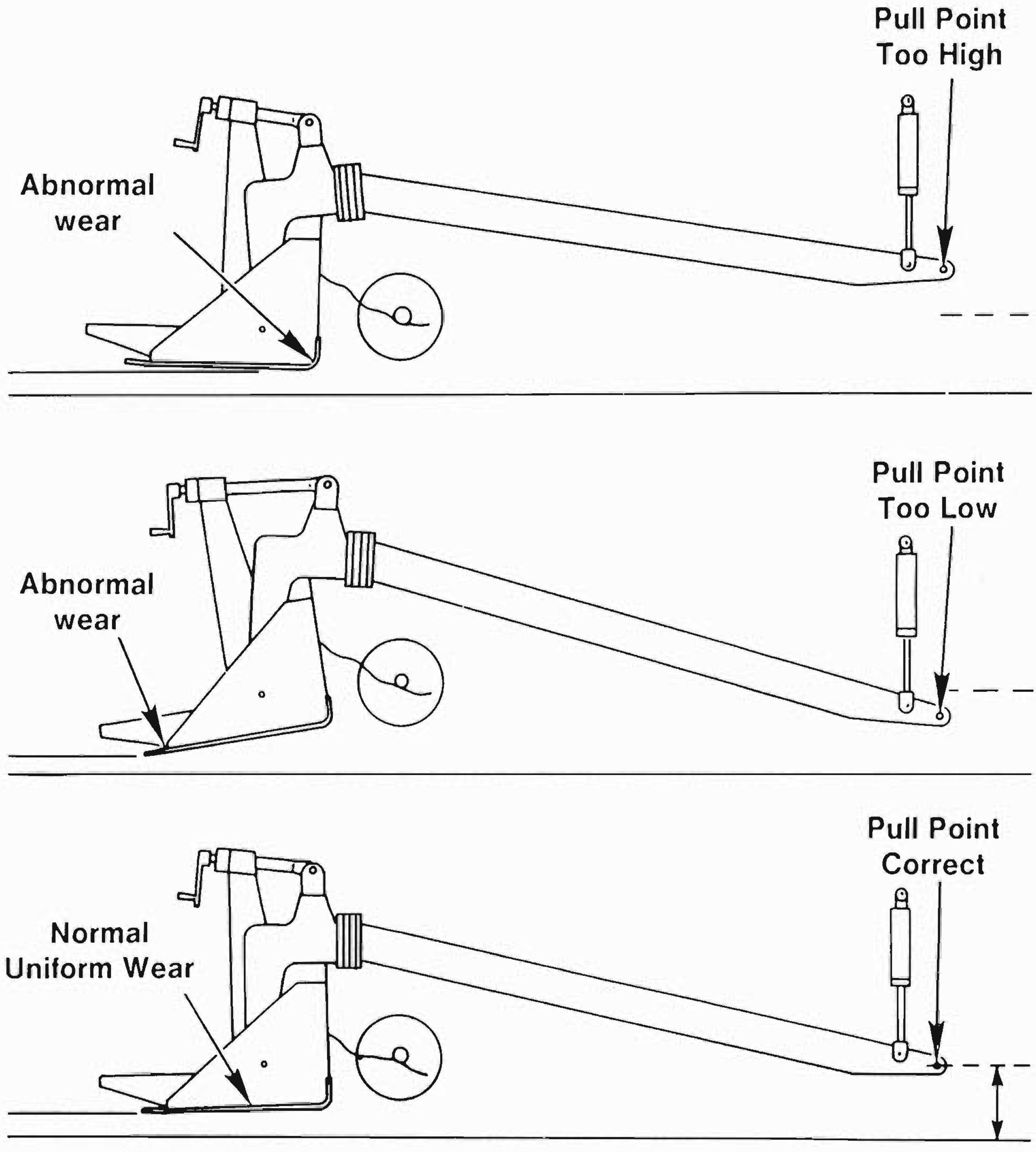


Figure 12.18. Location of the pull point.

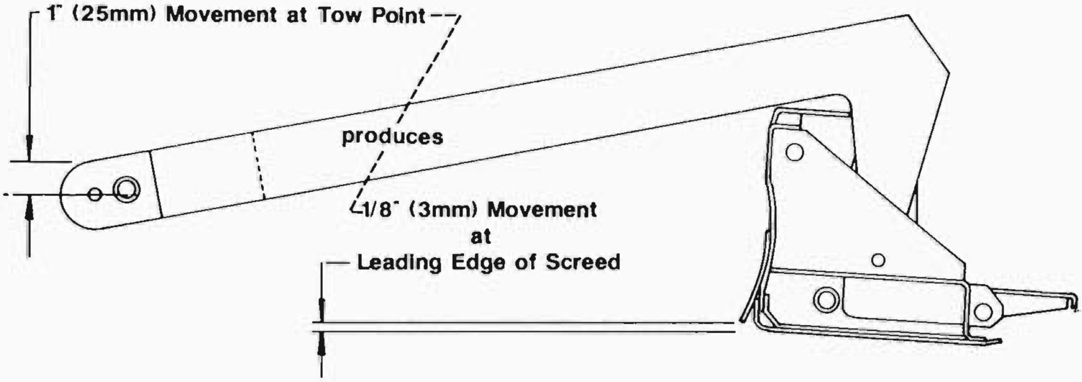


Figure 12.19. Relationship between the tow point and the screed.

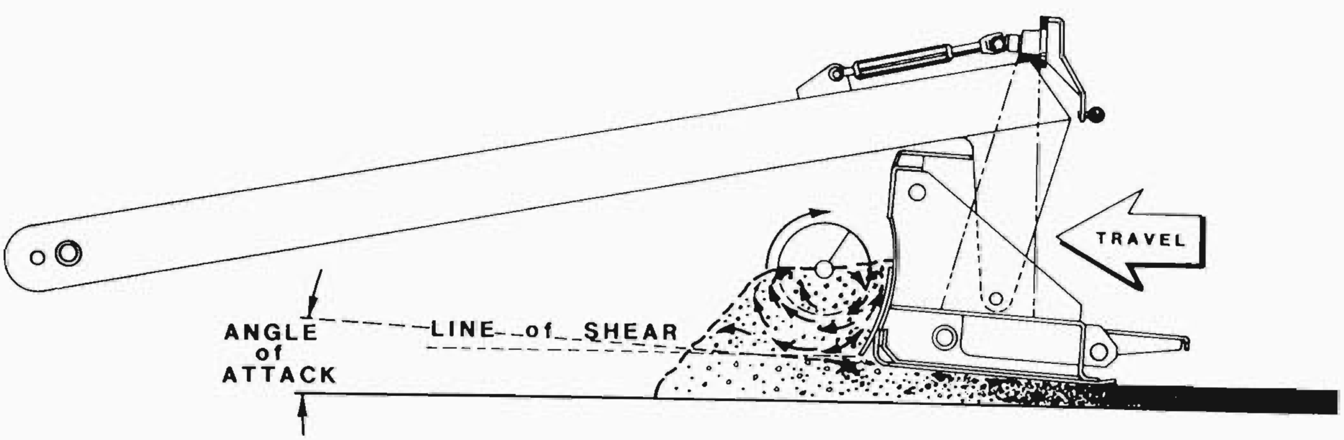


Figure 12.20. Angle of attack of the screed.

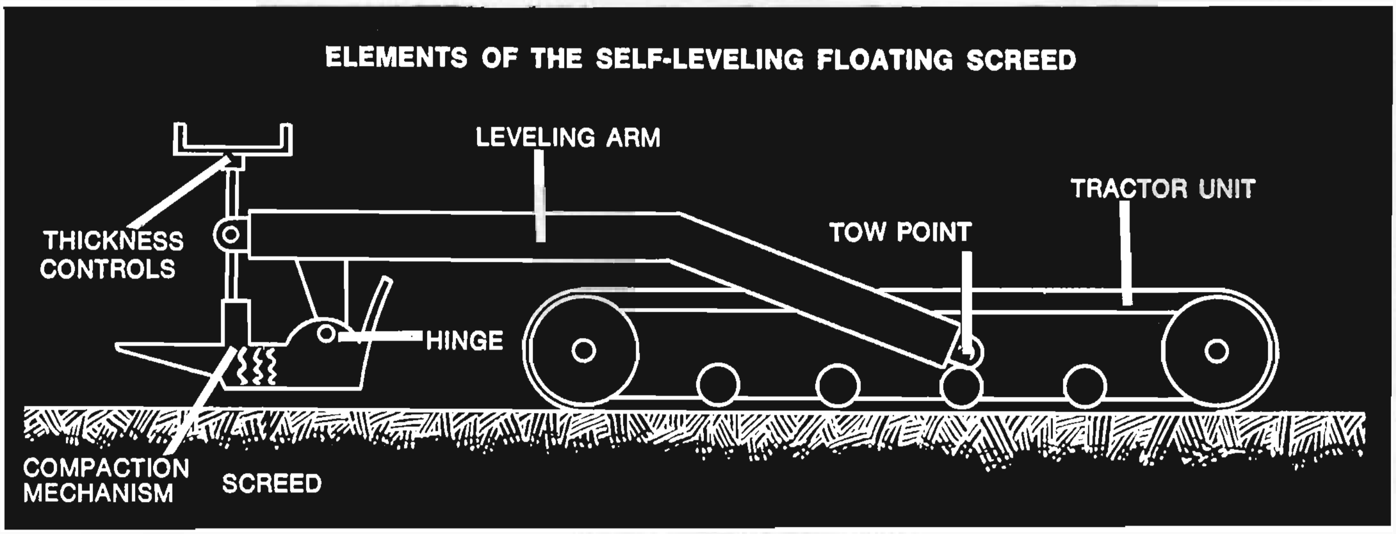


Figure 12.21. Parts of the screed.

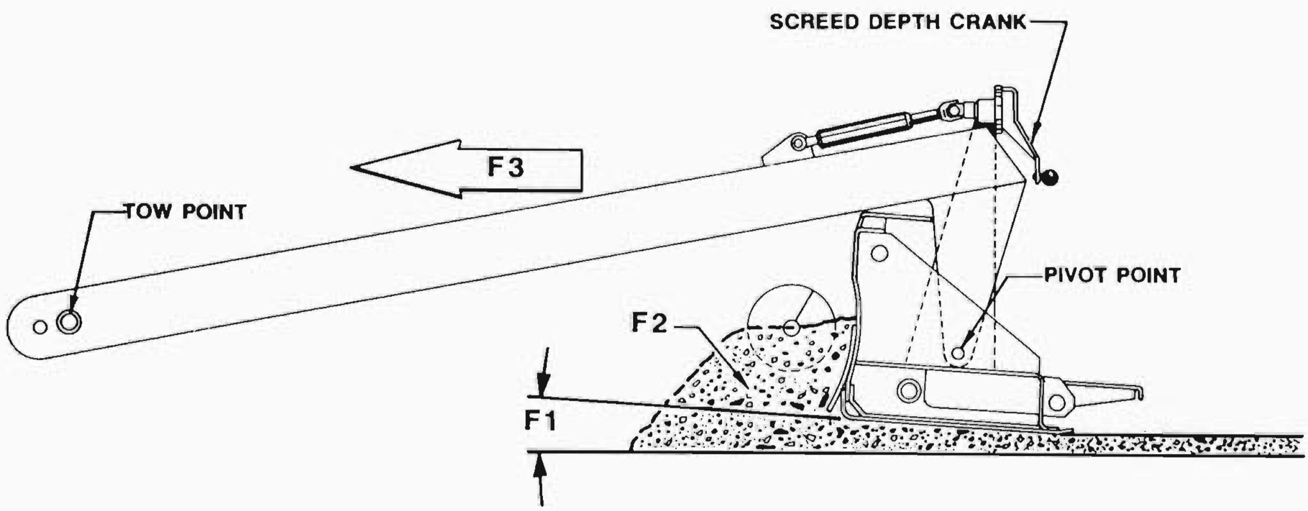


Figure 12.22. Forces on the screed

the method in which the screed is attached to the tractor, the screed acts the same as to a water skier being pulled by a speed boat.

Thickness Control Cranks

The screed is attached to the leveling or tow arms on each side of the paver through a hinge or pivot point, as illustrated in Figures 12.21 and 12.22. The thickness control mechanism, usually either a crank or a handle, allows the screed to be rotated around the pivot point. The key to the leveling action of the screed is its ability, by rotating around the pivot point and being attached to the tractor unit at only the tow point, to establish an equilibrium attitude based on the forces applied to the screed (Fig 12.22). As the mix passes under the screed plate, the screed floats on the mix, determining the mat thickness and the texture of the material, as well as providing the initial compaction of the asphalt concrete mix.

For a given position of the tow point, altering the setting of the thickness control device changes the attitude (angle of attack of the screed) and changes the forces acting on the screed. This, in turn, causes the screed to move up to, or down to, a new elevation as the paver moves forward, and thus alters the thickness of the mat being placed. The reaction of the screed to changes in the position of the thickness control settings is not instantaneous. Rather, there is a lag in the reaction of the screed which allows the screed to average out variations in the input forces acting on it.

Reaction of the Screed

Figure 12.23 provides information on the reaction time of the screed when a change is made to the location of the tow point. After the tow or pull point has been raised, as shown in this figure, it takes approximately five times the length of the leveling or tow arms on the paver screed for the screed to complete 99 percent of the change up to, or down to, the desired new elevation. This means that if the length of the leveling arm is 9 feet, the paver would have to move forward for a distance of a least 45 feet before the input to the thickness control device was completely carried out by the paver screed.

As an example, assume that it is desired to increase the thickness of the asphalt concrete mat being placed from 1 inch to 1-1/2 inches. A change is made in the thickness control crank, typically by turning it clockwise, in order to change the angle of attack of the screed. The movement of the thickness control mechanism causes the screed to rotate around the hinge or pivot point and to increase the angle compared to the road surface. The change in mat depth, however, is not immediate. The paver must move forward for some distance before the modification in mat thickness can be completed.

As shown in this figure, approximately 63 percent of the thickness change is accomplished after the paver has moved forward a distance equal to one leveling arm length, or 9 feet in this example. As the paver moves forward another 9 feet, about 87 percent of the desired thickness change has been completed. Approximately 95 percent of the elevation change is done by the time a distance of 27 feet has been traveled (three leveling arms lengths of 9 feet each). Again, it is not until the paver has moved down the roadway a distance equal to at least five leveling arm lengths, however, that some 99 plus percent of the thickness change has been completed.

The same exercise holds for a reduction in the thickness control settings at the screed. If the screed operator desires to reduce the depth of the asphalt concrete layer, he turns the thickness control crank counterclockwise and causes the screed to rotate around the hinge point. As the paver moves forward, the decreased angle of attack of the screed causes it to move downward, thereby reducing the amount of mix being fed under the screed. The screed will continue its downward movement until the forces acting on it are again in equilibrium. If the pavement layer depth were being changed from 1-1/2 inches to 1 inch, it

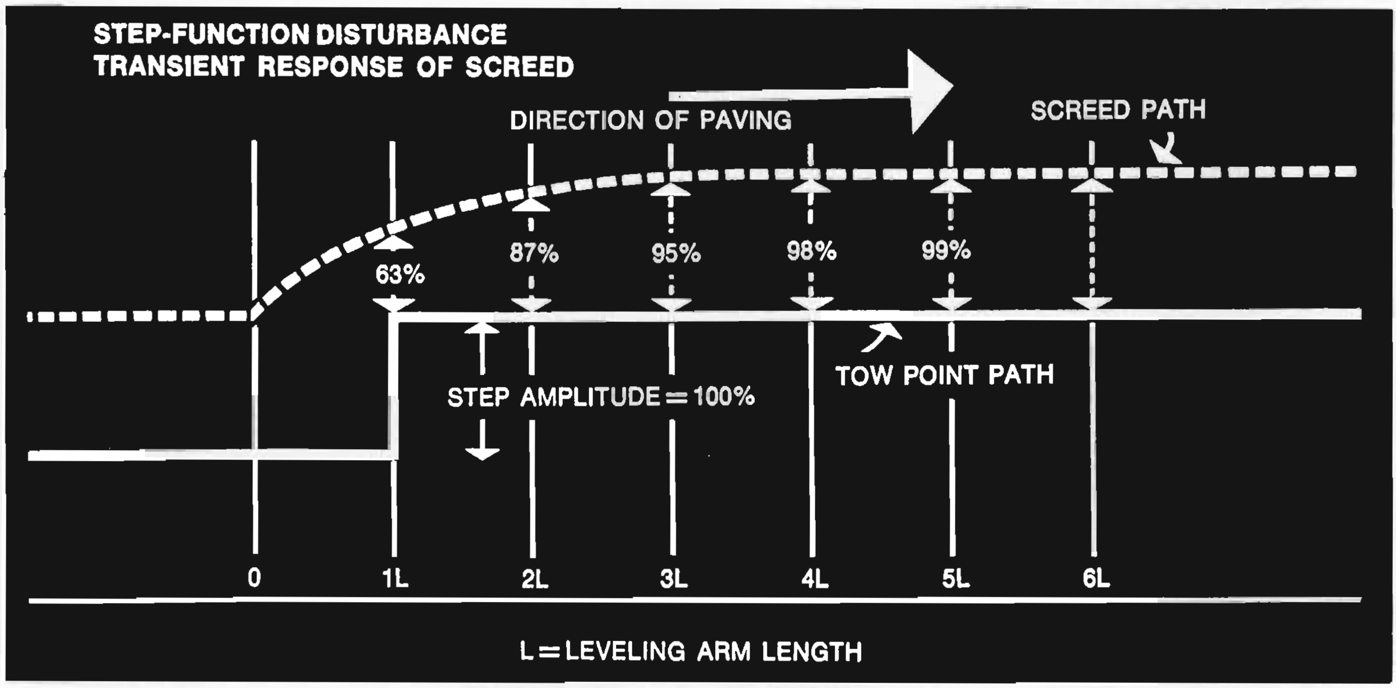


Figure 12.23. Transient response of the screed.

would still require the paver to move a distance of over five lengths of the leveling arm before 99 percent of the thickness change would be completed.

The same principle applies to a change in the location of the tow point or pull point of the screed leveling arm where it is attached to the tractor unit. If the tow point is displaced, the change in elevation of the tow point is translated to a change in the angle of attack of the paver screed. The paver must still move forward for a distance of approximately five times the length of the leveling arm on the machine for the screed to fully react to the change in the location of the tow point and move up to, or down to, the new elevation.

As a roadway is being paved, the tractor unit moves upward and downward in response to the grade of the underlying pavement. The vertical movement of the tractor translates into vertical movement of the tow point on the side of the paver. Each time the tractor goes over a hump or into a dip in the existing pavement surface, the elevation of the pull point changes. This, in turn, alters the angle of attack of the paver screed, causing the screed to decrease or increase the amount of material flowing under it. The fact that it takes five times the length of the leveling arm before the screed completely reacts to a change in the location of the tow point allows the screed to reduce the thickness of the asphalt concrete mix being placed over the high places in the existing surface and to place more mix in the low spots on that surface. It is this averaging or leveling action that is the basis of the floating screed principle of the asphalt paver.

When a paver is being operated manually, it is very important for the screed operator to realize that the reaction to a change in the setting of the thickness control crank is not immediate. The paver must move forward at least one leveling arm length before only 63 percent of the thickness change is completed. If a second change is made in the setting of the thickness control crank before the first change is accomplished, the first change will never be completed. It will still take an additional five times the length of the leveling arm for the second thickness change to be carried out. For this reason, continual changes in the setting of the thickness control devices are usually detrimental to developing a smooth mat behind the paver screed.

The use of automatic paver controls, discussed in detail in Chapter 13, allows the paver to construct a smoother pavement by keeping the location of the screed pull or tow point constant as the tractor unit moves up and down vertically in response to the changes in the grade of the underlying pavement surface. By maintaining the tow point at a constant level while the tractor moves vertically, the force on the screed remains constant and the angle of attack of the screed is unchanged. This allows the screed to carry out the leveling action needed to reduce the roughness of the existing surface through the application of the new asphalt concrete layer.

Forces Acting on the Screed

There are two primary forces which constantly act on the paver screed as the machine places an asphalt concrete mix. Figure 12.22 illustrates the screed assembly, including the tow point, the leveling or towing arm, the screw conveyor or auger, the thickness control crank, and the screed with its pivot point. The first force acting on the screed is the towing force of the tractor, F3 in Figure 12.22. This force varies as the speed of the tractor unit increases and decreases.

The second force on the screed is the head of material pushing against the screed, F2. As the amount of mix pushing against the screed in the auger chamber changes, the net force acting on the screed also changes. As the forces acting on the screed change, the screed must come to a new angle of attack, shown as F1 in Figure 12.22, in order to compensate for the change in force acting on it. The forces on the screed must be in equilibrium for the screed to remain at a constant ski angle as it is towed by the tractor unit. A change in any of the forces causes the screed to react by increasing or decreasing its angle of attack, thereby changing the thickness of the asphalt concrete mat being placed. If the angle of attack of the screed is increased, the screed will move up to a new equilibrium elevation, increasing the thickness of the mat. If the angle of attack of the screed is decreased, the screed will move down to a new equilibrium elevation, decreasing the thickness of the asphalt concrete layer.

Paver Speed

The speed of the paver has a major effect on the angle of attack of the paver screed. If the forces on the screed remain constant except for the change in paver speed, an increase in the speed of the paver will cause the thickness of the asphalt concrete layer being placed to decrease. Similarly, a decrease in the speed of the tractor unit will cause an increase of the thickness of the mat being laid. This will only occur, however, as long as no other changes are made in the system; i.e., the location of the pull points (tow points) of the screed remain at a constant level, and the head of material in front of the screed is constant.

As the paving speed is increased, less material is required under the screed to compensate for the increase in the movement of the paver. Less mix can not pass under the screed, however, without decreasing the angle of attack of the screed. This decrease in the angle of attack, in turn, causes the mat being laid to decrease in thickness as the paver speed increases. Conversely, as the paver speed is reduced, the thickness of the asphalt concrete mat will increase, as long as no other changes are made to the other forces acting on the screed. This reaction is caused by the fact that as the speed is reduced, more material is required to pass under the screed. In order to process more mix, the angle of attack of the screed is increased and the screed will have the tendency to move down to a lower elevation.

The change in the angle of attack of the paver screed with changes in paver speed occurs each time the paver stops between truckloads of mix. With all other factors remaining constant, it is thus better to stop the paver relatively quickly after emptying one truck and waiting for the next truck to back into the paver. This will minimize the tendency for the screed to rise as the paver slows from paving speed to being stopped. Further, as the paver picks up speed again once a new truckload of mix has been emptied into the paver hopper, the gain in speed should be as rapid as feasible in order to minimize the reduction in mat thickness that will occur as the paver speed is increased, all other factors remaining constant.

Head of Material

As the amount of material pushing against the screed changes, the forces acting on the screed also change. If the volume of mix in the auger chamber is increased, the force on the screed will also increase. This action will cause the angle of attack of the screed to change and will increase the thickness of the mat being placed. If the amount of material being carried on the augers is decreased, the thickness of the mat will be reduced, all other factors being equal, as the angle of attack of the screed is decreased and the screed moves down to a new, lower elevation.

One of the primary factors that affects the head of material in the auger chamber is the action of the slat conveyor and auger on each side of the paver. When the slat conveyors and augers are operating, the mix is being pulled from the paver hopper through the tunnel and is distributed across the front of the screed. As long as this flow of material is relatively constant, the head of material pushing against the screed will be relatively constant, and the screed will remain at a constant angle of attack.

If the head of material is allowed to vary, however, the screed will move up and down in relation and reaction to the forces acting on it. As the amount of mix being carried by the augers is decreased because the slat conveyor and auger system is shut off, the screed will move downward, reducing the thickness of the mat behind the screed. When the slat conveyor and auger system start up, mix is introduced to the auger chamber. This increase in the amount of mix increases the force on the screed and causes it to rise to a new elevation, resulting in a thicker asphalt concrete mat.

A change in the head of material in front of the screed occurs each time the slat conveyors and augers are turned off and on. For this reason, the use of automatic feed controls is important, since this device keeps the slat conveyors and augers running as much of the time as possible. This, in turn, keeps the head of material relatively constant and allows the screed to maintain a consistent angle of attack.

Screed Strike-offs

Depending of the make of the paver, the screed may be equipped with a device on the front of it called a strike-off or prestrike-off. The purpose of this device is to meter the asphalt concrete material under the paver screed, thereby regulating the amount of mix that reaches the nose of the screed plate. Further, the strike-off or prestrike-off is used to reduce the wear on the leading edge of the screed. The location of the strike-off assembly is shown in Figure 12.24.

When the strike-off is attached to the front of the screed, its position becomes important relative to the ability of the screed to properly handle the asphalt concrete material. If the strike-off is set too high, as shown in Figure 12.25, extra material will be fed under the screed. This action will cause the screed to rise. The resulting increase in the mat thickness will be overcome by manually reducing the angle of attack of the screed using the thickness control cranks. This, in turn, will cause the screed to pivot around its hinge point and ride on its nose. Rapid wear of the nose plate will result. In addition, the screed will settle when the

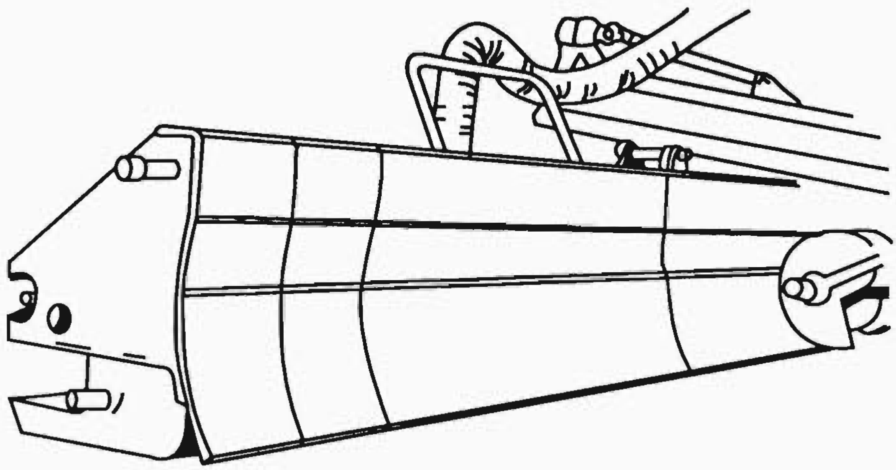


Figure 12.24. Strike-off attached to the paver screed.

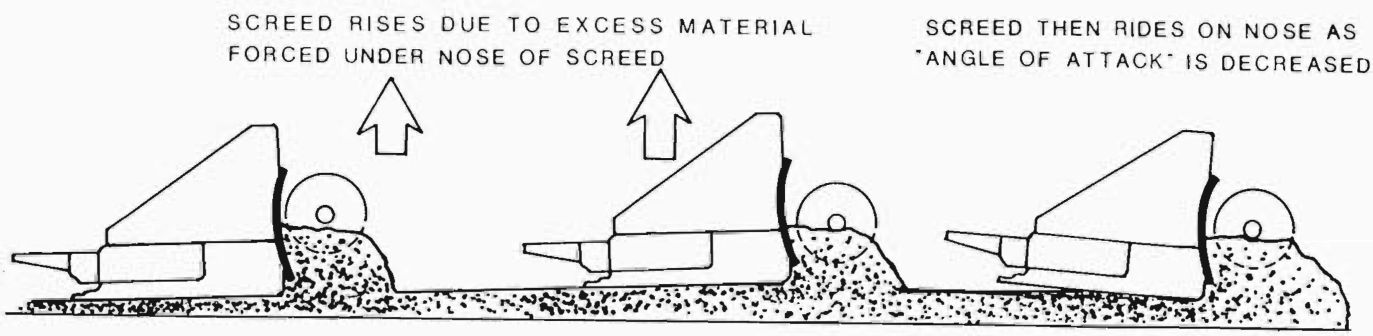


Figure 12.25. Strike-off set too high.

paver is stopped between truckloads of mix because the weight of the screed is carried on the front part of the screed only.

When the strike-off is set too low, as shown in Figure 12.26, the thickness of the asphalt concrete material will be reduced because of the lack of mix being fed under the screed. In order to maintain the proper thickness of asphalt concrete mix being placed, the angle of attack of the screed must be altered, causing the screed to ride on its tail. This increases the wear on the back of the screed and also causes the screed to settle whenever the paver is stopped due to the concentration of weight of the screed on a lesser surface area.

The exact location of the strike-off depends on the type of paver being used and on the depth of the layer being placed by the paver. For relatively thin layers of asphalt concrete (one inch thick or less), the strike-off is usually placed lower than when thicker lifts of mix are being placed. Similarly, for thick lifts of asphalt concrete (greater than 2 inches), the strike-off assembly is usually raised slightly above the normal position. In general, the strike-off is located in the range of 3/16 inches to 1/2 inches above the bottom plane of the main screed plate.

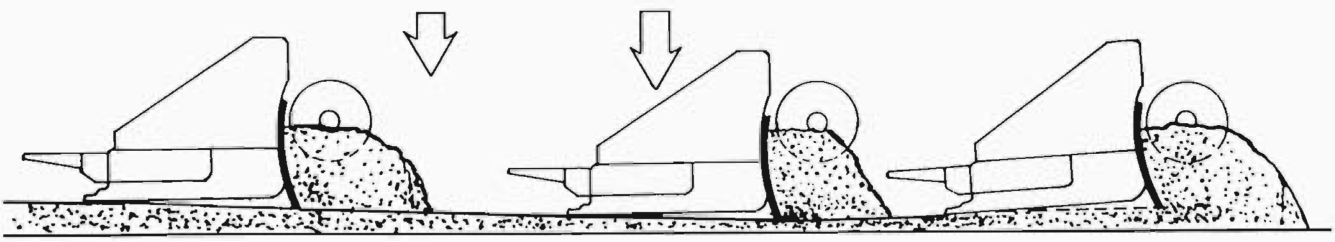


Figure 12.26. Strike-off set too low.

Screed Heaters

The screed is equipped with heaters or burners, the primary purpose of which is to increase the temperature of a cold bottom screed plate to the vicinity of 300°F. It is necessary for the screed to be at the same temperature as the asphalt concrete material passing under it in order to assure that the mix does not stick to the screed plate and tear, providing a rough texture to the mat. A properly heated screed, particularly at the start of the day's paving operations or after any extended shutdown of the laydown process, provides for a more uniform mat surface texture. The burners are normally operated for a period of 20 to 30 minutes to preheat the screed before the commencement of the laydown operation.

Usually within 10 minutes after paving begins, the temperature of the screed plate can generally be maintained by the temperature of the mix being placed. Thus, the burners are not needed and are shut off. If the mix delivered to the paver is too cool, however, the texture of the asphalt concrete mix may be improved by temporarily running the heaters on the screed.

Screed Crown Control

The screed on the paver can usually be adjusted at its center to provide for positive or negative crown. The amount of crown that can be introduced into the screed varies with the width of the basic screed and with the make of the equipment. The adjustment of the crown is typically done using a turnbuckle device to flex the bottom of the screed and impart the desired amount of crown. When rigid extensions are used with the main or basic screed, the crown being placed in the pavement by the paver can usually be altered at any of the points where the extensions are joined. If a hydraulically extendable screed is being used with the paver, the crown can be introduced not only in the center of the main screed but also at the points between the basic screed and the extensions.

Most of the paver manufacturers recommend that the screed be warped slightly, from front to back in the center of the screed, to facilitate the passage of mix under the screed and to obtain a more uniform texture on the asphalt concrete mat. This involves setting the lead crown on the front edge of the screed slightly greater than the tail crown on the back edge of the screed. In general, there should be more lead crown than tail crown, but the amount of difference depends on the make of paver and the type of screed on the machine. Normally, the lead crown setting is 1/16 to 3/16 inch greater than the tail crown position with 1/8 inch being the average difference in the crown settings.

Screed Vibrators

The amount of compaction imparted to the asphalt concrete mix is a function of many variables. The properties of the mix itself are very important: the stiffness of the mix, the temperature of the mix, and the amount of asphalt cement and moisture in the mix all affect the ability of the screed to densify the mix. Two factors within the screed itself also contribute to the degree of compaction. The first factor is the frequency of vibration, and the second is the amplitude of the compactive effort.

The frequency of vibration is controlled by the rotary speed of the vibrator shaft. Increasing the revolutions per minute of the shaft will increase the frequency of the vibration. The applied amplitude is determined by the location of the eccentric weights. The position of the eccentric weights can be altered to increase or decrease the amount of compactive effort applied to the mix by the screed, as illustrated in Figure 12.27. In general, the vibrators should be used at the maximum possible frequency and at an amplitude setting that is related to the thickness of the mat being placed — lower amplitude for thinner lifts and higher amplitude for thicker lifts.

The amount of density obtained by the paver screed is also a function of the speed of the paver. The faster the paver moves, the less time the screed sits over any particular point in the newly placed mat. Thus, as the paver speed increases, the amount of compactive effort applied by the screed decreases. For normal dense-graded asphalt concrete mixes, it can be expected that approximately 70 to 80 percent of the maximum density of the mix will be realized in the mix as it passes out from under the paver screed.

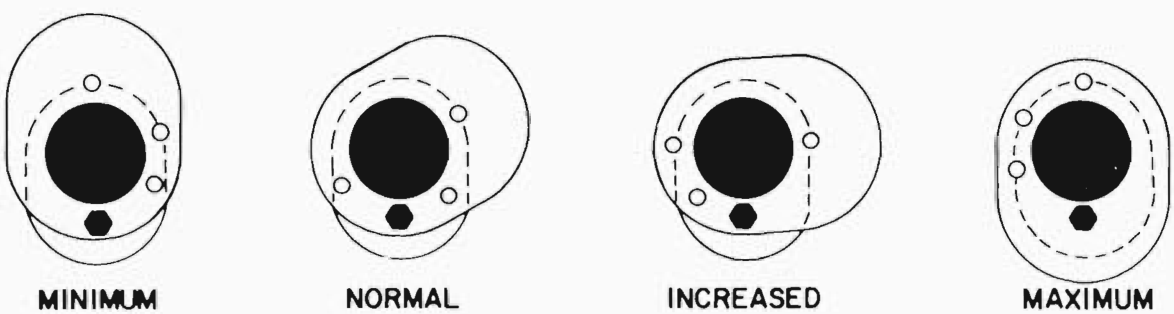


Figure 12.27. Position of the vibrator eccentric weights.

Screed Extensions and End Plates

When the basic width of the paver screed (8 feet for small pavers and 10 feet for the larger machines) needs to be changed to accommodate increased paving widths, rigid screed extensions can be employed (Figs 12.28 and 12.29). These extensions come in several widths, usually 6-inch, 1-foot, 2-foot, and 3-foot lengths. It is important for the screed extension to be attached securely to the main screed. Further, it is very important that the extension be set at the same elevation and angle as the basic screed to prevent the presence of a longitudinal transition line at the intersection of the main screed and the extension or between sections of extension. Alignment of the front edge of the extension is typically controlled independently of the alignment of the rear edge of the extension. This is illustrated in Figure 12.30 for one particular brand of paver.

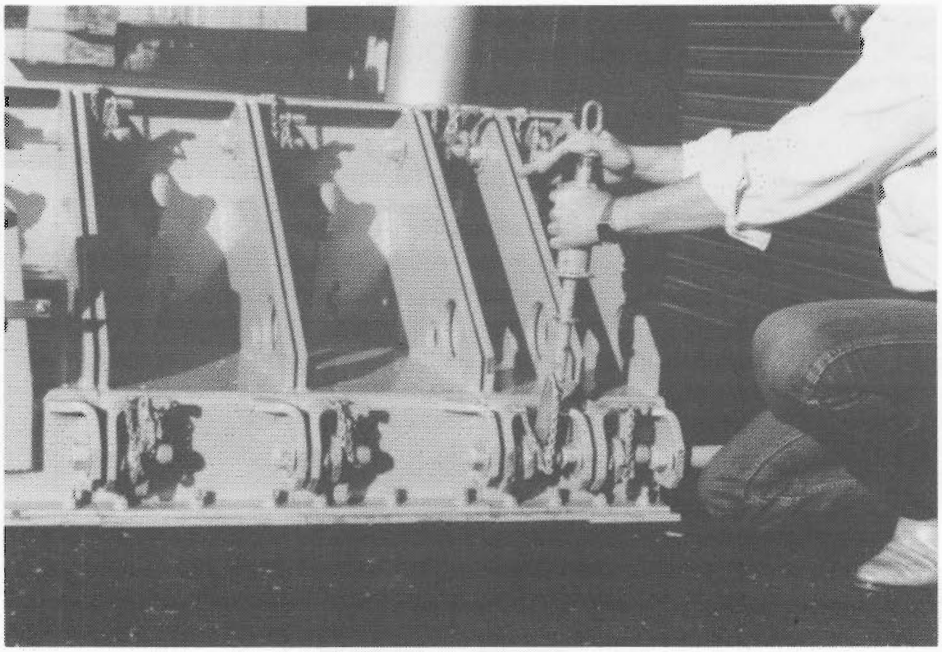


Figure 12.28. Rigid screed extension.

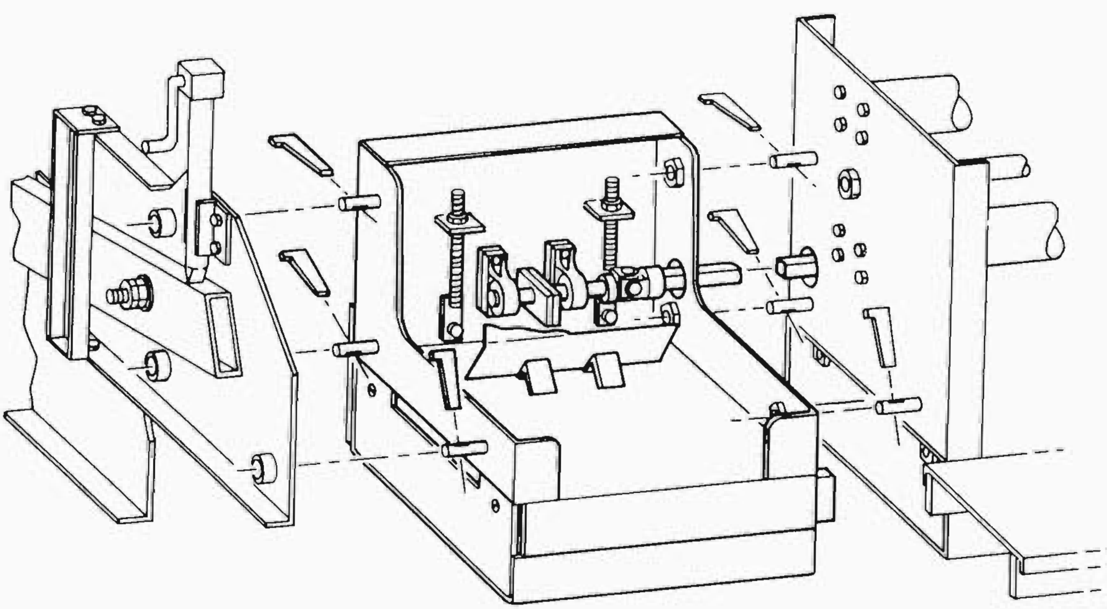


Figure 12.29. Rigid screed extension installation.

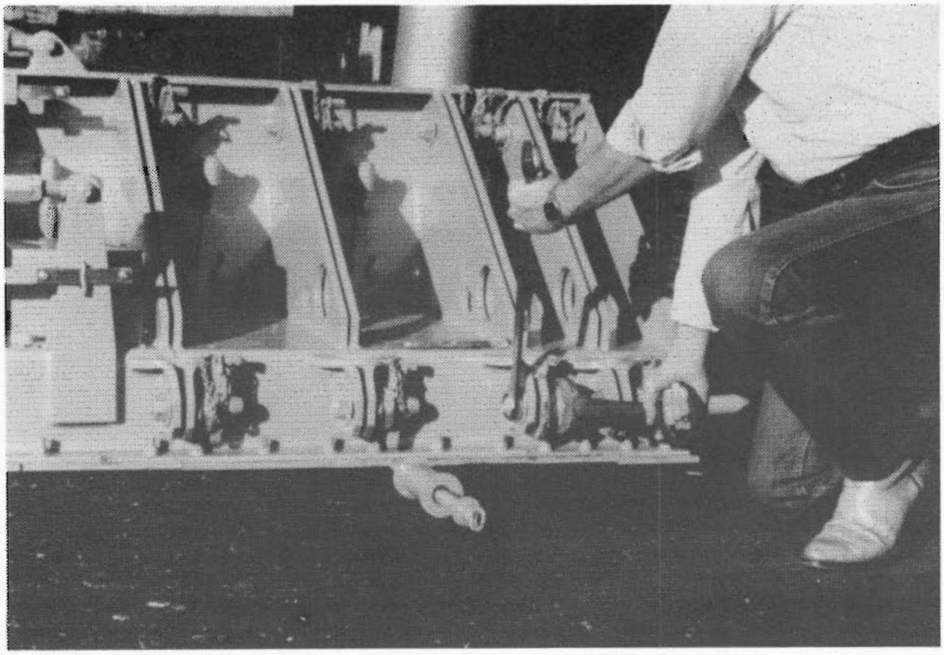


Figure 12.30. Alignment of the rigid screed extension.

Whenever a rigid screed extension is employed on the basic paver screed, auger extensions should also be added to the paver augers. The length of all the auger extensions should, in general, be the same length as the added extensions to allow room between the end of the auger and the end plate of the screed. Further, whenever rigid screed extensions are employed, the strike-off or prestrike-off assembly must also be added to the extension and set at the same location as the strike-off on the main screed.

An edger plate or end gate is attached to the end of the screed to restrict the outward movement of the mix around the end of the screed, as shown in Figure 12.31. The vertical alignment of the end gate is changeable so that mix can be bled out from under the gate if necessary. In typical operating mode, however, the end plate is positioned tight to the surface being paved to retain the mix and control the width of material being placed.

If it is necessary to reduce the width of mix placed to less than the basic main screed width, cutoff shoes can be used. As illustrated in Figure 12.32, the standard cutoff shoes are attached to the paver end gate and are employed to restrict the width of mix being laid between the end plates. Typically, the cutoff shoes come in widths of 1 foot or 2 feet, and are adjustable in various increments depending on paver manufacturer.

Hydraulically Extendable Screeds

Most paver manufacturers have adopted hydraulically extendable paver screeds which trail the primary or basic screed on the paver. One make of pavers, however, is equipped with a power extendable screed which places the extendable portion of the screed in front of the main screed. An example of each type of extendable screed is shown in Figures 12.33 and 12.34.

For any extendable of screed, it is very important that the angle of attack for the extendable screeds (one on each side of the main screed) is the same as the basic screed (See Figure 12.35). In some cases, it will be necessary for the trailing (rear) screeds to have a slightly positive attack angle compared to the main screed. In general, however, the forces acting on the

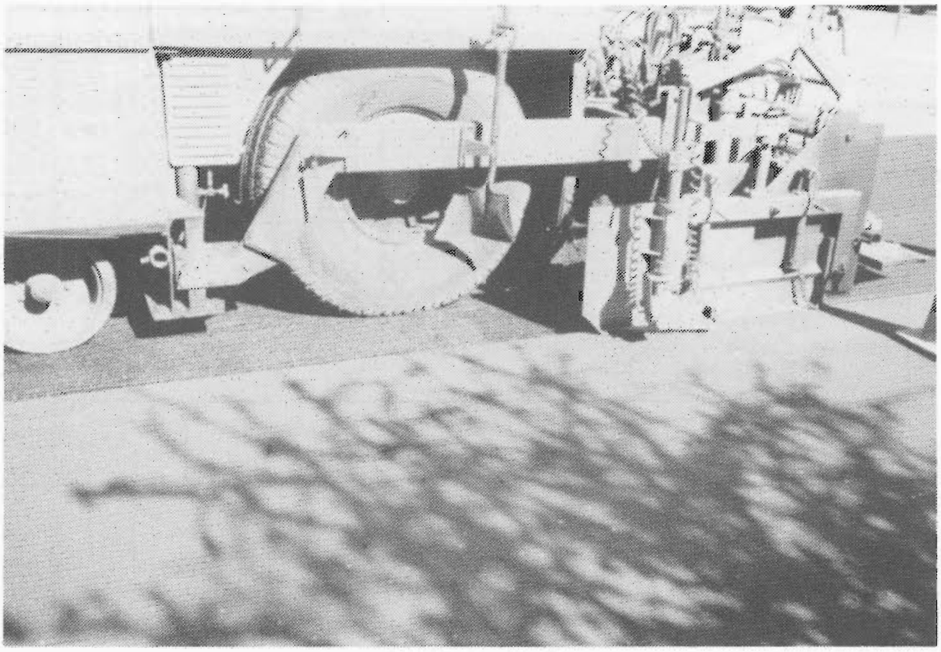


Figure 12.31. Screed end gate.

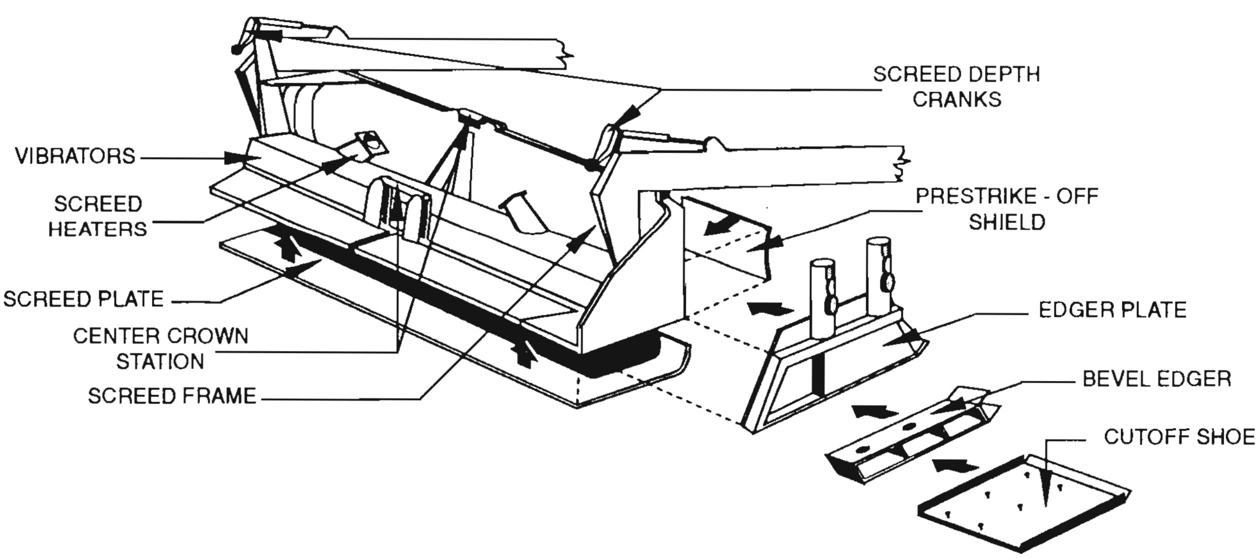


Figure 12.32. Parts of the paver screed, including cutoff shoe.

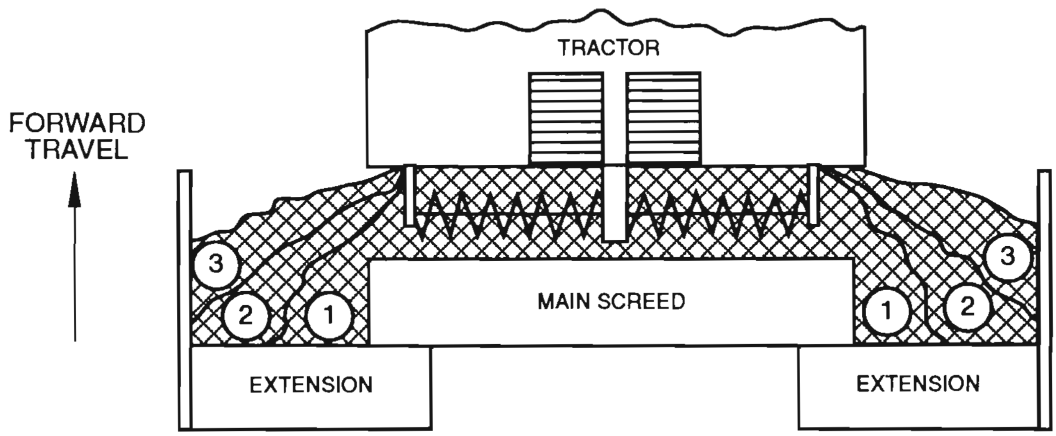


Figure 12.33. Extendable screeds trailing main screed.

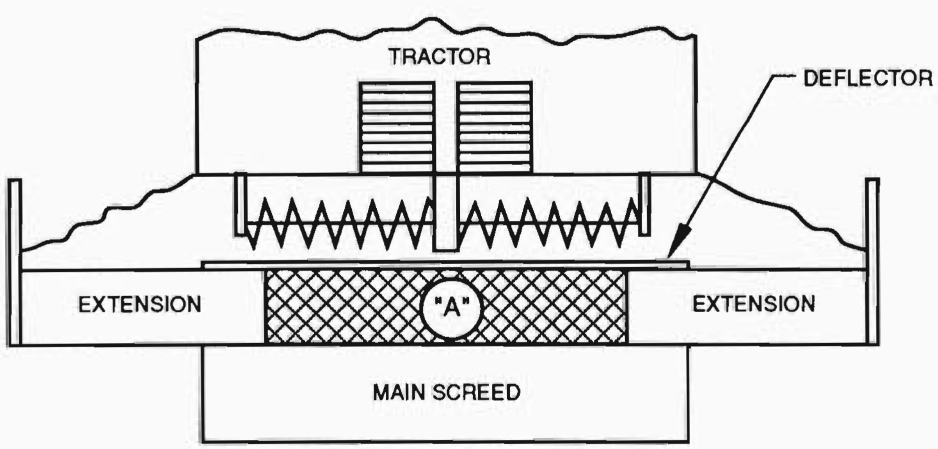


Figure 12.34. Extendable screeds in front of main screed.

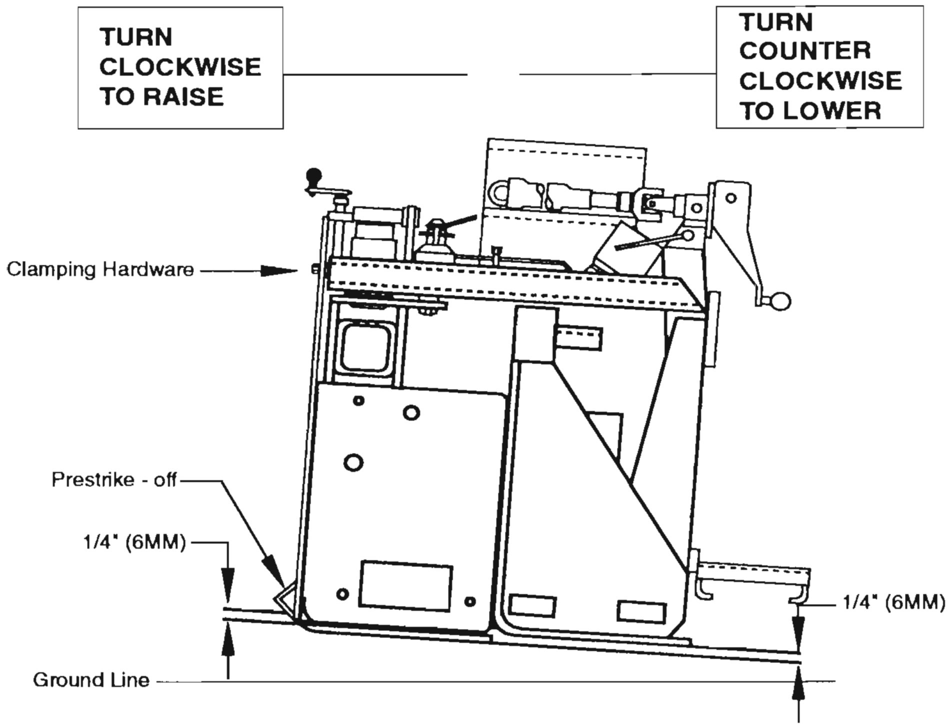


Figure 12.35. Relationship of the extendable screed to the main screed.

CHAPTER 13. AUTOMATIC PAVER SCREED CONTROLS

13.1 PURPOSE OF AUTOMATIC SCREED CONTROLS

As discussed in the previous chapter, the asphalt paver operates on the principle of the floating screed. Asphalt concrete mix is deposited in the hopper of the paver from the haul trucks and then transported by the slat conveyor at the bottom of the hopper, through is the tunnel on the paver, and back to the augers which distribute the mix across the width of the screed. The speed of the paver and the amount of mix in the auger chamber determine the primary forces acting on the screed unit and, thus, the angle of attack of the screed itself.

Automatic feed control devices are used to assure that the amount of mix delivered to the screed is relatively constant. The paddles which are located between the end of the augers and the end gate on the paver screed are used to monitor and to control the volume of material being fed to the screed. If the head of material in front of the paver screed is too high, the material feed controls stop the movement of the slat conveyors and the augers, thus reducing the amount of material in front of the screed. As the amount of mix in front of the screed is lessened, the automatic feed control sensors restart the movement of the slat conveyors and the augers and mix is again delivered to the auger chamber.

Manual Thickness Control

If the paver were always operated on a level grade, the automatic feed control system on the paver would not be needed. The height of the flow gates on the back of the paver hopper and the speed of the slat conveyors and augers could be set one time and a constant amount of material could be fed to the screed in order to maintain a consistent head of material in front of that device. This would permit the screed to have a constant angle of attack, thereby producing a pavement layer of uniform thickness.

With the paver riding on a level grade, the forces on the screed would be constant as long as the paver was moving at a constant speed. The towing force on the screed would be stable, and the head of material in front of the screed would be consistent as long as the feed control system was set to operate as much of the time as possible. Under these conditions, a very smooth asphalt concrete mat could be obtained without a screed operator ever changing the setting of the thickness control cranks on the back of the screed. Indeed, once the angle of attack of the screed is set when the paver starts up in the morning, no changes would ever need to be made to the setting of the thickness control handles.

In the real world, however, the tractor unit operates on a grade which is variable. As the elevation of the existing surface moves up and down, the wheelbase of the tractor unit (either crawler or rubber tire) follows that grade. This vertical movement of the tractor as it moves forward causes the elevation of the tow or pull point on the tractor to change in direct relation to the movement of the tractor unit. As the location of the tow point is altered by the movement of the tractor, the angle of attack of the screed is changed.

If the elevation of the pull point is raised, the screed will be rotated upward at a ratio of one to eight compared to the change in elevation of the tow point. As the paver moves forward a distance equal to at least five times the length of the leveling arm on the machine, the screed will float up to the new elevation and the asphalt concrete mat will be thicker. If the tractor unit moves into a dip in the existing pavement surface, the elevation of the tow point will be lowered, reducing the angle of attack of the screed. If no other changes are made in the forces acting on the screed, the screed will move downward as the paver travels forward, lessening the thickness of the asphalt concrete layer being placed.

The self-leveling action of the screed takes place continuously as the tractor unit travels over the roadway being paved. The reaction of the screed to the location of the tow point, the speed of the tractor, and the head of material in the auger chamber determines the thickness of the mat being laid. This whole operation occurs without the thickness control cranks on the screed ever being changed. The floating screed principle permits the paver to reduce the thickness of the mix placed on the high points in the existing pavement surface and increase the depth of the material deposited in the low spots on the same surface.

If the thickness control cranks or handles are turned by the screed operator, the angle of attack of the screed will be altered. Depending on the direction that the cranks are turned, the screed will react to the change in setting by rotating around the hinge or pivot point where it is attached to the leveling arm and thus to the tow point of the screed. As the paver moves forward, the screed will float up to or down to the new elevation. Similar to the change in elevation of the tow point on the leveling arm, however, the paver must travel forward a distance of at least five lengths of the leveling arm before the change in the depth of the mat is fully realized.

On many projects, particularly involving the resurfacing of an existing highway, the screed operator is forced by the job specifications to maintain a certain yield of asphalt concrete mix per square yard or per station. It is not uncommon to watch a screed operator continually check the thickness of the mat being placed by the paver and then adjust the setting of the thickness control cranks to increase or decrease the amount of mix being placed. This change in the setting of the thickness control system is done without regard to the changes being made at the same time to the screed as the elevation of the tow point changes while the tractor unit moves forward over a variable grade.

Two inputs, then, are being introduced into the self-leveling system at the same time. The first input is the vertical movement of the tow point of the screed which reacts to changes in the grade of the wheelbase of the paver. The second input is the manual changing of the thickness control cranks by the screed operator. The input from the movement of the tow point and the input from the change in setting of the thickness control device may be additive to one another or they may be opposite to one another, even cancelling each other out.

Under manual screed operation, the ability of the screed operator to produce a consistently smooth asphalt concrete layer is dependent on a number of factors. The first is the frequency at which the operator feels the need to adjust the setting of the thickness control cranks. The more the screed operator changes the angle of attack of the screed, the more uneven will be the resulting asphalt concrete layer. The second factor is the roughness of the existing pavement surface. The more the screed operator tries to assist the self-leveling action of the screed, the rougher will be the resulting pavement surface. The third factor is the need to meet a certain maximum yield specification. It is usually not possible, particularly for thick courses of asphalt concrete, to produce a smooth pavement layer and stay within a certain volume of material usage at the same time. This is particularly true if a minimum overlay thickness is specified at the same time as the yield criteria is to be met. This problem will be discussed in more detail below.

Automatic Screed Controls

The primary purpose of automatic screed controls is to produce a smoother asphalt concrete pavement layer — smoother than the paver can accomplish by itself and smoother than a screed operator can accomplish by continually changing the setting of the thickness control cranks. The automatic screed control functions by maintaining the elevation of the screed tow points in relation to a reference other than that of the wheelbase of the paver itself. Figure 13.1 illustrates the automatic grade and slope control system for one particular make of paver.

The elevation of the tow point is kept at a constant relationship to a given grade reference. The automatic system does not permit the relative position of the tow or pull point to change even though the tractor unit is moving up and down vertically in response to the roughness

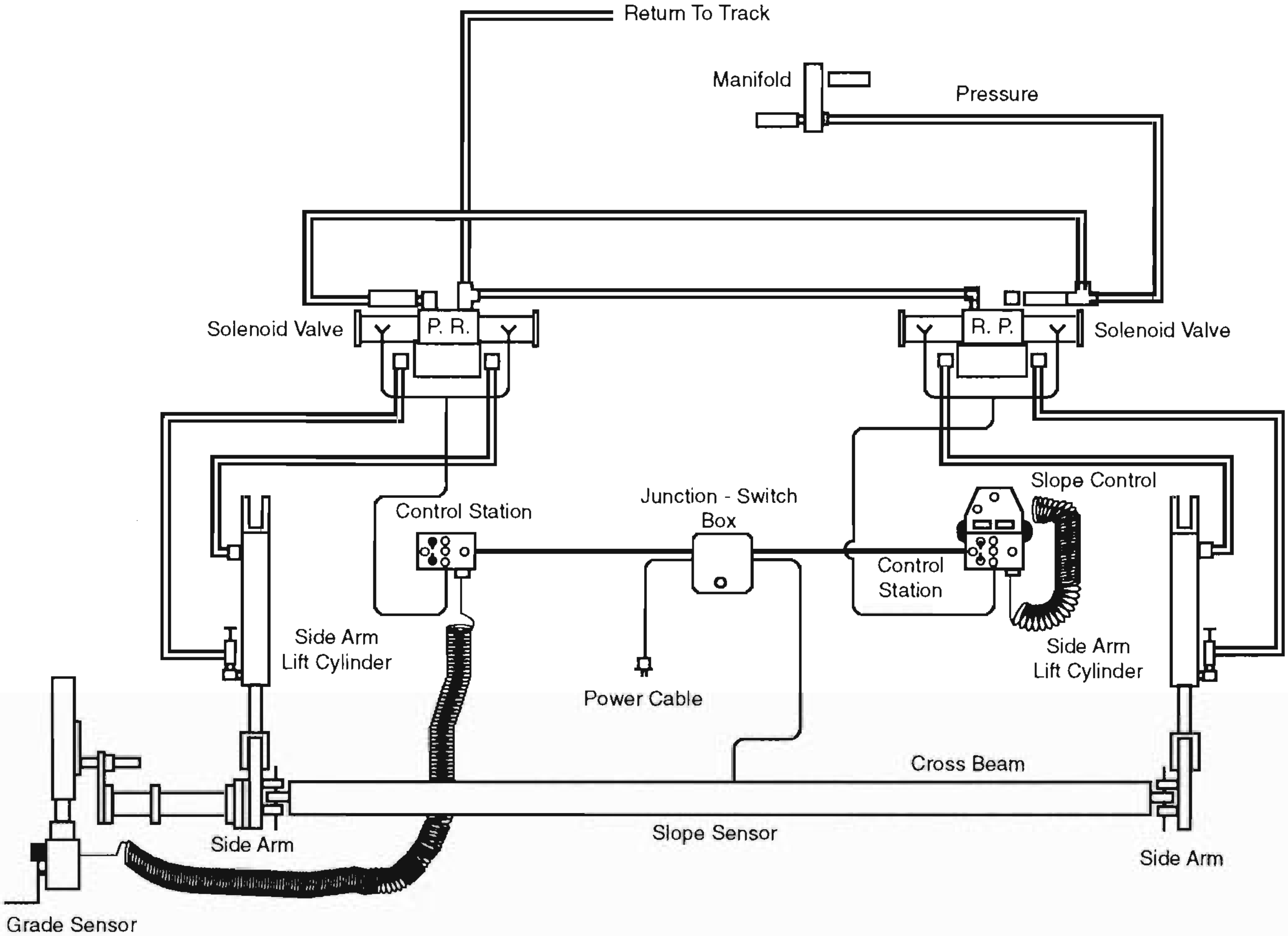


Figure 13.1. Automatic grade and slope controls.

of the surface it is traveling over. Thus, by maintaining the tow point at a constant elevation, the angle of attack of the screed is also maintained at a constant setting. This allows the screed to ski at a consistent angle, permitting the screed to do an even better job of reducing the quantity of mix placed over the high spots in the existing pavement surface and increasing the amount of mix laid in the low spots. The principles of the automatic screed control system are shown in Figure 13.2.

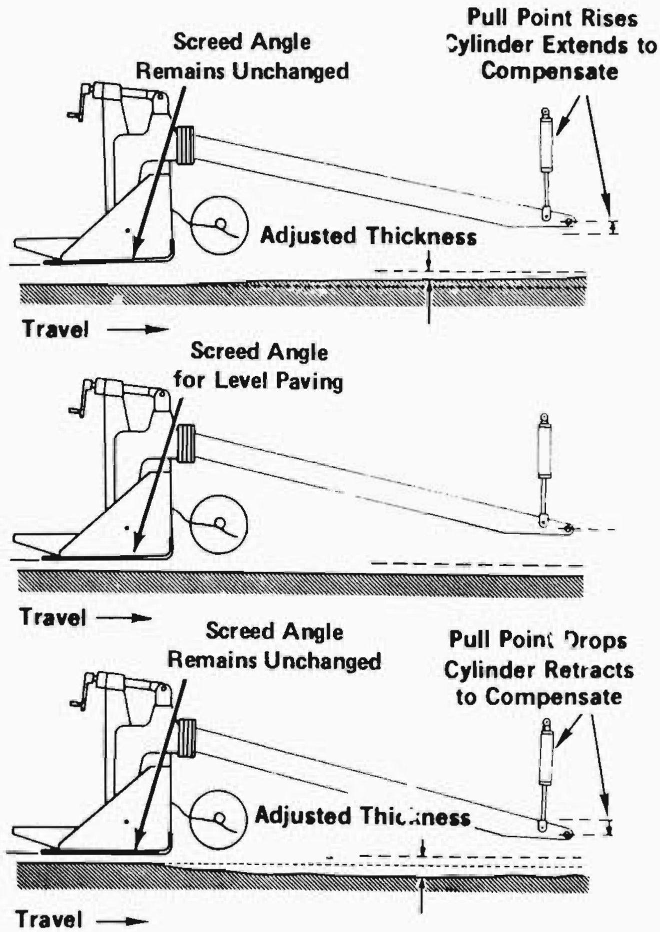


Figure 13.2. Principles of automatic screed control.

The action of the automatic control on the elevation of the screed tow point keeps the height of the tow point at a relatively constant elevation. The tractor unit moves up and down vertically in response to the grade over which it is traveling. The screed, however, maintains a constant angle of attack, providing a smooth mat behind the paver.

Figure 13.3 provides information on the location of the grade controls for a typical asphalt paver. Slope sensors are usually on the cross beam located behind the operator's chair.

13.2 TYPES OF GRADE REFERENCES

There are three basic types of grade references that can be employed to maintain the elevation of the screed tow point. Those three devices are: (a) the erected stringline, (b) the mobile reference, and (c) the joint-matching shoe.

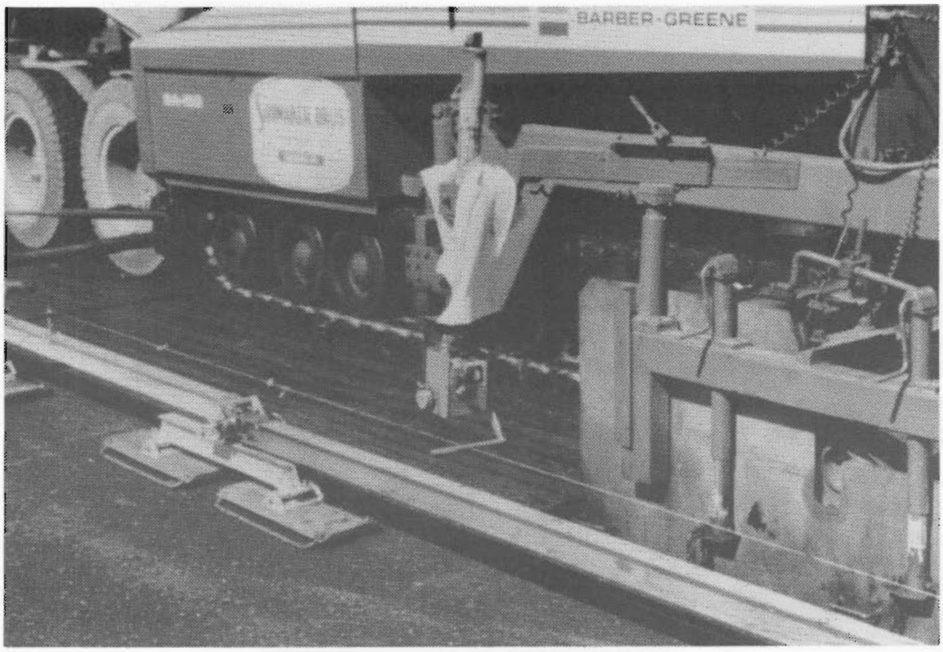


Figure 13.3. Location of grade controls.

Grade sensors are used to monitor the elevation of the existing pavement surface in a longitudinal direction. They can be used only on one side of the paver and can be mounted on either side. When used in conjunction with a slope control device, the grade sensor is typically positioned on the centerline side of the paver with the slope controller determining the grade of the outside edge of the pavement. Grade sensors can also be employed, however, on both sides of the paver at the same time. This use of the grade sensors will average out the variations in the grade of the existing pavement surface on both sides of the lane being paved but will not produce a uniform cross-slope to the new asphalt concrete layer.

Erected Stringline

Theoretically, the use of an erected stringline, shown in Figure 13.4, should allow for the smoothest possible asphalt concrete layer out of the paver screed. This method of supplying an elevation input provides the longest reference for the paver tow point. Practically, however, the use of the erected stringline has a number of drawbacks that usually offset the increase in smoothness obtained by its use.

The elevation of the erected stringline is set by a surveying crew. The accuracy of the elevation of the line is directly dependent on the care taken in its erection. If the grade set by the surveyors is incorrect in any way, the paver screed will duplicate that error in the pavement surface. The cost of setting the stringline by the survey crew is usually significantly greater than the cost of using a mobile reference system.

On horizontal curves, it is very difficult to use an erected stringline to control the grade of the new pavement layer. The string can not be set in a curve and therefore a series of cords must be used around the radius of the curve. This, in turn, requires the positioning of a large number of support posts and rods, usually at 10-foot intervals, around the curve. The surveying done to set the stringline must be exact so as to prevent a misalignment of string and the setting of the wrong grade reference for the paver.

Figure 13.4. Erected stringline.

The stringline must be very taut when it is set. Typically, the string is supported at 25-foot intervals on metal posts and rods. The string is anchored at one end of its length and then pulled tight and anchored at its other end. It is extremely important that the string be stretched very taut, without any dips or sags in the line between the support rods. If the string is not stretched tightly, the sensor on the paver will react to the sags in the line and duplicate those sags in the new pavement surface. Even when high-strength line (over 100 pounds tensile strength) is used, it is not always possible to keep the line tight enough to prevent some small sags from occurring.

Another disadvantage of the erected stringline is the fact that the haul trucks and all paving personnel must keep away from the line and not disturb it in any way. Once the line is set at the proper elevation, it is imperative that the line remain untouched both before and after the paver sensor passes over the line. Any change in the elevation of the line due to someone leaning on the line or a truck backing into the line will result in a change in the input to the grade sensor and movement of the pull point on the paver leveling arm.

With a properly set and maintained stringline, the mat placed by a paver equipped with automatic screed controls will be very smooth. This is primarily because of the extended length of the reference being used compared to the limited length of a mobile reference such as a 30- or 40-foot ski. Unless smoothness is an extremely important criteria on a paving project, however, it is doubtful that the added price of erecting and maintaining the stringline is cost effective for the typical asphalt concrete paving job.

Mobile References

Different paver manufacturers use different types of mobile reference devices to extend the relative wheelbase for the automatic screed control system. The operation of these reference systems, however, is essentially the same. The purpose of the mobile reference is to average the deviations in the existing pavement surface out over a distance which is greater than the wheelbase of the tractor unit itself.

One paver manufacturer offers two different versions of a mobile reference or ski. They both employ a semirigid tubular grade reference (pipe) that is 20, 30, or 40 feet in length. For one version, the pipe rides directly on the existing pavement surface. A spring-loaded wire is stretched between the ends of the ski, on top of the pipe (Fig 13.5). The grade sensor that inputs the electrical signal to the paver tow point rides on top of the wire. As the pipe moves up and down, and flexes, over the existing grade, the stretched string on the ski is used to average out the differences in elevation that occur between the ends of the mobile reference.

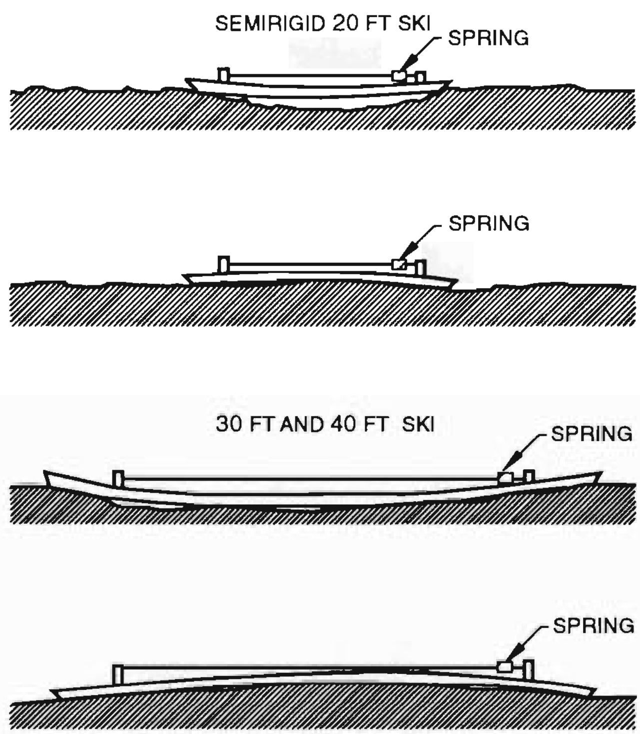


Figure 13.5. Semirigid tubular grade reference.

The second variation of the pipe ski is a tubular grade reference that is equipped with a set of wheels on each end of the pipe. As with the tubular reference that sits directly on the grade, the wheels on each end of the pipe move up and down with changes in the height of the existing roadway. A spring-loaded string is stretched between the ends of the pipe, and the grade sensor sits on the string. The grade sensor is usually set in the center of the length of the ski so that an average of the elevation difference between the ends of the pipe is measured.

Another paver manufacturer provides a different type of mobile reference, termed a floating beam. A series of feet or shoes are attached to the bottom of the floating beam (Figs 13.6 and 13.7). The purpose of the shoes is to allow one or more of the feet to pass over a singular high or low point in the existing pavement surface without altering the slope of the whole beam. The feet are spring loaded to allow them to be deflected by a large stone on the pavement surface, for example, without pushing the whole beam upward. The grade sensor usually rides directly on the beam at its midpoint. As with the other types of mobile references, this floating beam system averages out the variation of the existing grade over a 30- or 40-foot distance, depending on the length of the beam.

Figure 13.6. Floating beam grade reference.

A third paver distributor also supplies a floating beam type of mobile reference system. The beam is normally 30 feet in length. Instead of multiple feet spread out along the length of the beam, however, a series of shoes is placed at each end of the beam. These shoes are allowed to rotate and can be individually displaced by isolated disruptions in the existing pavement surface without changing the height of the whole beam. This allows the beam to average the grade of that surface over the length of the reference without being influenced by the presence of a single high point or dip in that surface. As for the other mobile reference systems, the grade sensor is located near the center of the length of the beam.

As shown in Figure 13.8, one paver manufacturer has produced a mobile reference ski which is 55 feet in length from front to back. Part of the reference beam is located in front of the paver screed. This part is basically a floating beam type system, equipped with a series of spring-loaded shoes. To the rear of the screed, riding on a series of spring-loaded wheels, is another floating beam part which is used to reference the grade of the newly placed asphalt concrete mix. A set of intermediate bridge beams, which go up and over the screed, are used to join the two parts of the floating beam together. The grade sensor rides on one of the intermediate bridge beams and transmits the average grade of the front and back beam to the paver tow point to control its elevation.

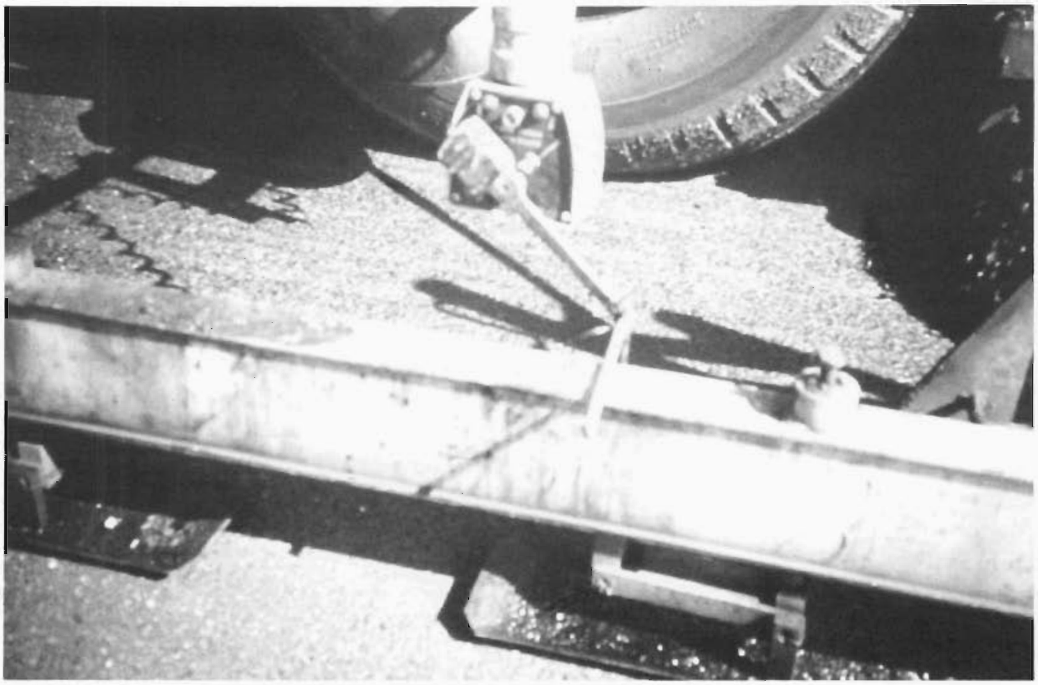


Figure 13.7. Feet on floating beam grade reference.

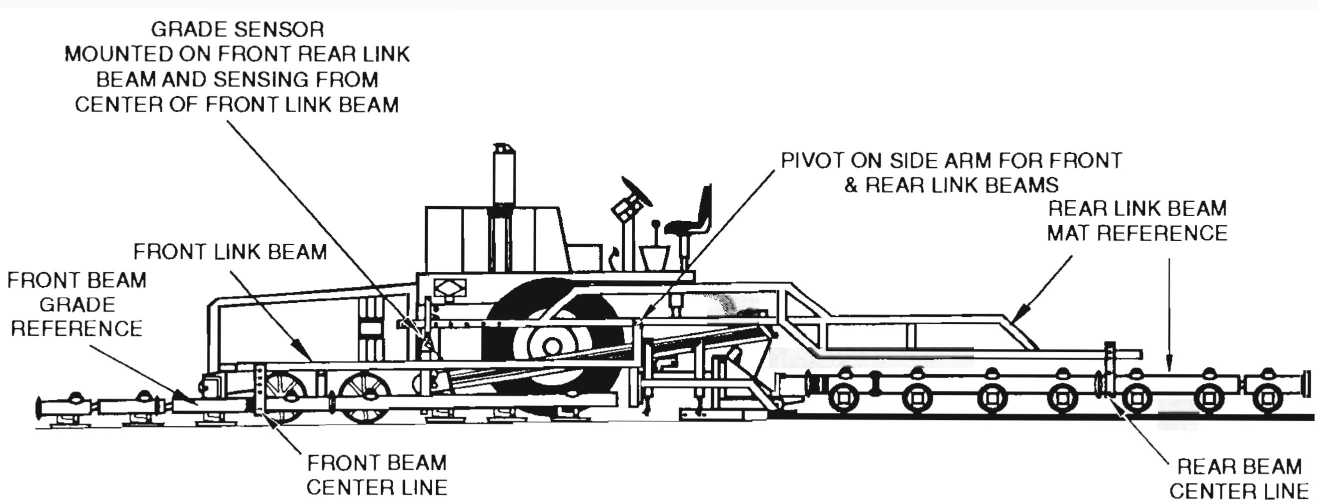


Figure 13.8. Fifty-five foot floating beam grade reference.

Joint-Matching Shoe

The third type of reference is the joint-matching shoe, which is shown in Figure 13.9. This device consists of a short (approximately one foot in length) shoe or ski which is used to reference the grade of an adjacent pavement or curb. This type of mobile reference is used only when the grade being sensed is relatively smooth. The shoe rotates around a pivot point and supplies an input signal to the paver tow point when the shoe or ski is displaced (See Figure 13.10). Because of its short length, the joint-matching shoe will not remove any variations that occur in the pavement surface. Indeed, the purpose of the shoe is to duplicate the grade of the adjacent surface.

Location of the Grade Reference

Different paver manufacturers have different recommendations for the placement of the grade reference control sensors. Occasionally, the grade sensor will be mounted adjacent to the tow point on the paver, as seen in Figure 13.11. As pictured in Figure 13.12 (top), the grade sensor is sometimes located at various different positions on the leveling arm. This side-mounting position is typically recommended when it is desired to correct long vertical deviations in the present pavement surface. When located on the leveling arm, the reaction time to changes in grade is short, and the angle of attack of the screed is altered quickly. On some occasions, and particularly for wide width paving, the grade sensor is mounted near or on the paver screed (see Figure 13.1 [bottom] and Figure 13.13). To function properly, the grade sensor must be located in front of the pivot or hinge point of the screed.

There are a variety of possible positions recommended by the different major paver manufacturers for the location of the grade sensor. It is well known that the location of the grade sensor makes a difference in the reaction of the tow point and the screed to the grade being sensed. There is not a set rule that can be followed, however, as to the proper location to place the grade sensor. It is recommended, therefore, that the paver manufacturer's suggestions be followed for the particular make and model of paver being used.

13.3 SLOPE CONTROL

In most cases, paving that is done with automatic screed controls is accomplished with a combination of grade control on one side of the paver and slope control to determine the grade on the other side of the machine. The slope control operates through a slope sensor that is located on a cross beam between the two sides of the paver. One side of the paver screed is controlled by the grade sensor. The other side of the screed is controlled by the slope sensor (Figs 13.1, 13.3, and 13.14).

When slope control is used, the thickness of the mat on the side of the machine (usually the outside edge of the roadway) that is controlled by the slope sensor will be variable in depth. The desired degree of cross-slope is dialed into the slope controller, seen in Figures 13.15 and 13.16. This cross-slope is then regulated by a pendulum-type device which is part of the slope control system. Without regard to the grade of the existing pavement, the slope controller will set the grade of one side of the screed in order to maintain a constant cross-slope, regardless of the resulting thickness of the asphalt concrete layer placed. If there is a high point in the present pavement surface, the slope controller will place less material over that location. If there is a low point in the existing pavement, the slope controller will allow the screed to deposit more mix in that location. Thus, except for the fact that it operates in a transverse direction instead of a longitudinal direction, the slope control system functions in a similar fashion to the longitudinal grade control system.

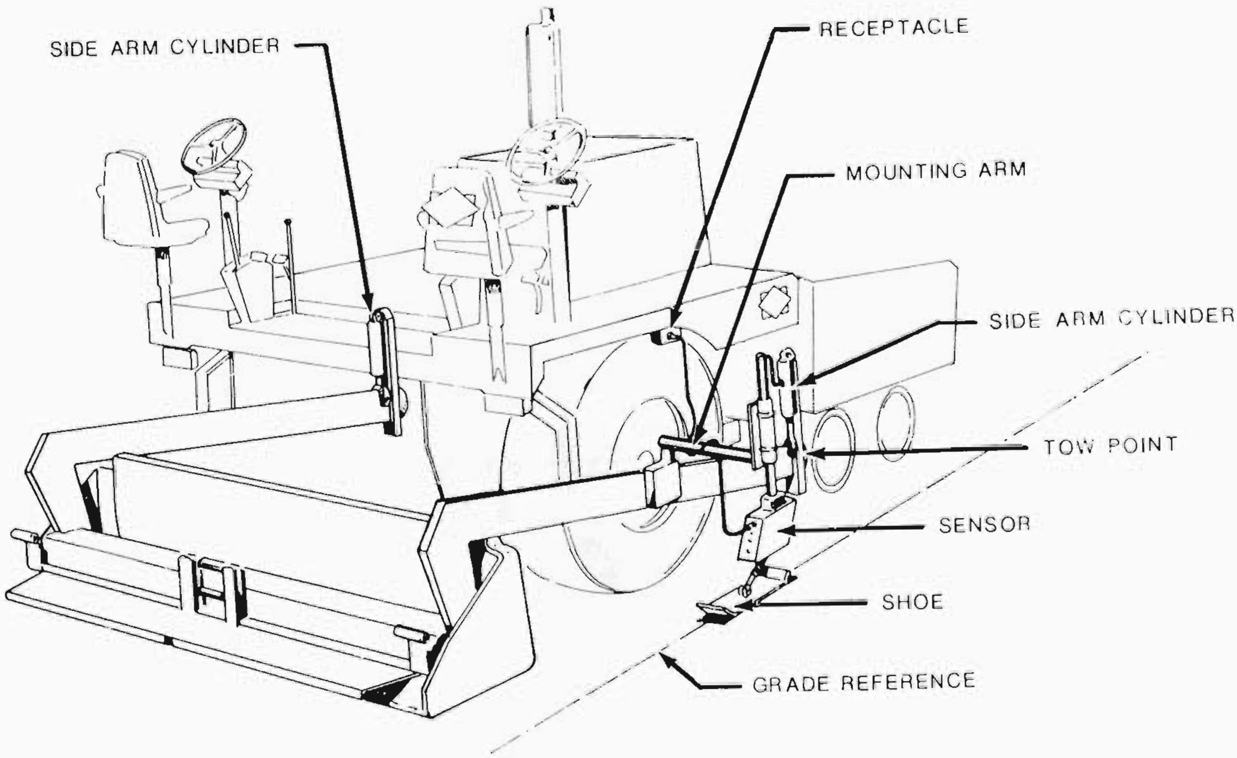


Figure 13.9. Joint-matching shoe grade reference.

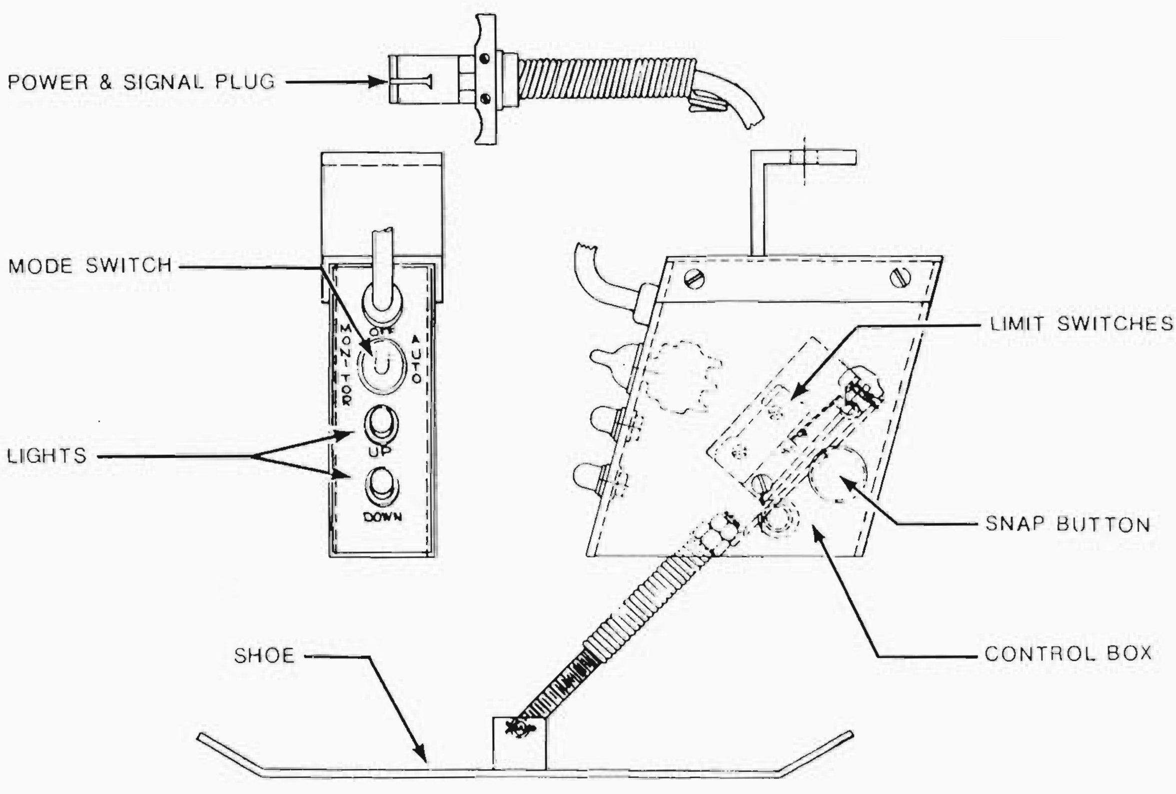


Figure 13.10. Joint-matching shoe sensor.

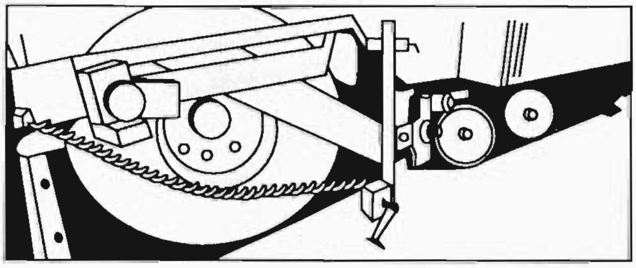


Figure 13.11. Grade sensor near paver tow point.

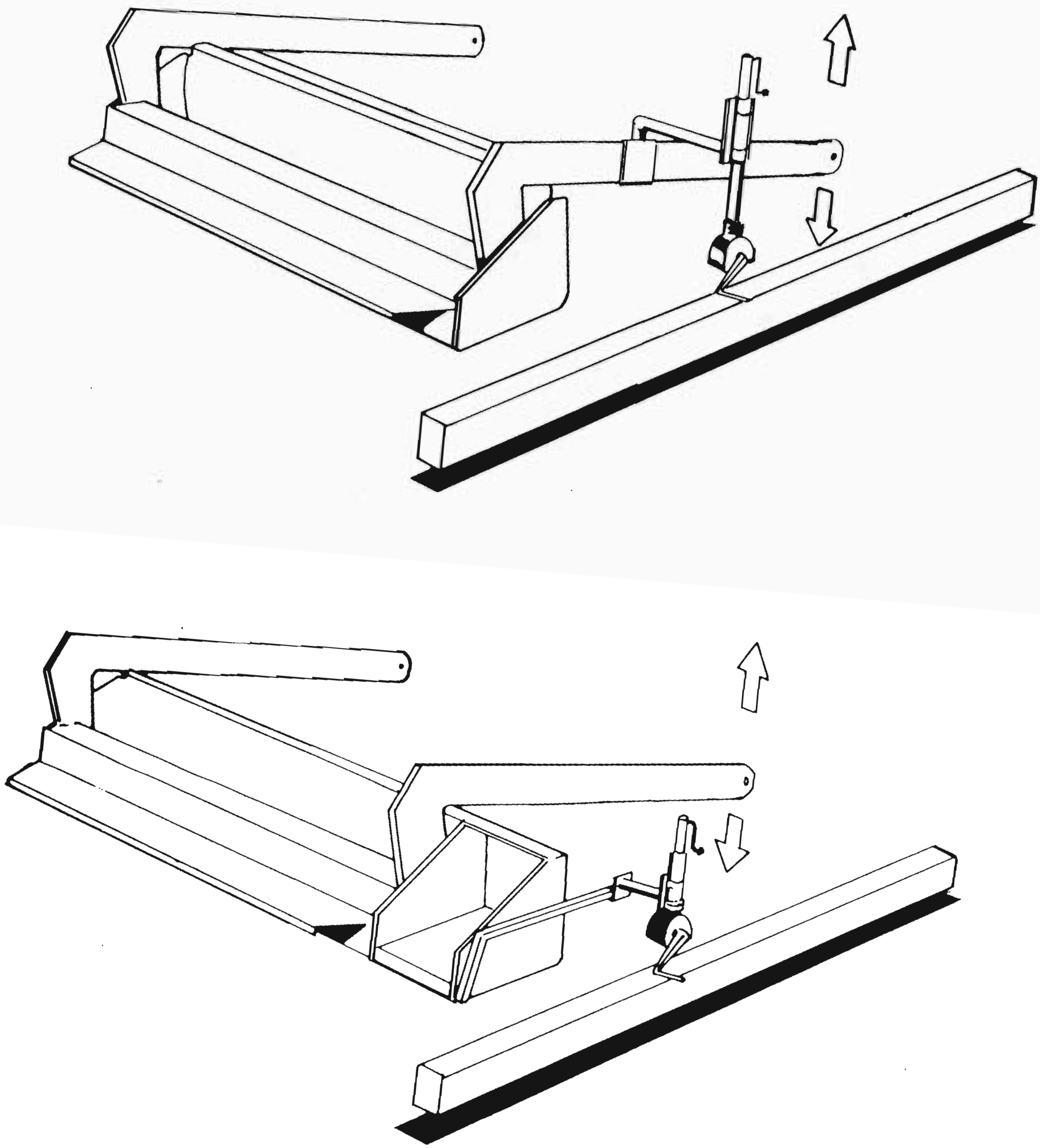


Figure 13.12. Grade sensor locations.

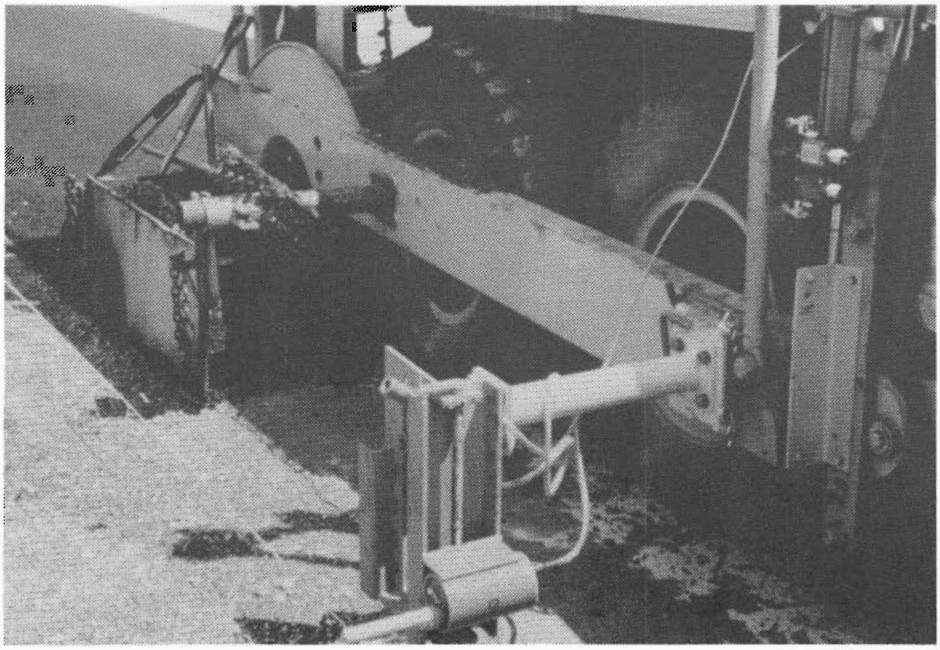


Figure 13.13. Grade sensor near paver screed.

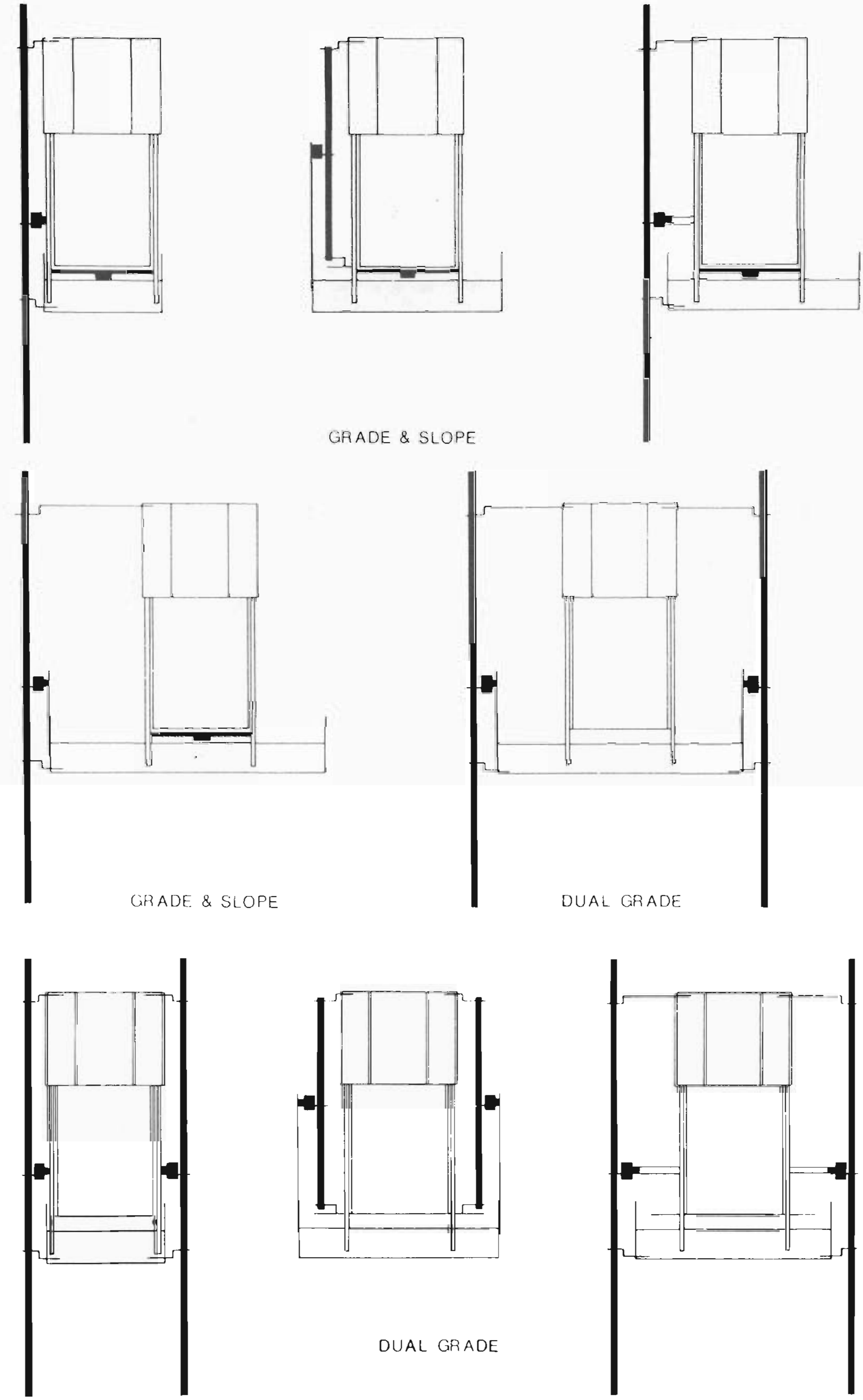


Figure 13.14. Grade and slope controls.

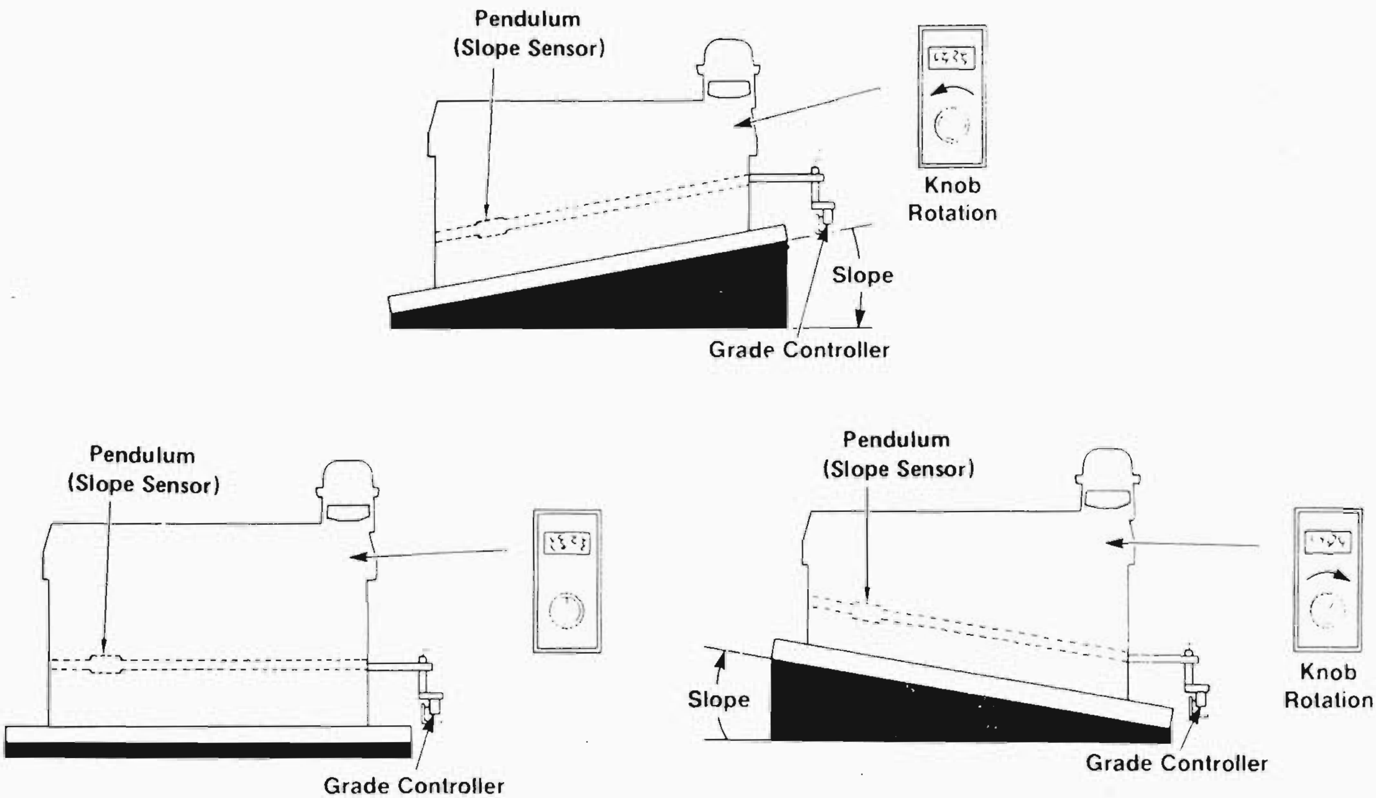


Figure 13.15. Setting cross-slope.

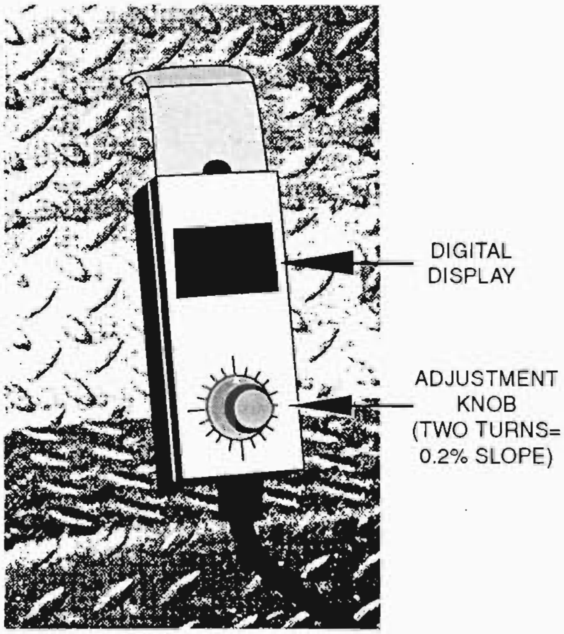


Figure 13.16. Slope control setting device.

13.4 YIELD, MINIMUM THICKNESS, AND SCREED CONTROLS

The paving specifications for asphalt concrete overlay projects are written in a variety of ways. In some cases, the specifications call for a minimum thickness of mix to be placed. For this type of requirement, in order for the minimum thickness specification to be met at all points in the pavement layer, it is usually necessary for the paver operator to place a mat thickness that is greater than the minimum depth required in the contract. The amount of extra thickness depends on the roughness of the existing pavement: the more uneven that roadway, the greater will be the volume of mix needed to assure compliance with the minimum thickness requirement.

As an example of this type of specification, if the existing pavement is relatively uneven, and if a minimum compacted overlay thickness of 1 inch is required, the paver thickness control system would need to be set so as to place an average depth of asphalt concrete of approximately 1-1/2 inches. This means that the angle of attack of the screed would have to be positioned so that the average thickness placed would assure that the minimum depth of mix was laid over all the high spots in the pavement surface.

The second type of specification would call for the placement of a given amount of mix, in terms of pounds of mix per square yard, over the pavement surface area. In this case, the thickness requirement is an average depth, not a minimum depth. If the specifications for a project called for the placement of 110 pounds of mix per square yard (approximately 1 inch of compacted thickness for a dense-graded asphalt concrete mixture), the angle of attack of the paver screed would not have to be set at as great an angle in order to place the mix an average depth of 1 inch, compared to a minimum thickness of 1 inch. This type of specification, however, is really a yield-type of requirement. Through some simple calculations, the amount of mix needed to average 110 pounds of mix over the length of a truckload of mix or a station and the width of the lane being paved can be quickly determined.

The paver screed, left to operate without human intervention on the thickness control cranks and run either with or without automatic controls, will typically overyield mix. This means that the paver will require more materials than generally expected to react to variations in the grade of the existing pavement and to shave off the high spots and fill the low spots in that surface. In order to meet the yield requirement, therefore, it is usually necessary to reduce slightly the thickness of the mat being placed in order to comply with the yield requirement.

The third type of specification is one that requires a certain degree of smoothness for the finished pavement surface. Many different smoothness specifications exist. Most are related to the amount of deviation permitted from a straightedge of a given length or to a certain maximum number of inches of roughness per unit of length, typically a mile or some portion of a mile. While it is normally possible to meet such smoothness specifications through the use of automatic screed controls, the ultimate success in making the requirements depends on the amount of mix available to be placed, the condition of the existing pavement, and the number of layers of mix to be laid. The amount of mix that will be consumed by the paver to meet a smoothness requirement, however, will usually be greater than the amount needed to meet a given yield requirement.

The problem comes when it is desired to meet some maximum yield requirement and to meet a minimum thickness requirement or smoothness requirement at the same time. Because of the principle of the floating screed, it generally is not possible to accomplish both of the specifications at the same time on the same project. Particularly for thin overlays, the paver is normally not capable of meeting a minimum thickness and/or a smoothness specification at the same time as a yield-type requirement.

CHAPTER 14. JOINT CONSTRUCTION

During the placement of asphalt concrete pavements, two types of joints are constructed. The first type of joint is a transverse joint. This joint occurs whenever the paving operation is interrupted for a period of time. The second type of joint is a longitudinal joint. This kind of joint occurs when one lane of asphalt concrete mix is constructed adjacent to a previously placed lane. The techniques for constructing each type of joint are discussed in this chapter.

14.1 TRANSVERSE JOINTS

End of Paving

When the placement of the asphalt concrete mix is to be suspended for a period of time — for an hour or more, overnight, or for several months — it is necessary to construct a transverse joint across the pavement being placed. This is accomplished in one of several ways depending primarily on whether or not traffic is to travel over the asphalt concrete mix between the time the paving is stopped and it is started again.

If traffic is not going to pass over the new pavement layer, a vertical butt joint can be constructed. If traffic will be permitted to travel over the transverse joint, a tapered joint will be necessary. In either case, the operation of the paver is essentially the same. The actual construction of the joint itself, however, is somewhat different.

It is very important that the paver be run in normal fashion right up to the point where the transverse joint is constructed. This means that the head of material carried in front of the screed should be as consistent as possible at the location of the joint. This requirement permits the forces acting on the screed to be constant and maintains the angle of attack for the paver screed. The result of such a paving operation is a uniform mat thickness at the joint — the same thickness as for the previously placed mix.

It is common but incorrect practice, however, to empty out the paver hopper whenever a transverse joint is to be built. The paver operator normally anticipates the location of the joint by drawing down the mix in the paver hopper. In most instances, the hopper is emptied and the amount of mix carried on the augers is minimal. This process reduces the head of material in front of the paver screed, causing the angle of attack of the screed to be lessened, thereby decreasing the thickness of the mat somewhat. It is much better practice to locate the transverse joint at the point where the amount of material in front of the screed is normal than it is to run the hopper and the auger chamber empty and then construct the transverse joint at the point the paver runs out of mix.

Butt Joints

For a butt joint, a vertical face is constructed by hand methods across the width being paved. This operation consists of raking, shoveling, and then removing the mix that is located downsteam of the selected joint location. The asphalt concrete material that is in place upstream of the joint is not touched in any manner. The mix that is removed from the downstream side of the joint is then wasted or recycled.

Compaction of the mix on the upstream side of the joint is accomplished in normal fashion. It is necessary, however, for the rollers to compact the mix immediately adjacent to the joint. For this to be properly done, runoff boards must be placed in a longitudinal direction next to the joint. The thickness of the boards should be approximately equal to the thickness of the layer being placed. In addition, the boards must be wide enough and long enough to hold the full length of the roller. The compaction equipment passes over the mix at the joint and onto the boards before the rolling direction is reversed. This assures that the transverse joint receives the same degree of densification as the rest of the mix in the pavement layer.

Normal but incorrect practice is to run the front wheel of the compaction equipment up to the transverse joint, stopping just short of the joint. The roller direction is then reversed and the rest of the mat is compacted. Occasionally, one wheel or roll of the roller will be driven over the end of the course, over the vertical face of the joint. Passing the rollers over the edge of the transverse joint, without having any boards beyond the edge to support the weight of the rollers, will cause rounding of the edge of the joint. The degree of rounding that will occur will depend on the number of times the roller runs off of the joint and on the thickness of the layer being constructed.

This type of joint construction results in two problems. First, because of the rounding of the edge of the old mat upstream of the joint, running over the edge of the joint with the roller during the compaction process prevents the construction of a proper vertical butt joint when paving is restarted. Second, the amount of compactive effort applied to the asphalt concrete mix adjacent to the joint is not adequate. The lack of proper compaction results in a high air void content in the mix upstream of the joint and a weak spot in the pavement structure. The use of runoff boards for the rolling equipment is thus necessary to assure the correct construction of a butt-type transverse joint.

Tapered Joints

If traffic is to be carried over the transverse joint, it is necessary to build a tapered joint. For this type of joint, as for the butt joint, it is proper for the paver operator to keep the head of material in front of the paver screed as uniform as possible up to the point that the joint is to be built. This process assures that the thickness of the mix being placed is uniform up to the joint. There is more opportunity for this to be done in practice with tapered joint construction than with butt joint construction because the mix left in the paver hopper can be used to build the taper.

At the point of the transverse joint, the asphalt concrete mix downstream of the joint is temporarily pushed aside longitudinally, away from the joint. A vertical edge is formed at the upstream face of the mix. Kraft paper is then placed downstream of the joint directly on the existing pavement surface. This type of paper is used because the asphalt concrete mix will not stick to it. The length of the kraft paper is dependent on the thickness of the course just placed but is typically about three or four feet long and the width of the lane. Once the paper is in place, the asphalt concrete mix is shoveled back over the paper, and a ramp is formed in this mix with a lute or rake. Any asphalt concrete mix that is not used to construct the ramp or taper is wasted or recycled.

Another type of tapered joint is the nonformed, sawed joint. For this joint, the paver operator keeps the paver operating normally until the paver runs out of mix in the hopper and in the auger chamber. At the point where the mix becomes nonuniform across the width of the lane being paved, a ramp is constructed with the mix by raking and shoveling the mix run out by the paver. No vertical face is formed (it will be sawed later) and the mix is merely tapered from the proper layer thickness to the level of the adjacent existing pavement. Any mix not needed to make the ramp is removed and wasted or recycled.

One advantage of the tapered joint is the fact that the compaction equipment can run over the edge of the transverse joint and down the ramp without rounding the joint. Because the rollers can easily pass over the end of the mat, the compaction of the mix upstream of the joint is generally superior to the mix adjacent to the butt type joint. A second advantage is that there is generally less mix to shovel from the joint since some of the extra mix is used to make the ramp or taper. The disadvantage of this kind of joint is that this mix must eventually be removed before paving commences downstream of the transverse joint.

Start of Paving

Removal of the Taper. If a tapered joint has been constructed at the transverse joint, the mix in the ramp must be removed before the paving can be restarted. For a taper built with kraft paper, there is no bond between the mix in the ramp and the underlying pavement. The paper and mix are readily removed and wasted. A vertical face is left at the upstream edge of the joint.

If a nonformed, tapered transverse joint is used, it is necessary to first saw a transverse joint in the asphalt concrete mat. The advantage of this type of joint is that the saw cut can be made at any longitudinal point in the asphalt concrete layer. It should be placed far enough back from the taper to assure that the thickness of the layer is constant. Once the joint is cut completely through the asphalt concrete mat, a front end loader is used to pry up the mix that is downstream of the saw cut in the ramp. One disadvantage of this type of joint is that it is often very difficult to remove the mix from the existing roadway, depending on the amount of traffic that has passed over the transverse joint and on the environmental conditions of the site.

Use of Starting Blocks

The asphalt concrete mix that passes from under the paver screed must be compacted. As a rule of thumb, the mix will normally to densify approximately 20 percent under the action of the compaction equipment. This means that the mix must be placed about 1-1/4 inches thick in order to produce a compacted mix that is 1 inch thick. This rule must be applied when the paver is used to place mix on the downstream side of a transverse joint.

Proper paving practice requires that the paver screed be placed on a set of starting blocks on the upstream side of the joint. The thickness of the blocks, or strips of wood, should be proportional to the thickness of the layer being constructed. If the mat being paved is to be 2 inches thick (compacted), the wood blocks should be 1/2 inch thick. If the mix being laid is to be 3 inches thick upon completion of the compaction process, the thickness of the starting blocks should be 1/4 inch for each 1 inch of compacted pavement thickness, or 3/4 inch.

The starting blocks should be placed completely under the length of the screed, front to back. At least two strips of wood should be used for a standard 10 foot wide paver screed. For a screed equipped with rigid extensions or hydraulic extensions, enough strips of wood should be used to have at least one starting block about every four feet across the width of the mat.

If the paver is starting out at a new location where there is no old mat to set the starting blocks and screed on, the thickness of the starting blocks must be increased to compensate for the lack of mix on the upstream side of the joint. In this case, if a 2 inch (compacted) layer of mix is being constructed, the blocks must be about 2-1/2 inches thick in order to allow for the compaction of the mix by the rollers. For a 3 inch thick compacted mat, the depth of the starting wood strips should be approximately 3-3/4 inches.

Nulling the Screed and Setting the Angle of Attack

Once the paver screed has been set on starting blocks of the proper thickness, the screed should be nulled. This means that the angle of attack of the screed should be set in the neutral or flat position. The thickness control cranks should be able to be turned slightly in both directions when the screed is in the nulled position without any pressure being put on the screed and without the angle of attack of the screed being altered.

An upward angle of attack should then be set into the screed. This is accomplished by turning the thickness control cranks approximately one full turn (depending on the make and model of the paver) and introducing an up angle to the front of the screed. Both thickness control cranks or handles must be adjusted in order for the screed to be properly set.

Before the paver pulls off the starting blocks, the material feed system on the machine is activated and mix is deposited in the auger chamber in front the the screed. The amount of mix delivered should be enough to cover the augers up to the center of the auger shaft. This will provide the proper head or volume of material against the screed. Once the auger chamber is properly filled, the paver is started and the screed is pulled off of the starting blocks. The angle of attack of the screed is adjusted, as needed, as the paver moves down the roadway in order to provide the proper thickness of the asphalt concrete mat. If the paver screed is nulled and the angle of attack set correctly while the screed is on the starting blocks, the amount of adjustment necessary to the screed should be minimal.

Raking the Joint

If the transverse joint is properly constructed up to this point, the amount of raking that needs to be done is minimal. If the paver screed starts out on blocks and if the head of material against the screed is constant, the thickness of the mat downstream of the joint will be correct. Very little mix, if any, will need to be brushed back from the joint. There is never any reason to excessively rake the transverse joint.

When a joint is raked, there is a tendency for the raker to reduce the thickness of the new, uncompacted mat to match the elevation of the compacted pavement on the upstream side of the transverse joint. This is accomplished by pushing the mix at the joint farther downstream onto the new mat. When the level of the new uncompacted mat has been raked to the point that it is the same as the old compacted mat, the final elevation of the newly placed material, after compaction by the rollers, will be lower than the mix on the upstream side of the joint. The proper way to rake a transverse joint is to not rake the joint at all.

Before the material on the downstream side of the joint is compacted, it is often the practice to determine if the joint is smooth by running a straightedge across the joint. If this exercise is done, it should be remembered that the straightedge should have daylight under it over the old (upstream) mat. This is because the uncompacted, downstream mix still has to be rolled and must therefore be higher than the compacted mix on the upstream side of the joint. If the mix on the downstream side of the joint is placed properly by the paver and is not raked, there generally is no reason to use a straightedge to check the elevation or smoothness of the joint.

Compacting the Joint

Ideally, a transverse joint should be compacted transversely. This means that the equipment that is used to roll the joint should operate across the width of the lane instead of longitudinally up and down the mat. If the rolling is done transversely, wood boards must be used to support the roller as it moves beyond the longitudinal edge of the pavement. The roller should operate in a manner so that the whole width of the joint receives equal compactive effort. This is very difficult to accomplish unless the wood boards placed on each side of the lane are long enough to allow the roller to move completely off the mix on both sides of the pavement layer.

In actual practice, the transverse joint can be properly rolled in the longitudinal direction. The initial (breakdown) rolling should be accomplished, however, as quickly as possible after the paver has moved off of the joint. The roller should pass completely over the joint before the equipment is reversed. If the joint has been constructed properly, the compaction process is no different from the application of ordinary compactive effort on any other part of the asphalt concrete mixture.

14.2 LONGITUDINAL JOINTS

Overlapping the Joint

The key to the construction of a good longitudinal joint between lanes of asphalt concrete mix is the amount of overlap between the new mat and the previously placed mat. The end gate on the paver screed should extend over the top surface of the adjacent mix a distance of not more than 1 to 1-1/2 inches. This amount of overlap provides just enough material on top of the longitudinal joint to allow for proper compaction without having extra mix which must be pushed back from the joint by a raker. The height of the new mix above the compacted mix should be 1/4 inch for each inch of compacted mix thickness. Thus, similar to the amount of mix placed at a transverse joint, for a 2 inch thick (compacted) asphalt concrete layer, the new mix should be 1/2 inch above the level of the compacted mix surface.

The primary problem with most longitudinal joint construction is an excessive amount of overlap of the paver screed over the previously placed mat. It is not uncommon to see the screed end gate hanging over the old mat a distance of 3, 4, or even 6 inches. Because this extra asphalt concrete mix can not be pushed into the compacted mat, it is necessary to rake or lute the material into the new mat. If the adjacent course is properly lapped, however, the amount of raking that must be done is minimal, if any.

Raking the Joint

There is no reason to rake a longitudinal joint if the mix is correctly placed along that joint by the paver. If too much mix is deposited on the old mat, the excess material is normally brushed back (raked) onto the new mix. During the raking process, there is a tendency for too much material to be pushed off of the joint, leaving the level of the mix adjacent to the longitudinal joint at the same elevation on both sides of that joint. In some cases, so much mix is raked off the joint that a dip occurs at the longitudinal joint even before compaction of the mix is done.

Mix that is pushed off the longitudinal joint is deposited on the new asphalt concrete mat. This material changes the surface texture of a portion of the mat where the mix is placed. Depending on the gradation of the mix, the extra mix raked onto the new mat can make a significant difference in the texture of the mat from one side of the lane to the other. Raking the longitudinal joint is detrimental to the long term performance of that joint.

Compacting the Joint

If the level of the new, uncompacted mix is even with or below the level of the compacted mix in the adjacent lane, the compaction equipment will not be able to properly densify the mix along the joint. Whether the first pass of the roller is on the cold side of the joint or on the hot side of the joint, part of the weight of the roller will be supported on the previously compacted mat. This means that the compaction equipment will bridge the mix in the joint, leaving it essentially uncompacted or only partially compacted. Thus, the level of the uncompacted mix at the longitudinal joint must be above the elevation of the compacted mix by an amount equal to approximately 1/4 inch for each 1 inch of compacted pavement if proper compaction of the mix at the joint is to be accomplished.

Rolling on the Cold Side

In the past, it was common practice to do the initial rolling of the longitudinal joint from the cold (previously placed mat) side of the joint. The vast majority of the weight of the roller was supported by the cold, compacted mat. Only 6 inches or so of the width of the roller was in contact with the fresh mat, compressing the mix along the joint. The majority of the compactive effort was wasted because the roller essentially was applying its force to an already compacted asphalt concrete material.

During the time that the roller was operating on the cold side of the longitudinal joint, the mix on the hot side of the joint and the rest of the mix in the course being laid was cooling. Depending on the environmental conditions and the thickness of the mix being placed, the process of compacting the joint from the cold side often proved to be detrimental obtaining density on the rest of the whole pavement layer.

The reason often given for rolling the joint from the cold side of the joint was that this compaction method allowed the rollers to "pinch" the joint and obtain a higher degree of density. There is no evidence that this is true.

Rolling on the Hot Side

The most efficient way to compact the longitudinal joint is to put the roller on the hot mat and overlap the joint by a distance of approximately 6 inches over the cold mat. This places the majority of the weight of the compaction equipment where it is needed. The mix at the joint is still pushed into the joint area by the roller as long as the elevation of the mix at the joint is proper. The longitudinal joint can be effectively compacted by keeping the roller on the new mix instead of on the already compacted mix.

Sometimes the first pass of the roller is completed with the edge of the machine about 6 inches inside of the longitudinal joint. The theory behind this method of compaction is that the mix will be shoved toward the joint by the roller and the joint will be "pinched" and thus better compaction will be obtained. The asphalt concrete mix being placed should be stable enough that the roller should not be able to move the material laterally to any significant degree. If the mix design is proper, this method of compacting the joint does not provide any advantage over moving the first pass of the roller outward one foot (from 6 inches inside the joint to 6 inches outside the joint). Rolling the mat by lapping the roller over the adjacent old pavement is typically the most efficient way to compact both the longitudinal joint and the rest of the pavement width.

Any type of roller used for the breakdown rolling of the mix can be employed to compact the longitudinal joint. A vibratory roller, either single drum or double drum, is an excellent piece of equipment to use for the initial rolling as long as the elevation of the mix at the joint is above the level of the cold mat. If the joint has been raked (which is not recommended), a pneumatic tire roller will typically provide a higher level of density at the joint because of the ability of that piece of equipment to compact low spots in the pavement surfaces as well as high points in that surface.

Regardless of the method used to compact the longitudinal joint, the level of density obtained at that location is typically 1 to 1-1/2 percent below the average density that can be reached in the main part of the mat. This is primarily due to the fact that the first placed lane has an unsupported edge which is always more difficult to compact. It is the lack of density in this original part of the longitudinal joint that affects the level of density that can be obtained when the new mix is placed along the joint.

14.3 ECHELON PAVING

If echelon paving (two pavers running adjacent to each other) is used, the construction of the longitudinal joint is essentially similar to the building of a joint against a cold, compacted pavement layer. In this case, however, the amount of overlap between the first and second lanes is very critical. The distance the screed end gate of the trailing paver should extend over the uncompacted mat behind the first paver should be limited to no more than 1 inch. This will prevent the screed of the second paver from dragging on the mix placed by the first or leading paver.

No raking of the joint need be done. The compaction process is modified to require the rollers densifying the mix behind the lead paver to stay about 6 inches away from the free edge of the mat on the side toward the second paver. Once the mix from the second paver is placed against the uncompacted edge of the mix from the first paver, the rollers compacting the second lane are employed to densify the mix on both sides of the joint. Properly lapped and properly compacted, it is usually difficult to see the longitudinal joint produced by the echelon paving process.

CHAPTER 15. MAT PROBLEMS

Mat problems can be defined as defects that occur in the asphalt concrete mixture during the laydown and compaction operations or soon after they are completed. These problems can be divided into two primary categories: (a) equipment-related problems; and (b) mixture-related problems. Several different types of mat deficiencies will be discussed below, with emphasis on the description of the problem, the cause of the problem (equipment or mix related), the cure, and the effect on pavement performance.

Figure 15.1 summarizes the various kinds of problems that can occur in an asphalt concrete layer during construction. Listed in the first column is a description of various mat defects. Marked in the remaining columns are one or more possible causes for each particular mat problem. The check marks indicate equipment-related causes and the X marks indicate mix-related causes.

15.1 SURFACE WAVES

A wavy asphalt concrete surface can be of two types: short waves (ripples) and long waves. Short waves are generally 1 to 3 feet apart, with 1-1/2 to 2 feet being the most common distance. Long waves are considerably farther apart and may correspond to the distance between truckloads of mix.

The primary cause of ripples or short waves is a fluctuating head of material in front of the paver screed. As discussed in detail in Chapter 11, the variation in the amount of mix being carried back to the augers by the slat conveyors and deposited in front of the screed causes the screed to rise and fall as the pressure against it changes. Too much (the mix at the top of the augers) and then too little (the mix at the bottom of the augers) asphalt concrete material being carried in the auger chamber in front of the screed causes the wavy surface as the screed reacts to the variable forces on it.

A secondary cause of ripples can be a screed that is in poor mechanical condition–one which has loose screed plates or has excessive play in the screed control connections. Ripples can also be formed in the mat by improper mounting or setting of the automatic grade control on the paver or by use of an inadequate grade reference device. In the latter case, the problem might be related to a mobile reference (floating beam) that is bouncing for some reason.

Short waves can also be a function of the mix design, particularly in regard to a tender mix or one that varies in stiffness caused by changes in mix temperature or in mix composition. As the stiffness of the mix varies, the force of the mix pushing on the screed also varies, causing the screed to rise and fall and place a mat with ripples in it. Finally, ripples can be formed in the asphalt concrete mat by compaction equipment, especially with a tender mix. If the mix design is improper — either in aggregate gradation, asphalt content, moisture content, or mix temperature — the rollers may shove and displace the mix during the compaction process. Normally, however, the ripples are placed in the mat by the paver, either because of its operation or because of changes in mix stiffness, rather than by the compaction equipment.

Long waves are caused by many of the same variables that cause short waves. A fluctuation in the amount of material in front of the screed and mix stiffness variation causes the screed to react to the change in the pressure on it. If the distance between the wave peaks, however, corresponds to the length of pavement between truckloads of mix, then the waves may have been caused by incorrectly set hopper flow gates on the paver or by emptying the paver hopper and slat conveyor between loads of mix. Mechanical condition and improper operation of the screed — continually changing the manual thickness control cranks, for example — as well as incorrectly mounted automatic grade controls can cause a long wave

MAT PROBLEM TROUBLE SHOOTING GUIDE

CAUSES

PROBLEM	Fluctuating Head of Material	Feeder Screws Overloaded	Finisher Speed Too Fast	Too Much Lead Crown in Screed	Too Little Lead Crown in Screed	Overcorrecting Thickness Control Screws	Excessive Play in Screed Mechanical Connection	Screed Riding on Lift Cylinders	Screed Plates Worn Out or Warped	Screed Plates Not Tight	Cold Screed	Moldboard on Strikeoff Too Low	Running Hopper Empty Between Loads	Feeder Gates Set Incorrectly	Kicker Screws Worn Out or Mounted Incorrectly	Incorrect Nulling of Screed	Screed Starting Blocks Too Short	Screed Extensions Installed Incorrectly	Vibrators Running Too Slow
Wavy Surface — Short Waves (Ripples)	✓	✓	✓				✓	✓		✓									
Wavy Surface — Long Waves	✓	✓				✓	✓	✓					✓	✓					
Tearing of Mat — Full Width			✓						✓		✓								
Tearing of Mat — Center Streak					✓				✓		✓			✓	✓				
Tearing of Mat — Outside Streaks				✓					✓		✓	✓		✓				✓	
Mat Texture — Nonuniform	✓	✓	✓					✓	✓	✓	✓		✓					✓	✓
Screed Marks							✓												
Screed Not Responding to Correction			✓				✓	✓		✓									
Auger Shadows		✓																	
Poor Precompaction			✓					✓											✓
Poor Longitudinal Joint	✓	✓				✓		✓											
Poor Transverse Joint		✓					✓	✓		✓						✓	✓		
Transverse Cracking (Checking)																			
Mat Shoving Under Roller																			
Bleeding or Fat Spots in Mat																			
Roller Marks																			
Poor Mix Compaction																			

PROBLEM	Grade Control Mounted Incorrectly	Grade Control Hunting (Sensitivity Too High)	Grade Control Wand Bouncing on Reference	Grade Reference Inadequate	Sitting Long Period Between Loads	Improper Joint Overlap	Improper Mat Thickness for Max. Agg. Size	Trucks Bumping Finisher	Truck Holding Brakes	Improper Base Preparation	Improper Rolling Operation	Reversing or Turning Too Fast of Rollers	Parking Roller on Hot Mat	Improper Mix Design (Aggregate)	Improper Mix Design (Asphalt)	Mix Segregation	Moisture in Mix	Variation of Mix Temperature	Cold Mix Temperature
Wavy Surface — Short Waves (Ripples)	✓	✓	✓	✓						X	X			X	X	X		X	
Wavy Surface — Long Waves	✓			✓	✓			X	X	X		X	X			X		X	
Tearing of Mat — Full Width							X							X	X	X	X	X	X
Tearing of Mat — Center Streak																			X
Tearing of Mat — Outside Streaks																			X
Mat Texture — Nonuniform					✓		X			X				X	X	X		X	X
Screed Marks								X	X										
Screed Not Responding to Correction	✓						X											X	X
Auger Shadows														X	X	X			
Poor Precompaction							X			X									X
Poor Longitudinal Joint	✓	✓	✓			✓					X								X
Poor Transverse Joint											X								X
Transverse Cracking (Checking)										X	X			X	X		X	X	
Mat Shoving Under Roller										X	X	X		X	X		X	X	
Bleeding or Fat Spots in Mat														X	X		X	X	
Roller Marks										X	X	X	X					X	
Poor Mix Compaction										X	X	X	X	X	X		X	X	X

1. Find problem above.
2. Checks indicate causes related to the paver. X's indicate other problems to be investigated.

NOTE: Many times a problem can be caused by more than one item, therefore, it is important that each cause listed is eliminated to assure solving the problem.

Figure 15.1. Mat troubleshooting chart.

type of surface problem in the mat. If a stringline is being used as a grade reference, a sag in that line between support posts can easily be a cause of long waves. Delivery of the mix to the paver can also be a factor in long wave roughness, particularly if the haul truck bumps into the paver or if the truck driver rides his brakes while the truck is being pushed by the paver.

In terms of mix design, long waves can be caused by segregation of the mix and by changes in mix temperature. Both of these deficiencies cause the forces on the screed to vary, causing, in turn, a wavy surface. Compaction equipment can also create a wavy mat if the roller operator turns or reverses the machine too abruptly or parks the roller on the hot mat while waiting for additional mix to be placed.

Ripples can be cured only by preventing their formation. The most important factor for short waves is to keep the amount of mix (head of material) in front of the screed as consistent as possible. In addition, the stiffness of the mix, which is related to both its temperature and its composition, should be maintained as constant as feasible. The amount of mix is controlled by the proper setting of the hopper flow gates and by keeping the slat conveyors and augers operating as much of the time (close to 100 percent) as possible while the machine is moving forward. Mix stiffness is controlled at the asphalt concrete batch or drum mix plant by keeping the mix temperature, aggregate gradation, and fluids content (asphalt content plus moisture content) within normal specification limits. Any factors that cause either the volume or the stiffness of the mix at the screed to change will cause ripples in the asphalt concrete mat.

Surface waves caused by automatic grade control problems can be detected by shutting off the grade controls and measuring whether or not the long or short waves continue to be formed. If the controls are at fault, the operation and maintenance manual supplied with the controls should be consulted to determine the proper corrective action to take. Sags in a stringline reference, if one is being used, can be found by sighting down the line. Short or long waves caused by the mechanical condition or operation of the paver screed can usually be detected by careful observation of the paver during mat placement. The long waves formed by incorrect haul truck operation and/or incorrect compaction equipment operation also can be easily detected by spending a few minutes watching each of these processes.

Long term pavement performance is affected by surface waves (short and long) in two primary ways. First, the waves cause a decrease in the smoothness of the pavement. This in turn lowers the pavement condition rating (PCR) or present serviceability index (PSI) for a stretch or highway. Structural performance of the pavement may be changed, however, only if the waves are severe enough to increase the dynamic or impact loading of the pavement under heavy truck traffic. Second, ripples, or factors that cause the ripples, can affect pavement density levels. A tender mix generally cannot be compacted to the same density value as can a stable mix. The resulting decrease in density and the corresponding increase in air void content can cause a significant reduction in the fatigue life of the asphalt concrete mat.

15.2 TEARING OF THE MAT

There are three types of mat tearing or pulling of the asphalt concrete mix under the screed of the paver. Each of the types is described by the location of the tear marks in the mat: (a) full-width, (b) center streak, and (c) outside streaks. Tearing of the mat is usually caused by improper paver condition or operation, or by a cold mix temperature.

The screed on a paver can be adjusted to provide the proper degree of crown to the mix being placed. The crown of the whole screed can be changed, but the tearing problem is most likely with the relationship between the crown at the leading (front) edge and trailing (back) edge of the screed. A streak up the center of the mat is usually caused by a lack of lead crown in the paver screed. Conversely, streaks up both outside edges of the asphalt concrete mixture are normally caused by an excess of lead crown in the screed. For most mixes, the lead edge crown should be set slightly greater than the tail edge crown.

Center streaks can also be caused by a lack of asphalt concrete material being tucked under the auger gearbox area at the center of the auger chamber. This is caused by both improper flow gate settings and by worn or improperly set reverse augers or paddles on the augers. Edge streaks can be formed by improper flow gate settings or by incorrect installation of the screed extensions.

Full-width tearing of the mat can be attributed to a number of factors. If the paver is operated at too fast a forward speed for a particular mix, tearing can occur. Tearing can also take place — either full width, in the center, or along the edges of the mat — because of warped or worn-out screed plates. Cold mix temperatures, particularly combined with a cold paver screed, can significantly affect the amount of tearing that may occur. Mix design factors that create tender mixes can cause tearing of the mat as can the use of oversized aggregate (compared to the thickness of the layer being placed) in the mixture.

Center or outside edge mat tearing can usually be eliminated by adjusting the relationship between the lead and tail crown on the paver screed. If this change does not solve the problem, the setting of the paver flow gate should be modified. Full-width tearing is normally caused by a cold screed, cold mix temperature, or by worn screed plates and can be cured by correcting these three primary causes of the problem.

Tearing of the mat affects the long term pavement performance by causing changes in mixture density in areas where the tearing has occurred. Torn areas may appear segregated and are usually deficient in mix quantity, resulting from the pulling of the mix under the screed. Thus, pavement performance will be reduced somewhat, depending on the severity of the tearing, in relation to the degree to which the tearing affects the density and air void content of the mat. In addition, torn areas may be susceptible to raveling caused by the rough texture of the mat in the area adjacent to the tear.

15.3 NONUNIFORM MAT TEXTURE

Nonuniform mat texture can be described as differences in the appearance of the asphalt concrete mixture, both transversely and longitudinally, as the mix is placed and compacted. Normally, minor differences in surface texture will be apparent because of differences in the alignment of the large coarse aggregate particles as the mix passes out from beneath the paver screed. Additionally, a mix with a higher fine aggregate (sand) content will have a more uniform surface texture than a mix containing a larger percentage of coarse aggregate.

Many variables concerning the operation of the asphalt paver affect the uniformity of the surface texture of the mix. A variable amount of mix against the screed, caused by overloaded augers or running the hopper empty between truckloads, can cause variations in the amount of mix tucked under the screed and thus can produce a nonuniform texture. Improper screed maintenance, including screed plates being worn or loose, the screed riding on the tow point cylinders, screed extensions incorrectly installed, and low screed vibratory frequency can significantly alter the mat texture and cause nonuniformity. A low mix temperature, caused either by plant problems or by the paver sitting too long between truckloads of mix, can also be a factor in obtaining uneven mat texture, especially if the paver screed is also cold.

A good rule of thumb for the relationship between maximum aggregate size used in the mix and the minimum course thickness is that the depth of the layer should be at least two times the largest coarse aggregate size. Thus, a mix containing a 3/4 inch top size aggregate should be placed at least 1-1/2 inches thick. If this relationship is violated, the mat texture will be affected. When the layer placed is at least twice the coarse aggregate size, the mat texture should be uniform. When the layer thickness is less than two times the dimension of the largest aggregate particles, tearing of the mat and nonuniform surface texture result.

A soft or yielding base under the course being constructed will cause a variable surface texture for the new layer. Segregation of the mix, caused by poor mix design or improper handling of the mix during the mixing, loading, hauling, unloading, or placing operations, can obviously contribute to a nonuniform surface texture. The variability of the texture will also be increased by any factors that cause nonuniformity in the mix such as deviations in aggregate gradation, asphalt content, or mix temperature.

The causes of nonuniform surface texture are many, and thus the solutions to the problems are many. Paver operation, particularly in regard to the need for a constant head of material in front of the screed, should be closely monitored. The paver and screed should both be well maintained and in good operating condition. The thickness of the mat being placed should be specified so that it is at least twice the value of the largest coarse aggregate particle used in the mix. Finally, a mix that is tender, variable in aggregate gradation or asphalt content, or easily segregated should be modified to improve its characteristics during mix manufacture — before it is delivered to the paver for laydown.

Nonuniform surface texture usually goes together with nonuniform density. Areas where the coarse aggregate has been dragged by the paver screed will normally have a high air void content. Areas where segregation of the mix has occurred, causing a variation in texture, will generally have a lower density even with the same compactive effort applied by the rollers. As density decreases and air void content increases, the fatigue life and serviceability of the asphalt concrete mat decreases significantly.

15.4 SCREED MARKS

Screed marks are transverse indentations in the asphalt concrete mat. They occur when the paver stops between truckloads of mix. Depending on the tenderness of the mixture being placed, some screed marks are barely noticeable, while some can be very deep.

There are two basic causes for screed marks. The first is caused by "slop" or excessive play in the mechanical connections on the screed. If this is the problem, the screed marks will be visible each time the paver stops. The second cause of screed marks is the haul vehicle bumping into the paver when preparing to discharge the mix, and/or the truck driver holding the brakes on the truck when the paver starts to push the haul vehicle. In this case, the screed marks will appear only when the truck/paver interchange is improper.

The solution to screed marks is simple. If they are a result of the mechanical condition of the paver and the screed, the screed should be repaired. If the screed marks are caused by the haul vehicle bumping into the paver, the laydown operation should be altered so that the paver picks up the haul truck instead of the truck backing into the paver. In addition, the truck drivers should be instructed not to ride their brakes when the paver establishes contact with the truck. Screed marks are not detrimental to the durability of the mat. They do, however, affect the ride, creating a bump whenever the marks are visible.

15.5 SCREED RESPONSIVENESS

The paver and screed must be in good operating condition. The sensor for the automatic grade controls, if used, must be located according to the manufacturer's instructions. If the mix texture is uniform (indicating a proper relationship between course thickness and maximum aggregate size), the screed should be able to respond to changes in the settings of the thickness controls.

As the thickness control cranks on the screed are changed, the angle of attack of the screed is increased or decreased. As the paver moves forward to place the mix, the screed moves up to or down to the new equilibrium point for the new mat thickness. If the screed fails to respond to changes in the setting of the thickness control cranks, the operator is manually unable to alter the depth of the mat being placed. The paver also loses its inherent ability, through the principle of the floating screed, to provide the self-leveling action needed to place a smooth asphalt concrete mat.

An extremely fast paver speed may cause a lack of responsiveness of the screed. The mechanical condition of the screed affects the screed reaction. Loose screed plates, the screed riding on the tow point cylinders, or loose connections on the thickness control cranks will also cause the screed to be unresponsive. If automatic grade controls are used, an incorrect sensor location will cause the screed to be unable to react to input signals from the grade sensors. If the maximum aggregate size used in the mix is too great compared to the depth of mix being placed, the screed will ride on or drag the largest aggregate pieces. The screed, therefore, can not change angle and is thus unresponsive to changes in the thickness control settings. Variations in mix temperature also cause the screed to be unresponsive to angle of attack changes, since the mix stiffness variations themselves are causing the screed to continually seek new equilibrium points for the forces acting on it.

An unresponsive screed causes a rough asphalt concrete mat. The screed is unable to react to manual changes in the thickness settings. In addition, the screed loses its ability to level-up an existing pavement surface by reducing the amount of mix placed over the high points in that surface and increasing the volume of material placed in the low areas. Thus, the rideability of the course being placed is significantly affected by the unresponsiveness of the paver screed, and the paver is unable to function as it should.

15.6 AUGER SHADOWS

Auger shadows are dark areas that appear in the surface of the mat behind the paver. They are rarely visible except in certain sunlight conditions. These shadows are caused primarily by overloading the augers on the paver. The intensity of the shadows will sometimes be increased when a tender mix is being laid.

The asphalt concrete mixture carried in the auger chamber should be maintained at a level near the center of the auger shaft. In no case should the bottom of the augers be visible or should the top of the augers be completely covered with mix. Similarly, keeping the augers from being overloaded prevents the development of auger shadows in the mix. Auger shadows are not necessarily detrimental to the mix except as they may affect rideability in a minor way.

15.7 PRECOMPACTION LEVELS

A modern asphalt paver is normally equipped with a vibratory screed. This type of screed, which has replaced the original tamper bar screed, allows the mix to be compacted as it passes beneath the screed. This precompaction, before the conventional compaction equipment rolls the asphalt concrete mixture, reduces the amount of compactive effort needed by the rollers before the proper density and air void content is reached. A few pavers are now equipped with combination screeds — screeds that have both tamper bars and vibratory mechanisms. At slow forward paver speeds, the degree of compaction achieved in the mix by the combination screed is typically greater than that obtained by the vibratory screed alone. At paver speeds greater than 25 feet per minute or so, however, the increased effectiveness of the tamper bar compactive effort is lost and the degree of compaction obtained is similar to that achieved with a normal vibratory screed.

The amount of precompaction obtained by the paver screed decreases as the paver speed increases. It increases, within limits, as the frequency of the screed vibration increases. This is to be expected since compaction should increase as the number of impacts applied on the mix surface increases (slower paver speed and greater frequency of impacts). Precompaction will decrease significantly, however, if the paver screed is riding on the lift (tow point) cylinders, thereby limiting the available compactive effort. The level of precompaction obtained will be further limited if the mat is too thin for the maximum aggregate size used in the mix, if the mix being placed is too cold, or if the base on which the new layer is being laid is too soft and yielding.

Decreasing the paver speed and increasing the frequency of vibration of the paver screed should increase, within limits, the level of precompaction achieved during the laydown operation. Proper maintenance of the screed also helps obtain a uniform compactive effort from the screed. As long as the required density level is obtained using conventional rollers behind the paver, the absolute level of precompaction accomplished by the screed will not affect the long term performance of the asphalt concrete layer. It may be possible, however, to reduce the number of roller passes needed to achieve the density and air void content criteria if the amount of precompaction obtained by the screed is greater.

15.8 TRANSVERSE AND LONGITUDINAL JOINTS

Poor transverse joints are associated either with a bump at the joint, a dip in the pavement surface several feet beyond the joint, or both. Poor longitudinal joints between passes of the paver are usually characterized by a difference in elevation between the two lanes, by a raveling of the asphalt concrete at the joint, or both. The area adjacent to the longitudinal joint seam is sometimes dished out. It is usually depressed below the level of the surrounding pavement surface.

The problems with the construction of both transverse and longitudinal joints were discussed in Chapter 14. The key to a good transverse joint is to start the paver with the screed sitting on blocks on the cold side of the joint. The thickness of the blocks should be 1/4 inch for each 1 inch of compacted pavement thickness and thus should be related to the depth of the course being laid. The second factor is to do minimal, if any, raking of the joint. Finally, the joint should be compacted using normal compaction procedures. The key to a good longitudinal joint is the amount of overlap of the new mat over the adjacent cold material. If the overlap is only 1 to 1-1/2 inches, minimal, if any, raking is necessary, and the compaction equipment will be able to properly densify the mix at the joint.

A poor transverse joint will not affect pavement performance to any significant degree if proper density levels are obtained by the compaction equipment. A poor ride will usually be the only negative result. An improperly constructed longitudinal joint, however, can seriously decrease the serviceability of the pavement structure. A poorly placed and compacted joint will ravel and cause one side of the joint to be lower than the other side. If the density level is too low, it is possible for the whole pavement layer thickness at the longitudinal joint to wear away under the action of traffic. A poor joint will also be porous, allowing water to enter the underlying pavement courses.

15.9 CHECKING

Checking can be defined as short transverse cracks, usually 1 to 4 inches in length and 1 to 3 inches apart, which occur in the asphalt concrete mat. These surface cracks, or checks, are not visible when the paver places the material. The cracks usually occur after the first or second pass of the compaction equipment over the mix. The checks do not extend completely through the course but normally are only 1/2 to 3/8 inch in depth.

Checking can be caused by two primary factors: (a) excessive deflection of the pavement structure under the compaction equipment, and (b) a deficiency in the asphalt concrete mix design. In the former case, the pavement on which the new asphalt concrete layer is being placed is weak. The weight of the rollers causes the pavement layers to bend excessively, placing the new mix in tension. The check marks are then formed with the surface of the new mixture being pulled apart as the pavement deflects under the compaction equipment.

A more prevalent cause of checking is a deficiency in the asphalt concrete mixture. This is because of: (a) an excess of fluids in the mix — too much asphalt cement, too much moisture in the mix, or both and (b) a nonuniform sand gradation — too much middle size sand (No. 10 and No. 40 sieve size material) and too little fine size sand (No. 40 and No. 80 sieve size material). The excess of fluids makes the mix tender and allows it to be easily displaced by the compaction equipment. The mix tends to be shoved by the roller instead of being tucked under the compaction rolls or tires. The hump in the fine aggregate gradation curve also causes the mix to be tender. This is characterized by a bow wave that occurs in front of the rolls on a steel wheel roller. The mix deficiency is compounded, and the amount of checking that occurs is increased, when the mix temperature is too high for the particular asphalt cement grade being used in the mix. As the mix temperature increases, the viscosity or flow of the asphalt cement decreases, causing an increase in the tenderness of the asphalt concrete mixture.

The wrong action to take for a checking problem is to back the breakdown roller off from the paver. By delaying compaction, the mix has a chance to cool, and the viscosity of the asphalt cement in the mix increases. This, in turn, stiffens the mix and decreases the displacement by the rollers. If the mix is tender enough, because of excess fluids or a problem with the fine aggregate gradation, the mat temperature has to decrease to such a low point before the rollers can get on the mix without checking that proper density is very difficult to obtain.

The proper solution to the checking problem, therefore, is to change the mix characteristics, not the rolling procedure. The mix changes may be simple: reducing the asphalt content, reducing the moisture content, reducing the mixture temperature at the plant, or all of these. The other changes, however, might be time consuming and expensive: for example, changing the fine aggregate gradation to remove the hump from the grading curve in the area between the No. 10 and No. 200 sieves (usually between the No. 40 and No. 80 sieves). On a temporary basis, until the mix design can be altered, the mat can be initially compacted using a vibratory roller or pneumatic tire roller instead of a static steel wheel roller.

Because the cracks or checks extend only a short distance into the mix from the surface, they are detrimental to long term performance only as the tender mix phenomenon affects the compaction operation. If the rollers are kept back from the paver to try to decrease the amount of checking and the level of density obtained by the compaction equipment is thus reduced, checking can decrease the ultimate pavement life significantly as the air void content of the asphalt concrete mat is increased.

15.10 SHOVING

Shoving of an asphalt concrete mat is the displacement of the mixture in a longitudinal direction. It can take place during the compaction operation or can occur under traffic. In many cases, shoving is accompanied by a large bow wave in front of the steel wheel breakdown roller. Shoving may also occur together with mix checking. Finally, mat or mix shoving can happen at the reversal point of the rollers, especially closest to the paver.

Shoving is caused by an unstable or tender mix. This instability can be due to the same variables that cause checking: an excess of fluids in the mix, a hump in the fine aggregate grading curve, or excessive mat temperature during rolling. A mix that has a high Marshall stability can still be a mix that will distort longitudinally under the compaction equipment or later under traffic. Shoving can be particularly prevalent when a sand mix is placed in a thick layer (over 1-1/2 inches thick) at a high temperature (over 280°F).

The cure for a mix that shoves under the compaction equipment is to increase the internal stability of the mixture. This can be accomplished by reducing the fluids content (either asphalt content, moisture content, or both) of the mix. It can also be done by increasing the internal friction among the aggregate particles by changing the aggregate gradation or increasing the amount of angular (crushed) particles in the mix. Tender mixes should be placed at lower laydown temperatures consistent, however, with the ability to obtain sufficient density under the rollers. Sand mixes, because of their inherent tender nature, should be placed in several thin layers instead of one thick layer when used as base or binder courses.

Mats that tend to shove under the compaction equipment are basically unstable. These mixtures, under traffic, usually will continue to distort, both longitudinally and laterally. At stop intersections, this shoving is seen as waviness of the mat near the stop bar and sometimes even as forward movement of the mix under the painted stop line itself. Shoving of the asphalt concrete mixture during construction is a strong indication of the future lack of adequate durability of the material under traffic.

15.11 FAT SPOTS AND BLEEDING

Fat spots in an asphalt concrete mixture are isolated areas where asphalt cement has come to the surface of the mix during the laydown and compaction operation. These spots can occur very erratically and irregularly or they may be numerous and in a fairly regular pattern.

Bleeding of an asphalt concrete mixture occurs when the asphalt cement flows to the top of the mix surface under the action of traffic. Bleeding usually is characterized as two flushed longitudinal streaks in the wheelpaths of the roadway.

Fat spots are primarily caused by excessive moisture in the mix. The problem is more prevalent on mixtures that contain high percentages of fine aggregate (oversanded mixes) and on mixtures that contain aggregate that has a high porosity. If all the moisture in the coarse and fine aggregate is not removed during the drying and mixing operation at the asphalt batch or drum mix plant, that moisture will pull asphalt cement to the surface of the mix behind the paver as the moisture escapes from the mix and evaporates. Fat spots occur more frequently when the aggregate stockpiles are wet or when the moisture content varies in different parts of those stockpiles.

The cause of bleeding can normally be divided into two categories. The first cause is related to an excess of fluids in the asphalt concrete mixture, either asphalt cement or moisture or both. Under traffic, the extra moisture and asphalt cement is at its lowest level and it can be pulled to the surface by the suction of the vehicle tires. This bleeding usually occurs on new mats and during hot weather when the viscosity of the asphalt cement is at its lowest level. Bleeding can also accompany pavement rutting. If, during construction, adequate density is not achieved in the mixture, traffic will cause densification and rutting of the mix with time. This traffic compaction process will decrease the air void content of the mix and may, in turn, squeeze asphalt cement out of the mix and to the surface of the roadway. The extra asphalt will appear as a longitudinal fat spot along the length of each wheelpath.

A wide fluctuation in the asphalt concrete mix temperature is an indication that the moisture content of that mix is also variable. This latter phenomenon can contribute to both the generation of fat spots in the mix during construction and bleeding of the mix later under traffic. It is important, therefore, that the aggregate used in the mix be dry and that the moisture content of the mix, upon discharge from the asphalt plant, be as low as possible, but not more than 0.5 percent. Extra care in drying needs to be exercised when producing mixtures that incorporate highly absorptive aggregate. Bleeding problems caused by excess asphalt cement in the mix can most easily be solved by reducing the asphalt content of mix, consistent with other mixture properties such as air voids, voids in the mineral aggregate, and stability. Bleeding problems that occur in conjunction with pavement rutting may only be solved, however, by a redesign of the asphalt concrete mixture with emphasis on the air void content and the voids in mineral aggregate criteria.

Fat spots in the mix, if there are only a few of them, should not affect the ultimate durability of the mixture to a significant degree. A great number of fat spots or bleeding in the wheelpaths does affect pavement performance because of variable asphalt and air void contents in different parts of the mix. In addition, other mix problems, such as shoving and rutting, can occur in a mix that contains many fat areas or bleeding in the wheelpaths. The design of the asphalt concrete mixture, the operation of the asphalt batch or drum mix plant (more complete removal of the moisture), or both should be checked to assure adequate future pavement performance under traffic.

15.12 COMPACTION AND ROLLER MARKS

Most asphalt pavers in use are equipped with a vibratory screed. Depending on such variables as forward paver speed, layer thickness, mix temperature, and ambient environmental conditions, the density of the asphalt concrete mixture measured behind the paver screed, before roller compaction, is usually in the range of 70 to 80 percent of the theoretical maximum density (a voidless mix). The purpose of the roller compaction process, then, is to increase the density of the asphalt concrete mat to at least 93 percent of maximum density (a 7 percent actual air void content). The type and number of rollers needed to achieve this level of compaction depend on the same variables as screed density, as well as on the operational characteristics of each particular piece of compaction equipment.

A discussion of the causes of poor compaction, or the lack of an adequate level of density, can be divided into two parts. The first concerns mix-design-related problems. Any of the mix deficiencies that contribute to checking, shoving, or bleeding of the mix will also be a factor in the ability of the compaction equipment to reach the required density level. A mix that is unstable or tender because of excessive asphalt cement content, excessive moisture content, nonuniform aggregate gradation, rounded aggregate shape, or many other causes, will be a difficult mix to compact. A mix that has short waves or ripples in it will usually also have a variation in density level throughout the mat if the ripples are caused by mix-related deficiencies. For density to be obtained uniformly in the asphalt concrete layer, the mix design must be proper and the mix must be delivered to the paver at a consistent quality level with a minimum variation in mix characteristics and properties.

The roller operator will normally be unable to remove all the marks left by the compaction equipment if the mix is tender or unstable. A tender mix normally will not support the weight of the roller until the mix has cooled sufficiently for the asphalt cement viscosity to increase enough to stiffen the mix. By the time the mix has decreased in temperature to this point, however, the required level of density usually can no longer be achieved because the mix has lost its workability. For the same reason, the roller marks or indentations left during the breakdown roller passes usually cannot be rolled out during the finish rolling process. Roller marks left in the surface of an asphalt concrete mixture are an indication of tender mix problems and inadequate levels of density.

The second main cause of poor density is related to the operation of the compaction equipment. The variables that affect the ability of the roller to obtain density are the type of roller, the rolling pattern, the rolling zone (distance relationship of the breakdown roller to the paver), layer thickness, and environmental conditions. In addition, for vibratory rollers, the amplitude and frequency of the compactive effort affects the density level reached by that type of equipment.

The cures for inadequate compaction related to mix design deficiencies are all related to improvements in the design of the mix components and to the production of the mix at the asphalt plant. Asphalt cement quality and content, aggregate properties and characteristics, and mix temperatures all play a significant part in the workability and stability of the asphalt concrete material under the compaction equipment. The mix must, at the same time, be fluid enough to be workable and yet stiff enough support the weight of the compaction equipment without checking, shoving, or bleeding.

In terms of ultimate pavement durability, the air void content or density of the mix is probably the single most important characteristic that governs the performance of the asphalt concrete mixture under traffic. If the air void content of the mix is low (less than 7 percent), the pavement structure should perform well under vehicular loading, even with minor variations in mix design. If the level of density obtained during the compaction process is too low (too high an air void content), the mix will not be durable even with a good mix design and even without any other mat problems being present. If proper density is obtained in the asphalt concrete material, the mixture will serve its intended purpose for many years under traffic.

CHAPTER 16. COMPACTION

An asphalt concrete mixture consists of aggregate, asphalt cement, and air voids (Fig. 16.1). The primary purpose of compaction is to reduce the air void content and increase the density of the mixture. Thus, density is a measure of the degree of compaction and is used for field control and for acceptance of the mix.

16.1 DEFINITIONS

The two terms, density and compaction, are often used interchangeably when in reality the two terms are quite different.

Density

Density is the unit weight or the weight of material in a given volume of an asphalt concrete mixture. Thus, density is dependent on the type and amount of asphalt cement and aggregate and the degree of compaction which determines the air void content in the mixture. For example, an asphalt concrete mix containing limestone or gravel might have a compacted unit weight of 147 pound per cubic foot (pcf), while an asphalt concrete mix manufactured with expanded shale or similar light-weight aggregate, such as slag, might have a compacted density of only 84 pcf. The amount of asphalt cement in the mixture can also increase the compacted density by filling the voids and thus increasing the weight. The intent, however, is to achieve a given density by reducing the volume of the mixture (reduced air void content) by compaction.

Compaction

Compaction is the process by which the asphalt cement and aggregate are compressed into a reduced volume. Since these two materials are relatively incompressible, compaction results in a reduction in the air void content and an increased density. In addition, the aggregate particles are forced together which produces increased aggregate friction and interlock.

Maximum Density

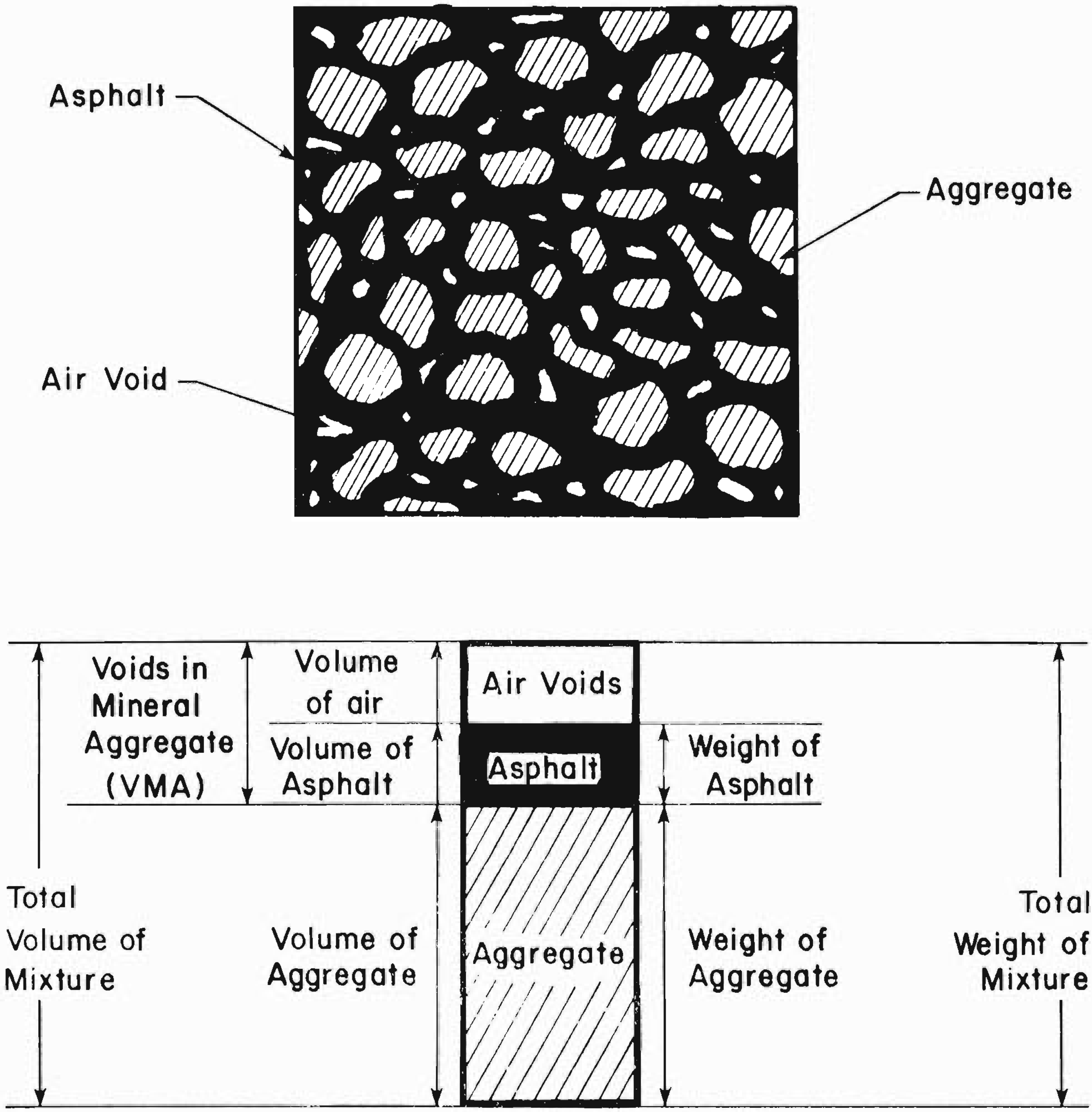
Theoretically, it is possible to compact an asphalt concrete mixture until there are no air voids remaining, and no further compaction would be possible. The density at this voidless condition would be the maximum density which can be achieved and, therefore, is called the *maximum theoretical density*. Maximum theoretical density can be calculated from the amount and specific gravity of the individual components or by the Rice Method. The Rice Method is the recommended procedure.

16.2 IMPORTANCE OF DENSITY

The long term satisfactory performance of an asphalt concrete pavement is highly dependent on density, or more precisely the air void content of the mix. The three basic types of distress which result in reduced pavement performance and increased pavement maintenance and rehabilitation are thermal or shrinkage cracking, fatigue cracking, and permanent deformation or rutting.

Closely related to the degree of density are moisture damage and asphalt cement aging or hardening. Moisture damage, which includes both stripping (loss of adhesion) and softening (reduced cohesion), can weaken the pavement and cause increased fatigue cracking, rutting, and flushing. Asphalt cement aging (hardening) tends to cause a brittle mixture which can result in fatigue and thermal cracking of the pavement.

While a number of factors such as pavement design, mix design, and construction procedures can affect the magnitude of these distresses, the air void content (density) is one of the most important. Generally, reduced air void content or increased density achieved through



$$\text{Density} = \frac{\text{Total Weight of Mixture}}{\text{Total Volume of Mixture}}$$

$$\%\ \text{Density} = (100)\,\frac{\text{Bulk Specific Gravity of Compacted Mixture}}{\text{Theoretical Specific Gravity of Mixture}}$$

Figure 16.1. Typical asphalt mixture properties (Ref 40).

the compaction process will significantly reduce fatigue cracking, rutting and permanent deformation, moisture damage, and age hardening.

Fatigue Cracking

A number of laboratory studies have been conducted which illustrate the effect of air void content on fatigue life. The results indicate that mixtures containing high air void contents have relatively short fatigue lives. As shown in Figures 16.2 through 16.4, a decrease in air void content from 10 to 3 percent increased fatigue life by approximately a factor of 10. It can also be seen in Figure 16.4 that at low strain levels fatigue life decreased sharply with increased air void content. Decreased air voids also increased the stiffness of the asphalt mixture (Fig. 16.5) which in turn improves the load-carrying capacity of the pavement sections by reducing the stresses transmitted to the underlying layers. In addition, mix stiffness is closely related to fatigue resistance. In general, for a repeated constant stress (thick pavements), fatigue life will increase with increased stiffness, while for a repeated constant strain (thin pavements), fatigue life will decrease with increased stiffness (Fig. 16.6). The exception to this general rule is the effect of air void content. As shown in Figure 16.6, a decrease in air void content produced both an increase in stiffness and an increase in fatigue life for both constant stress and constant strain loading.

Permanent Deformation

Similarly, it has been found that an increasing air void content resulted in a significant loss of pavement life in terms of rutting or permanent deformation. As shown in Figure 16.7, a decrease in air void content increased the number of loads required to produce a given amount of permanent deformation by a factor of 10.

Asphalt Cement Aging

A hardness index has been used which ranged from zero, for no hardening, to 100, which corresponded to a penetration value of approximately 10. As shown in Figure 16.8, the hardness index increased significantly with an increase in air void content indicating a significant increase in the aging or hardening of the asphalt cement. In addition, other research has reported significant increases in hardening (reduced penetration) for increased air void contents (Fig. 16.9).

Moisture Damage

High air void contents have consistently been shown to be related to high levels of moisture damage (stripping). In many cases, highly moisture susceptible mixtures have performed satisfactorily when compacted to relatively high density. For example, an analysis of a pavement failure in Texas found that one section of the roadway failed by rutting, while another section performed extremely well with no signs of rutting. The evaluation of these failures indicated that the primary cause of the rutting was stripping with associated high moisture contents in the mix. Both sections contained essentially the same aggregate and asphalt cement. A high density, however, was achieved in the section which performed satisfactorily. The low air void content of this mix apparently prevented moisture penetration and thus moisture damage. Test samples taken from the roadway also indicated much lower moisture contents in the mix in the satisfactory pavement sections.

16.3 MIXTURE FACTORS AFFECTING COMPACTION

The resistance to compaction is composed of: (a) interparticle frictional resistance, (b) initial resistance (cohesion) of the asphalt cement, and (c) viscous resistance of the asphalt cement.

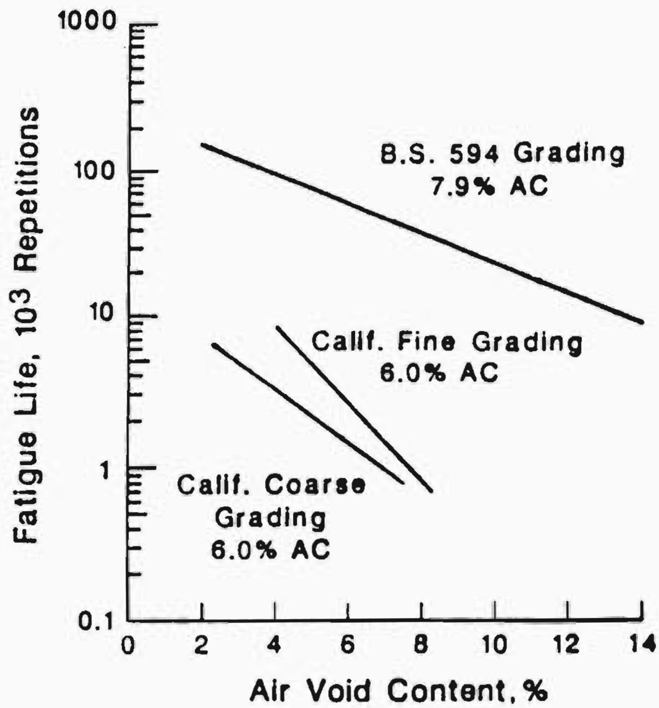


Figure 16.2. Effect of air void content on fatigue life (Ref 44).

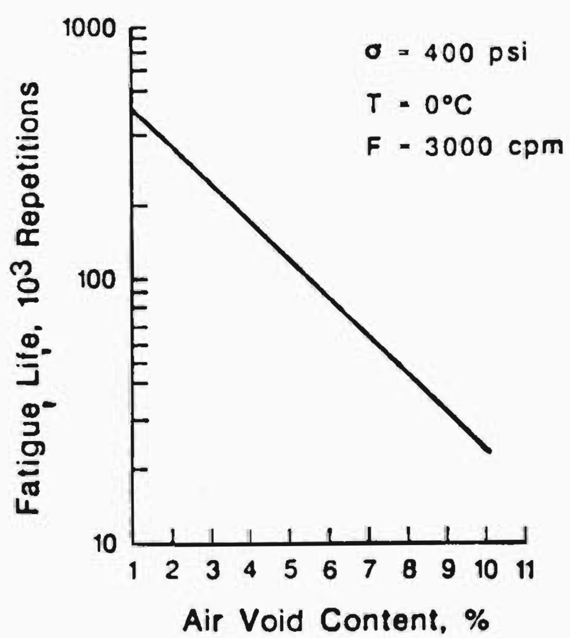


Figure 16.3. Effect of air void content on fatigue life (Ref 42).

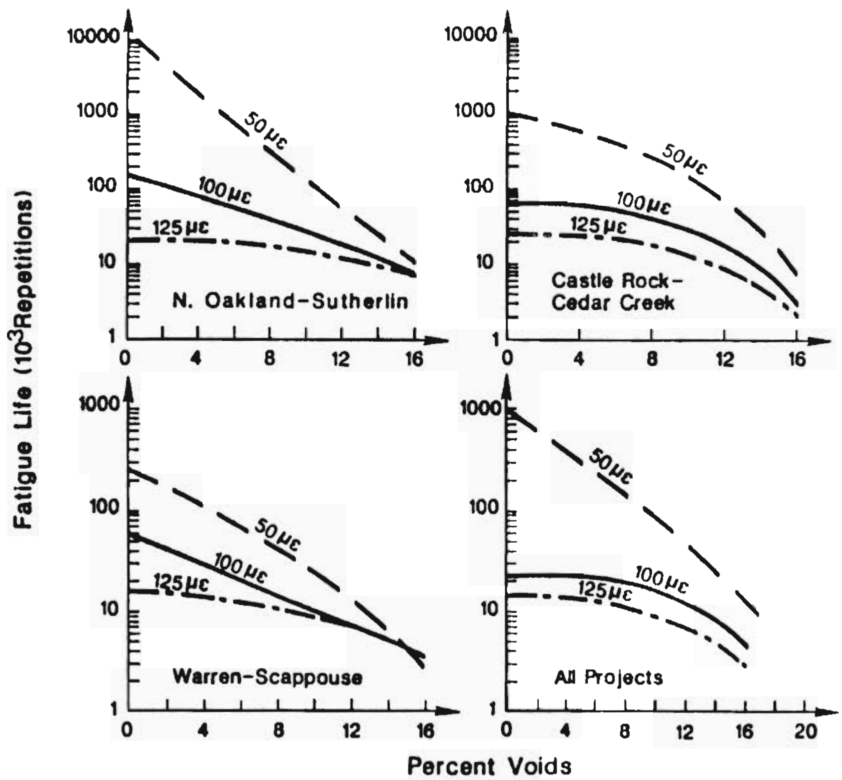


Figure 16.4. Effect of air void content on fatigue life at three different strain levels (Ref 45).

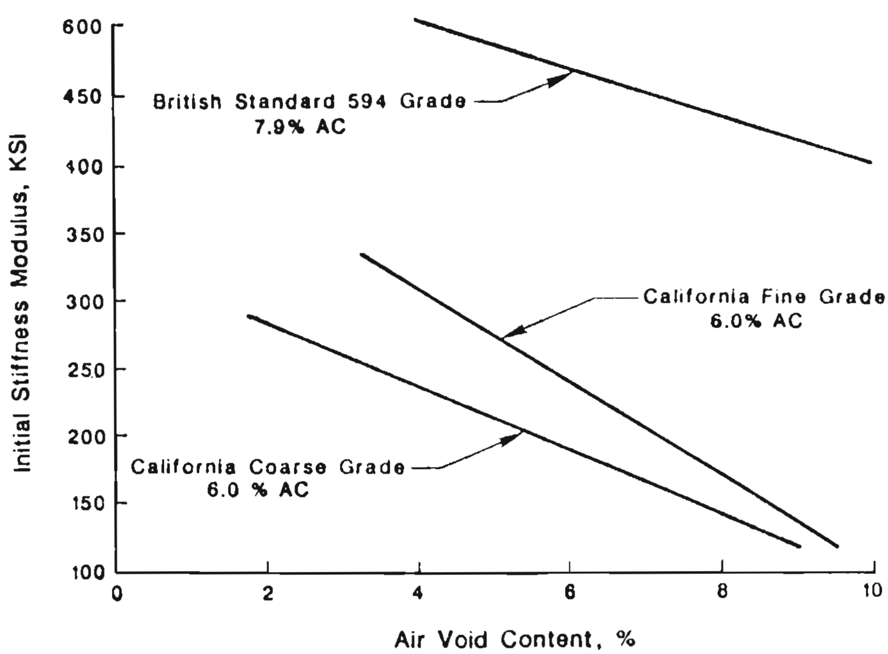


Figure 16.5. Effect of air void content on initial stiffness modulus (Ref 44).

Factor	Change in Factor	Effect of Change in Factor: On Stiffness	On Fatigue Life: In Controlled Stress Mode	On Fatigue Life: In Controlled Strain Mode
Asphalt Penetration	Decrease	Increase	Increase	Decrease
Asphalt Content	Increase	Increase (1)	Increase (1)	Increase (2)
Aggregate Type	Increase Roughness and Angularity	Increase	Increase	Decrease
Aggragate Gradation	Open to Dense Gradation	Increase	Inccrease	Decrease (4)
Air Void Content	Decrease	Increase	Increase	Increase (4)
Temperature	Decrease	Increase (3)	Increase	Decrease

(1) Reaches optimum at level above that required by stability considerations.

(2) No significant amount of data; conflicting conditions of increase in stiffness and reduction of strain in asphalt make this speculative.

(3) Approaches upper limit at temperature below freezing.

(4) No significant amount of data.

Figure 16.6. Factors affecting the stiffness and fatigue behavior of asphalt concrete mixtures (Ref 45).

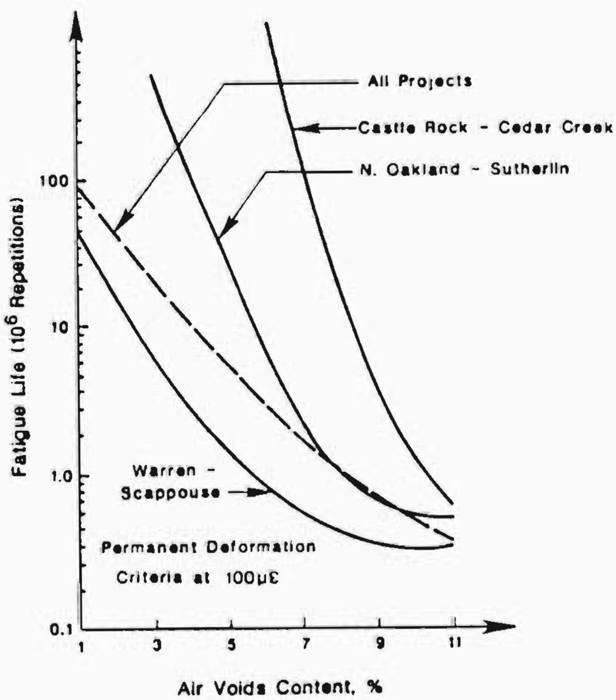


Figure 16.7. Effect of air void content on permanent deformation (Ref 45).

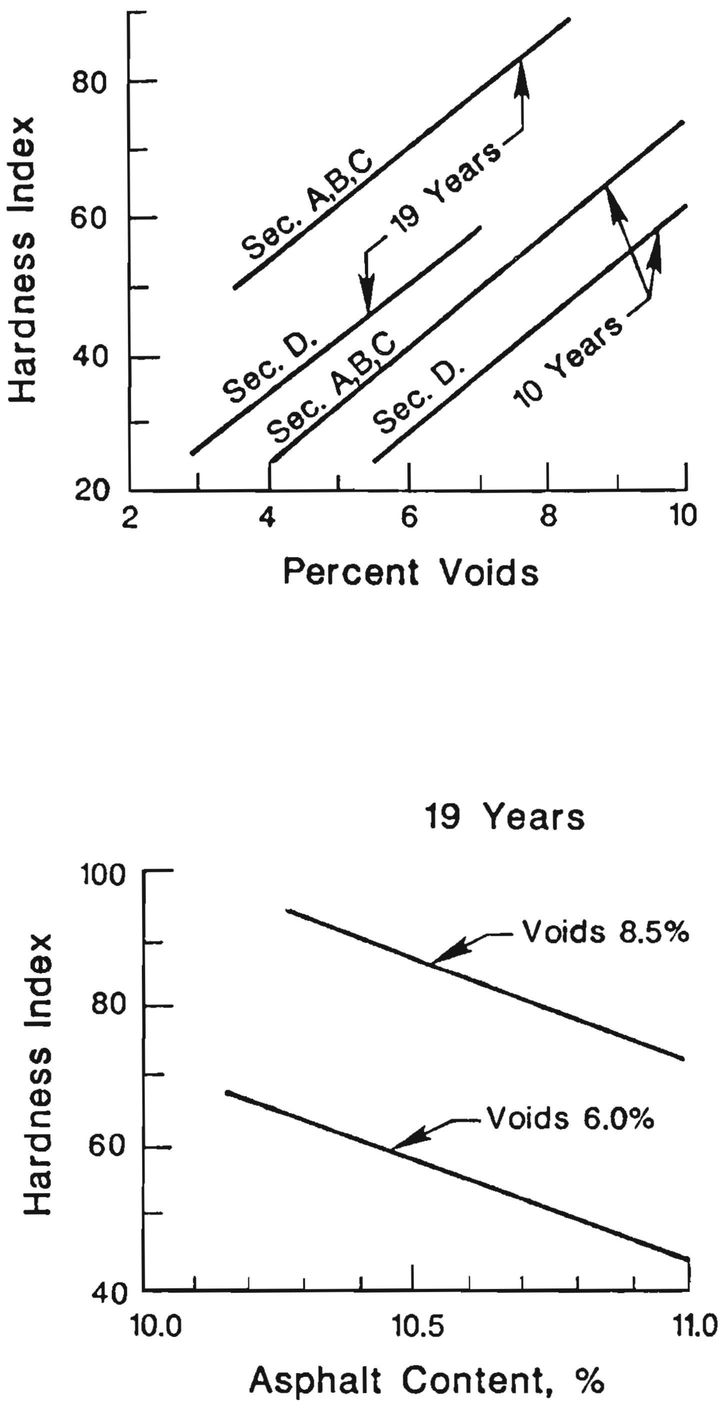


Figure 16.8. Effect of air void content on hardness index (Ref 46).

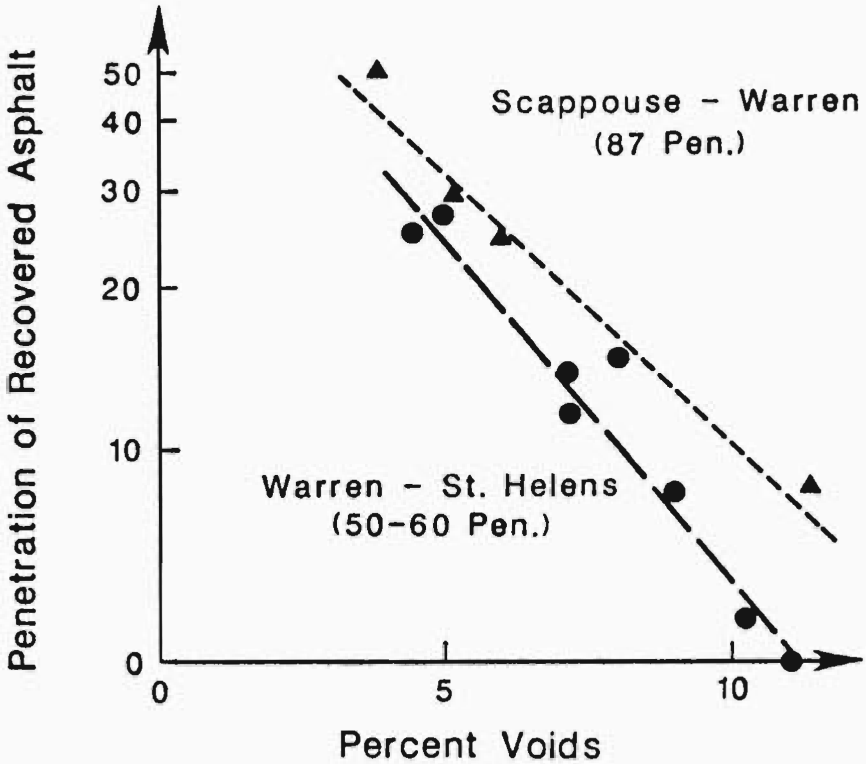


Figure 16.9. Effect of air void content on the penetration of recovered asphalt cement (Ref 45).

Immediately following laydown, asphalt concrete mixtures are hot and highly plastic. While in this plastic state, the air void content of the mixture can be reduced (the density increased) by means of compaction which reorients the aggregate particles into a denser configuration. The resistance to compaction of this plastic mixture is primarily a function of the asphalt cement and the aggregate properties and their interactions. Many compaction problems encountered in the field can be explained in terms of these factors.

Aggregate Properties

The six aggregate properties which affect the compaction resistance of the mixture are: (a) particle shape and texture, (b) amount of coarse aggregate, (c) gradation, (d) filler content, (e) absorption, and (f) soundness.

Particle Shape and Texture. Asphalt concrete mixtures containing angular and rough-surface-textured aggregate are more resistant to compaction than mixtures containing rounded, smooth aggregate. Angular (crushed) particles develop aggregate interlock which makes it difficult for the aggregate particles to reorient into a denser configuration under a given conpaction effort. Similarly, aggregate with a rough surface texture develops more friction between particles. The increased resistance to compaction can be equated to the increased resistance to permanent deformation exhibited by asphalt concrete pavement mixtures containing angular aggregate or aggregate with a rough surface texture.

Gradation. A mixture containing a uniformly graded aggregate can be compacted with less compactive effort than a mixture with either a single-sized or a gap-graded aggregate. For the production of dense-graded asphalt mixtures, it has been proposed that the aggregate be graded according to the equation.

$$P = \left(\frac{S}{M}\right)^{0.45}$$

where:

P = percent passing a specified sieve,

S = size of opening for the specified sieve (in microns), and

M = maximum size of aggregate (in microns).

Gradation curves (gradation B, Fig. 16.10) that cross back and forth over the maximum density line (gradation A, Fig. 16.10) especially in the region of the No. 40 to No. 80 sieves, tend to produce tender mixtures that displace excessively during compaction.

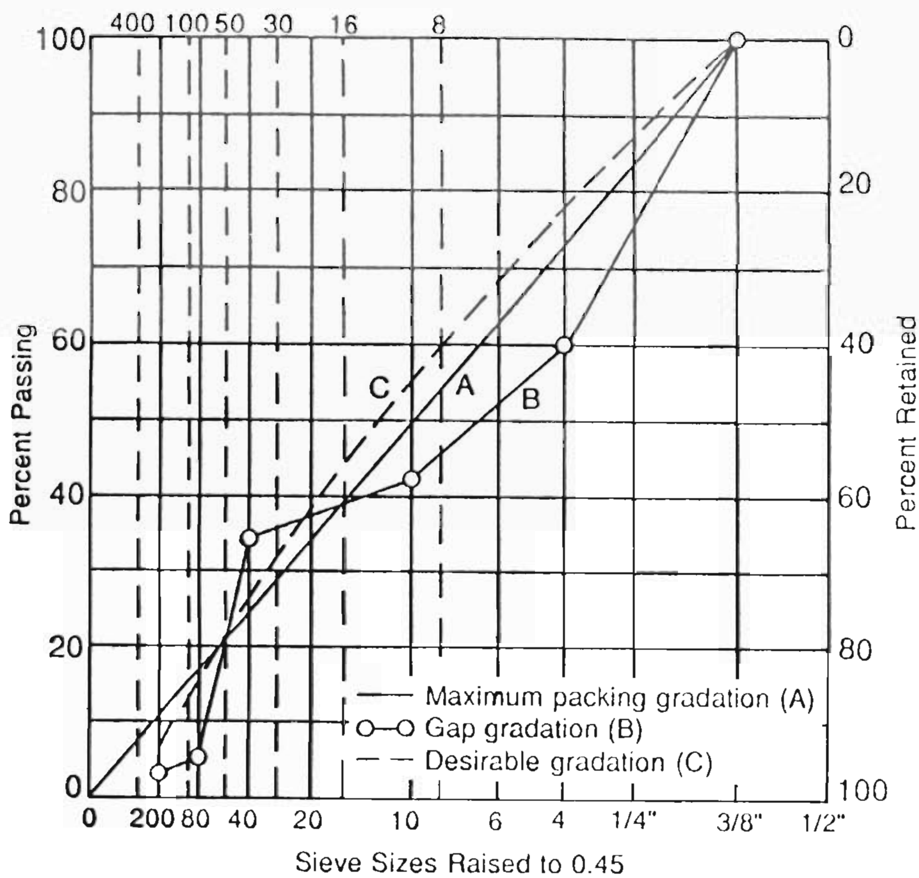


Figure 16.10. Typical aggregate gradations (Ref 13).

Amount of Coarse Aggregate. Mixtures containing a large amount of coarse aggregate will require significantly more compactive effort to obtain a specified level of density than will a fine-graded mixture. While an oversanded or fine-graded asphalt concrete mixture will be very workable, it may be extremely difficult to achieve the specified density since the mixture will be tender and shove under the compaction equipment. This causes the mixture to displace laterally rather than compress vertically. This is particularly true when the gradations have an excess of material in the midrange for sand (minus No. 30 sieve).

Filler Content. Adequate filler content (minus No. 200 sieve) is necessary for a mixture to develop enough cohesion to be compacted effectively. Filler material acting with the asphalt cement tends to hold the larger sized material in place. If the filler content is too high, "gummy" mixtures are produced. Such mixtures are difficult to compact because of a tendency to be picked up by the roller. In addition, these mixtures tend to exhibit excessive lateral displacement. Insufficient filler, however, may require additional asphalt to fill the voids in the mineral aggregate. This results in thicker asphalt cement films and possible instability of the mixture during compaction.

Absorptive Aggregate. Highly absorptive aggregate tends to increase the compaction resistance of the mixture by reducing the thickness of the asphalt cement film on the surface of the aggregate. The effect is reduced lubrication by the asphalt cement, which makes compaction more difficult.

Soundness. Although soundness does not directly affect the resistance of the mixture to compaction, it does tend to affect the level of density achievable by a given compaction procedure. Unsound aggregate may fracture under the dynamic loading of vibratory rollers. Fracturing will effectively change the gradation of the mixture and may reduce actual density and may increase the susceptibility of the mixture to moisture damage.

Asphalt Amount

Both the asphalt cement content and asphalt cement type can effect the density and compaction of the asphalt concrete mixture.

Asphalt Cement Content. A mixture containing either too little or too much asphalt cement is difficult to compact. A lean mix does not have an adequate amount of asphalt cement for lubrication and, therefore, is harsh and resistant to compaction. A rich mix, on the other handmay be tender and will shove laterally under the rollers.

Asphalt Cement Type. The type and grade of asphalt cement can significantly influence the compactability of asphalt concrete mixtures. An asphalt cement which has a higher viscosity (lower penetration) at the mix compaction temperature will require more compactive effort. Thus an AC-30 viscosity grade or a 60-70 penetration grade asphalt cement will generally be stiffer than an AC-10 viscosity grade or 120-150 penetration grade cement, and the mix containing the stiffer binder material will be more difficult to compact.

As the mixture temperature decreases, the viscosity of the asphalt cement increases at a rate determined by its temperature susceptibility. It is important to note that two different asphalt cements which have the same viscosity grade or penetration grade (Fig. 16.11) may have significantly different viscosities at the same temperatures. Since the viscosity of the asphalt cement affects the overall resistance of the mixture to compaction, a knowledge of the temperature susceptibility of the asphalt cement is vital for effective compaction of the asphalt concrete mixture.

Different asphalt cements can also harden more or less during mixing in the plant. This hardening can also be influenced by the type of plant (batch plant versus drum mix plant) and the mixing temperature used. Thus, as shown in Figure 16.11, it may be necessary to alter the compaction temperature in order to achieve the optimum asphalt cement viscosity for compaction. Higher compaction temperatures can result in tender mixes while lower temperatures will result in a greater compaction resistance and the need for a greater compactive effort.

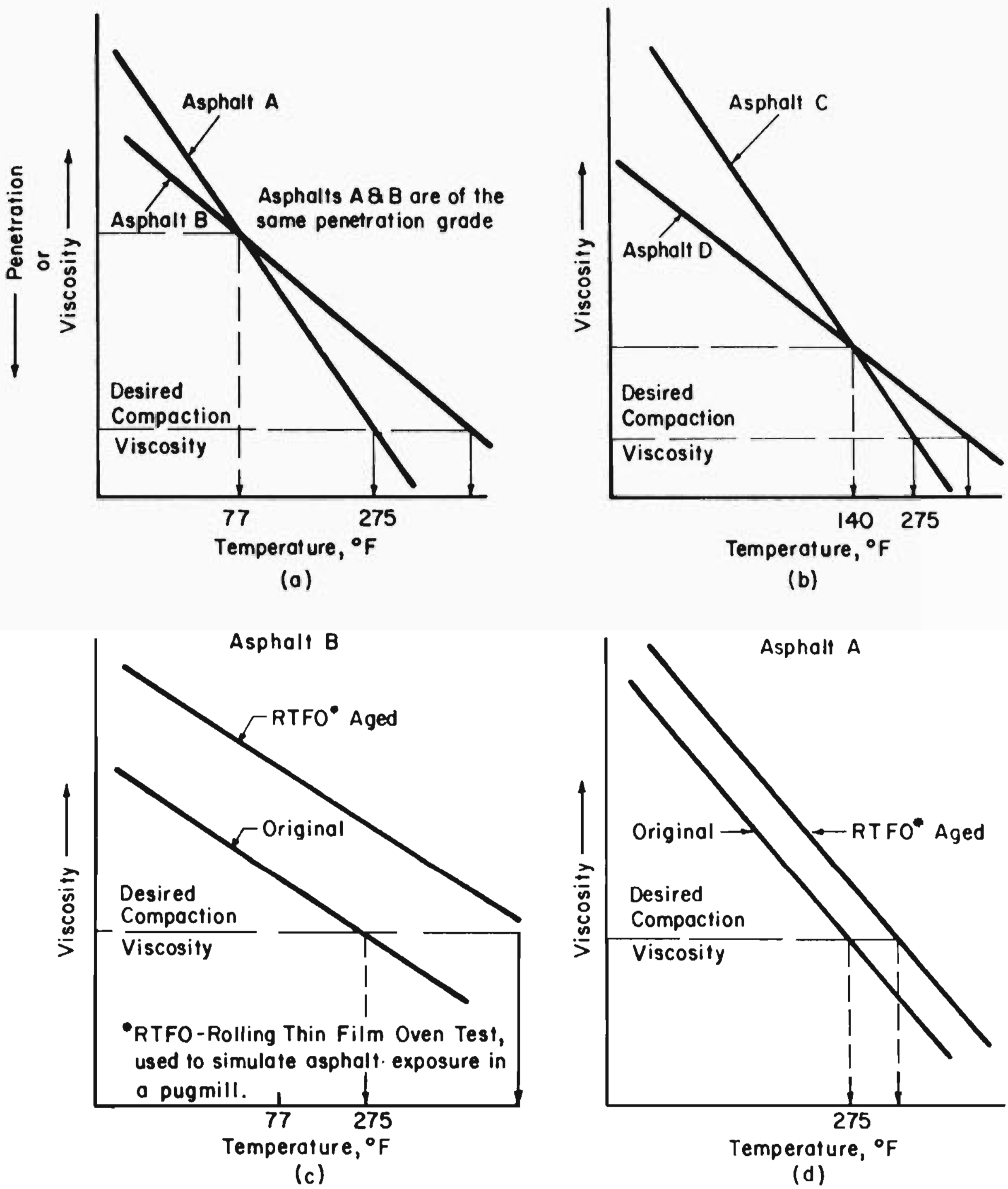


Figure 16.11. Temperature/viscosity relationships for asphalt cements (Ref 40).

16.4 TIME AVAILABLE FOR COMPACTION

The time available for compaction is the time it takes for the mixture to cool down from the laydown temperature to a minimum temperature for compaction, normally considered to be 175°F. At lower temperatures, the internal resistance to compaction increases significantly, requiring a much greater compactive effort. Additional compactive effort at low mix temperature often will fracture the aggregate and result in a decrease in density.

Six primary factors control the rate of cooling of an asphalt concrete layer. These factors are: (a) layer thickness, (b) air temperature, (c) base temperature, (d) laydown temperature of the mixture, (e) wind velocity, and (f) solar flux (cloud cover). Figures 16.12 and 16.13 show the relationships between time available for compaction and mat thickness, mix temperature and base temperature. The air temperature is assumed to be the same as the base temperature, the wind velocity is 10 knots (11.5 mph), and the solar flux is 50 BTU/ft^2/hr. These relationships are from a set of cooling curves developed for dense-graded asphalt concrete mixtures. Table 16.1 also provides another indication of compaction time as related to base temperature, mat thickness and mixture temperature at laydown. It should also be noted that all six factors are not independent factors. Thus, certain combinations or conditions are not possible.

Layer Thickness

Layer or lift thickness is probably the single most important factor affecting the cooling rate. As shown in Figures 16.12 and 16.13, cooling time is not directly proportional to lift thickness. It takes much longer for a 4 inch lift of material to cool to 175°F than for a 2inch lift. It is extremely difficult to achieve adequate density on thin lifts (less than 2 inches) under cool paving conditions.

Air Temperature

The surface of the asphalt concrete layer cools by transferring heat to the air. Thus, higher air temperatures allow more time for compaction equipment to obtain density.

Base Temperature

Heat from the bottom of the asphalt concrete layer is lost into the underlying base material. There is generally more cooling of the asphalt mat due to the base than due to the air. In addition, air temperature and base temperature are typically different. In the early spring, the base temperature may be 10 to 20°F less than the air temperature, while in the fall the difference is probably less. Thus, it will be easier to compact the mix in the fall than in the spring.

A moist base will cause the asphalt concrete mixture to cool even more by turning water into steam and by increasing the rate of heat transfer. Paving on a wet surface, therefore, is very detrimental to the ability to achieve compaction or density.

Mix Laydown Temperature

An increase in the laydown temperature increases the time available for compaction. The effect of mix laydown temperature is much greater and more important for thin lifts and low base temperatures. Batch plants usually produce asphalt mixtures at temperatures of 275°F to 325°F , while drum mix plant should operate in the temperature range of 270°F to 290°F . Depending on the environmental conditions and length of haul, the mixture can lose 5°F to 25°F between the plant and the paver. The mix temperature should be measured after it is placed by the paver, rather than being based on the mixture temperature at the plant.

Wind Velocity

High wind velocity will cause the mixture, especially the surface, to cool more rapidly. In fact, the surface may cool so rapidly that a crust will form on the mix. This crust must be

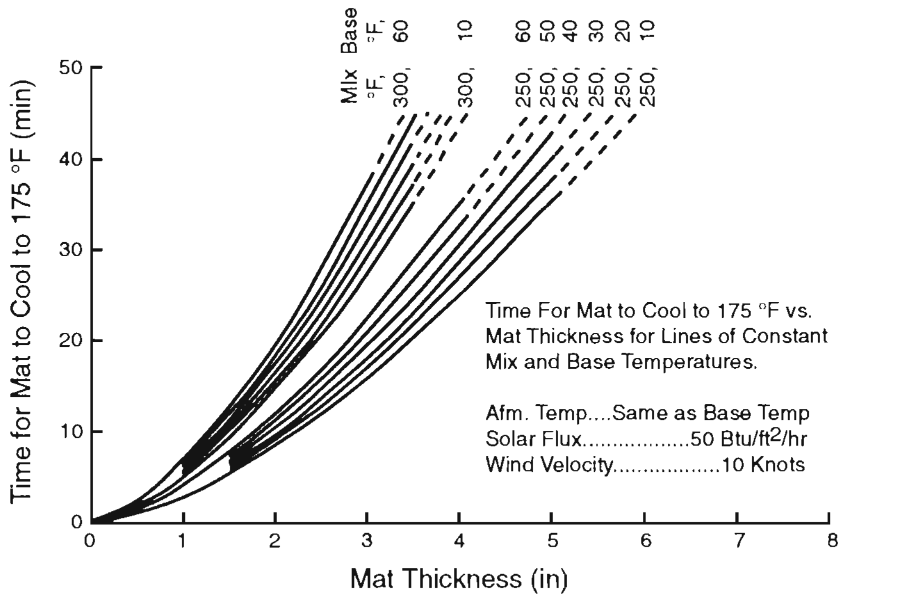


Figure 16.12. *Time for mat to cool to 175°F versus mat thickness for lines of constant mix and base temperature (Ref 50).*

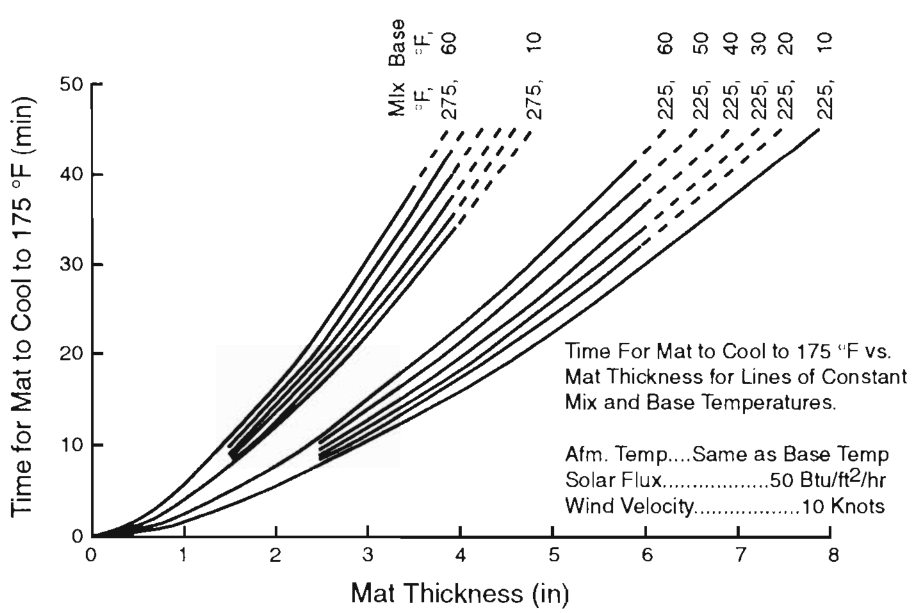


Figure 16.13. *Time for mat to cool of 175°F versus mat thickness for lines of constant mix and base temperature (Ref 50).*

Table 16.1. Recommended minimum spreading temperatures

Base Temperature (°F) (1)	Mat Thickness, inches (Customary Units)							
	1/2	3/4	1	1-1/2	2	3	3-1/2	4 (2)
20-32 (3)	—	—	—	—	—	—	275 (3)	260 (3)
+32-40 (3)	—	—	—	—	295	280	270	260
+40-50	—	—	—	300	285	275	265	255
+50-60	—	—	300	295	280	270	260	255
+60-70	—	300	290	285	275	265	255	250
+70-80	300	290	285	280	270	265	255	250
+80-90	290	280	275	270	265	260	250	250
+90	280	275	270	265	260	255	250	250
Rolling completed after placing-time, min.	4	6	8	12	15	15	15	15

(1) Base on which mix is placed.
(2) and greater
(3) Increase by 15 degrees when placement is on base or subbase containing frozen moisture.

broken down by the rollers before compaction can occur. Wind velocity is much more important for thin lifts and for mixtures placed under adverse environmental conditions.

Solar Flux

The effect of solar energy is obvious — the asphalt concrete mixture will not cool as rapidly on a sunny day compared to a cloudy day. The effect of the sun is more pronounced with respect to its effect on the base temperature. Base temperatures will be higher for sunny days than on a day with heavy cloud cover, even though the air temperature is the same for both days.

16.5 COMPACTION EQUIPMENT

The three types of self-propelled compaction equipment used include: (1) static steel wheel rollers, (2) pneumatic tire rollers, and (3) vibratory steel wheel rollers.

Static Steel Wheel Rollers

Static steel wheel rollers normally weigh from as little as three tons, to in excess of 14 tons, and have compression rolls that vary in diameter from 40 to 60 inches. For most highway work, a minimum roller weight of 10 tons is recommended. This type of equipment includes both three wheel and tandem rollers.

The actual compactive effort and effectiveness of the roller is determined by the contact pressure in pounds per square inch. The contact pressure is determined by the gross load and by the contact area, which is dependent on the depth of penetration of the roller into the mixture. As shown in Figures 16.14 and 16.15, as the depth of penetration increases, the contact area increases and the contact pressure decreases. Measured contact pressures for a 10 to 12 ton static steel wheel roller range between 40 and 60 psi.

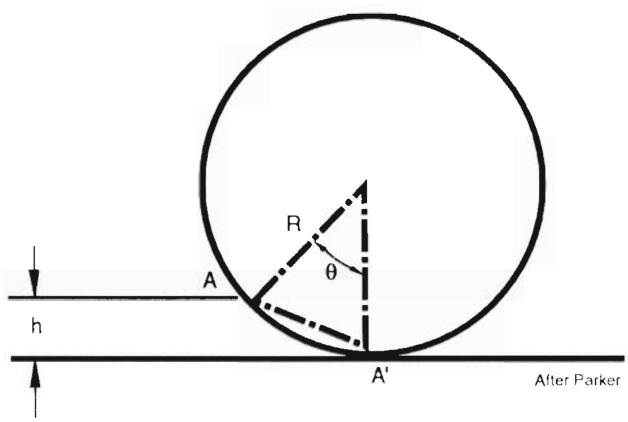


Figure 16.14. Contact area and angles of inclination (Ref 52).

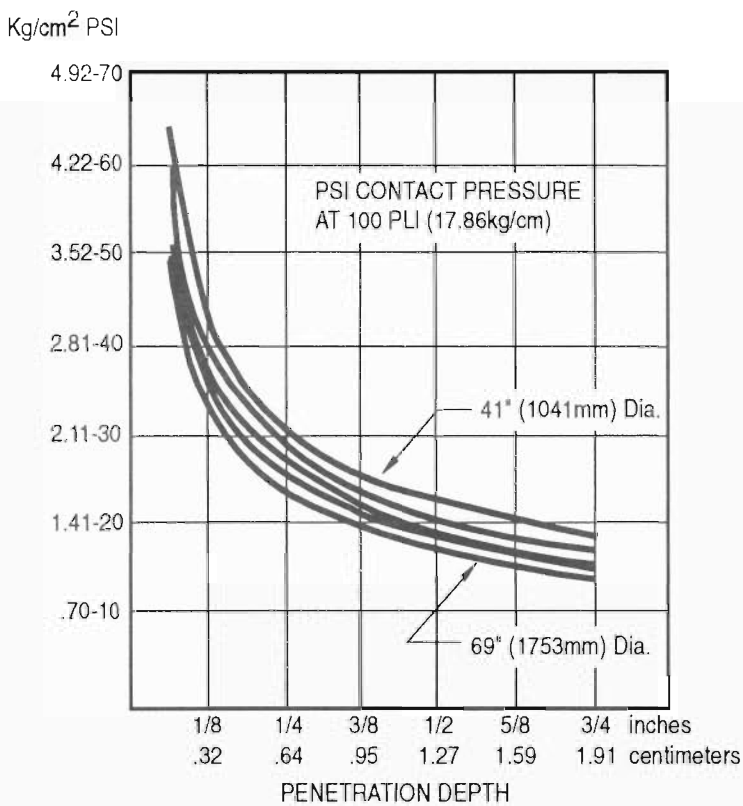


Figure 16.15. Relationship between contact pressure and both drum diameter and penetration (Ref 52).

The most desirable static roller generally is the one with the smallest drawbar pull (horizontal force required to move a roller). Rollers with larger diameter drums have less drawbar pull because they do not tend to penetrate the mix as much as a roller with a smaller diameter drum. Thus, as a general rule, static steel wheel rollers with large diameter drums should be used.

For this type of roller, the only variables which can be controlled by the operator are the rolling speed and the location of the roller with respect to the paver. Changing the weight of the roller by adding ballast can also be done, but seldom is.

Pneumatic Tire Rollers

As with the steel wheel rollers, the actual compaction effort applied by a pneumatic tire roller is primarily dependent on the contact pressure which is a function of the total load, tire pressure, tire design, (size and ply rating) and, to a lesser extent, penetration depth. Contact pressures normally range from a low of 40 psi to a high of 125 psi.

A pneumatic tire roller can be operated in any of the three rolling positions — breakdown, intermediate, or finish. For tender mixes, this type of roller will tend to shove the mix less than will a steel wheel roller and will reduce or eliminate checking of the mix. Thus, for tender mixes, a pneumatic tire roller can be used in the breakdown position, immediately behind the paver.

To prevent picking up the mix, pneumatic tire rollers are usually operated "dry-tire" — without any release agent sprayed on the tires. As long as the tires are at the same temperature as the mix being compacted, little if any mix picking up will occur. Diesel fuel should never be used since it can cause damage to the asphalt concrete mixture.

Vibratory Steel Wheel Rollers

Vibratory rollers are much more complex than the static steel wheel or pneumatic tire rollers because of the relationships which exist between the frequency of vibration, the magnitude of the load (amplitude), and the roller speed. Early model vibratory rollers had fixed vibration amplitude, and the only way to reduce the dynamic force applied to the mix was to reduce the frequency which increased the impact spacing. This required a decrease in roller speed which could not completely compensate for the reduced frequency and increased impact spacing. Therefore, design constraints on these first rollers caused an objectionable washboard pattern in the asphalt concrete mix. During the early 1970's, vibratory double drum rollers were introduced with variable amplitude and higher frequency ranges for both drums. Development of these more sophisticated rollers, coupled with use of the nuclear density gauge, made establishing roller patterns easier and helped facilitate more acceptable compaction results.

Five types of vibratory steel wheel rollers have been used. These are shown in Figure 16.16 and include: (a) single drum — rigid frame, (b) single drum — articulated frame, (c) double drum — rigid frame, (d) double drum — single articulated frame, and (e) double drum — double articulated frame. Most vibratory rollers used for compaction of asphalt concrete mixtures are the single and double drum rollers with articulated frames.

Vibratory rollers have two components of compactive force which provide energy for the compaction process: (a) static weight and (b) dynamic (impact) force. The static weight component is composed of the frame and drum weight. This can be increased by the addition of ballast material, usually water. The amount of ballast needed is a function of the desired compactive effort. The dynamic (impact) force is produced by a rotating eccentric located in the drum (Fig. 16.17). As the eccentric rotates about the shaft, a dynamic force is produced which is directly proportional to the mass, the square of the rotational velocity, and the length of the eccentric radius. In order to keep the drum pressed against the mix to be compacted, the eccentric is designed so that the ratio of the weight of the drum to the weight of

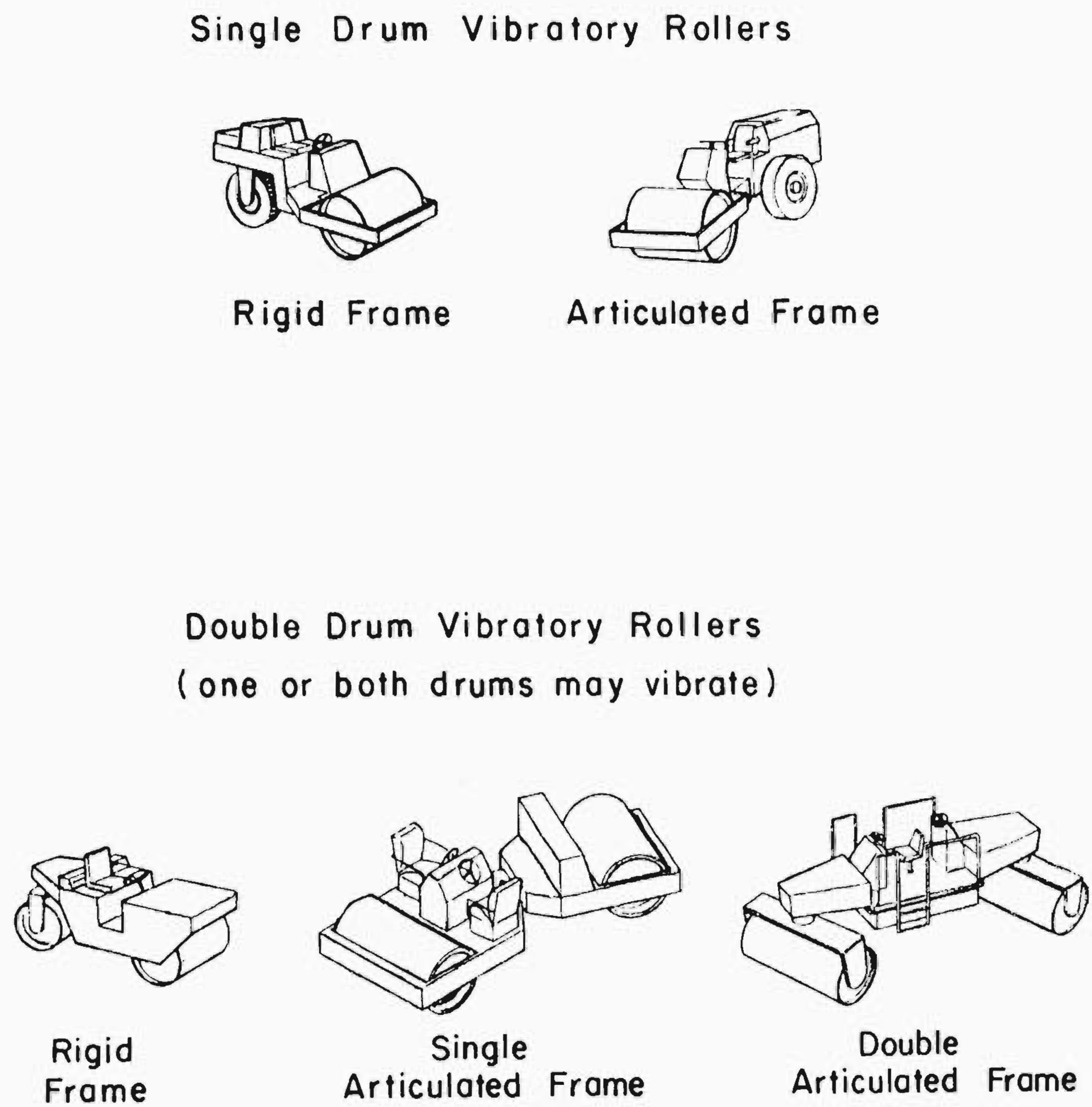


Figure 16.16. *Representative vibratory roller types commonly encountered in asphalt mixture compaction (Ref 55).*

Time for 1 Cycle	=	T, sec
Frequency 1/T	=	n, Hz, i.e., cycles per second
(Nominal) Amplitude	=	a, in
Weight of Eccentric	=	W, lb
Eccentric Moment	=	$W \times r$, in-lb
Centrifugal Force	=	$W \times r \times 4 \times \pi^2 \times n^2$, lb

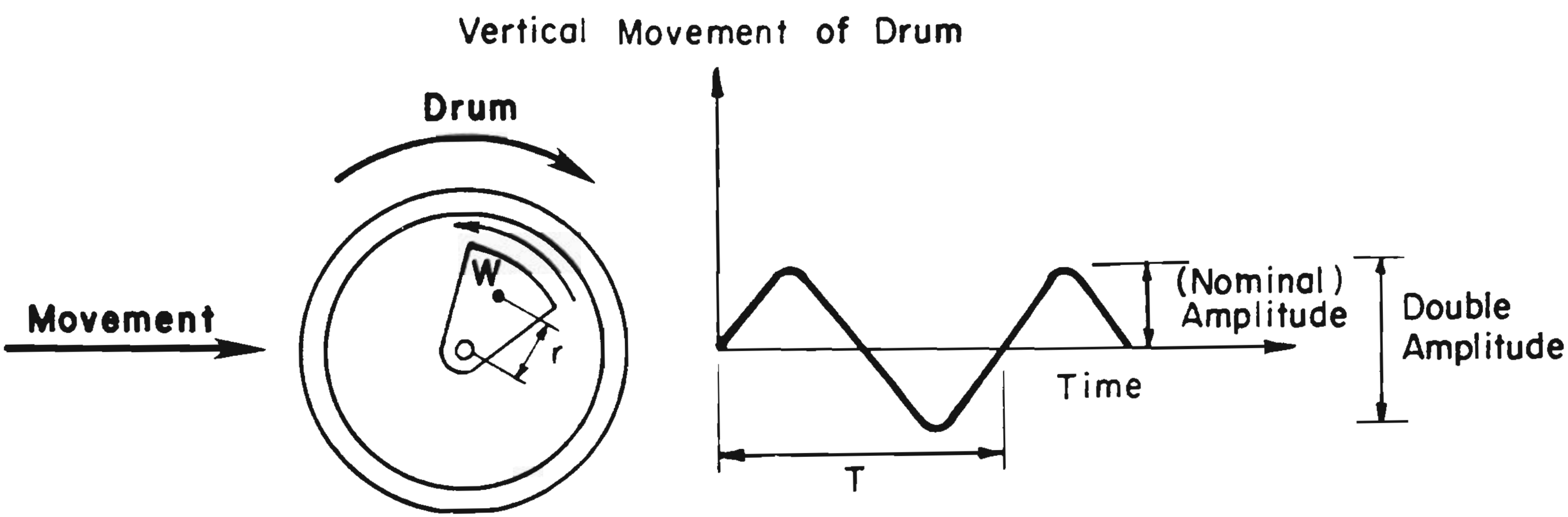


Figure 16.17. Mechanics of the rotating eccentric.

the frame is within a certain range. If the drum is relatively heavy compared to the frame, a large eccentric produces forces that will tend to bounce the frame up and down. A rubber element usually separates the drum from the frame in order to minimize frame vibration.

Total Applied Force. The total applied force is the sum of the static weight and dynamic (impact) force. A more meaningful comparison of rollers can be made by using the unit force — the static weight plus dynamic (impact) force per linear inch of drum at a stated frequency.

The total applied force or total force per unit width of drum (unit force) is resisted by the layer being compacted. The resistance is a function of the mixture. For compaction to occur, the total applied force must exceed the mixture's resistance to compaction which is a function of compaction temperature, degree of confinement, base support, and mixture characteristics.

Amplitude. Amplitude is a measure of the total applied force. Double amplitude is the total peak-to-peak vertical movement of the drum during a complete cycle of vibration with the drum in a freely suspended condition. It is dependent upon the drum weight, configuration of the eccentric, and the elasticity of the material being compacted. The nominal amplitude is half of the double amplitude. The perceptible vertical distance the drum moves is generally small due to the damping effects of both the layer being compacted as well as underlying support layers. Typical values of nominal amplitude range from 0.25 to 1.00 mm.

Amplitude changes are caused by changes in the configuration of the eccentric which, in turn, alter the radius of rotation. As the radius of rotation increases, the resulting amplitude increases which produces larger dynamic forces and more compactive effort.

Frequency and Impact Spacing. Frequency is the number of complete cycles of the vibrating mechanism per minute or the speed at which the eccentric rotates. The range of frequency is 1500-3000 vpm with a more common range of 2000-2400 vpm for vibratory rollers used to compact asphalt concrete mixtures. Impact Spacing, which is dependent upon vibration frequency and roller speed, is the distance the roller travels between dynamic force pulses (Fig. 16.18). A short impact spacing is usually desirable when compacting asphalt mixtures, since this will produce a smoother riding surface.

The impact spacing can be calculated by dividing the roller speed by the vibratory frequency:

$$\text{Impact Spacing} = \frac{\text{Roller Speed (ft / sec)}}{\text{Frequency (vib / sec)}}$$

For asphalt concrete mix compaction, the number of impacts per foot shall be in the range of 8 to 10. For a vibratory frequency of 2,400 vibration per minute, the roller speed should be less than 2.5 miles per hour to obtain the desired impact spacing.

16.6 CONTROL OF COMPACTION VARIABLE

Six primary compaction variables that can be controlled during the rolling process are: (a) roller speed, (b) number of roller passes, (c) rolling zone, (d) rolling pattern , (e) vibration frequency, and (f) vibration amplitude. The first four factors are applicable to all types of rollers — static steel wheel, pneumatic tire, and vibratory. The last two factors are applicable only to vibratory steel wheel rollers.

Roller Speed

The faster a roller passes over a particular point in the new asphalt concrete surface, the less time the weight of the roller "dwells" on that point. This in turn means that less compactive effort is applied to the mixture. As roller speed increases, the density achieved with each roller pass decreases (Fig. 16.19). Typically, 2.5 miles per hour (220 feet per minute)

$$\text{Impact Spacing (I)} = \frac{\text{Roller Speed, fps}}{\text{Frequency, Hz}}$$

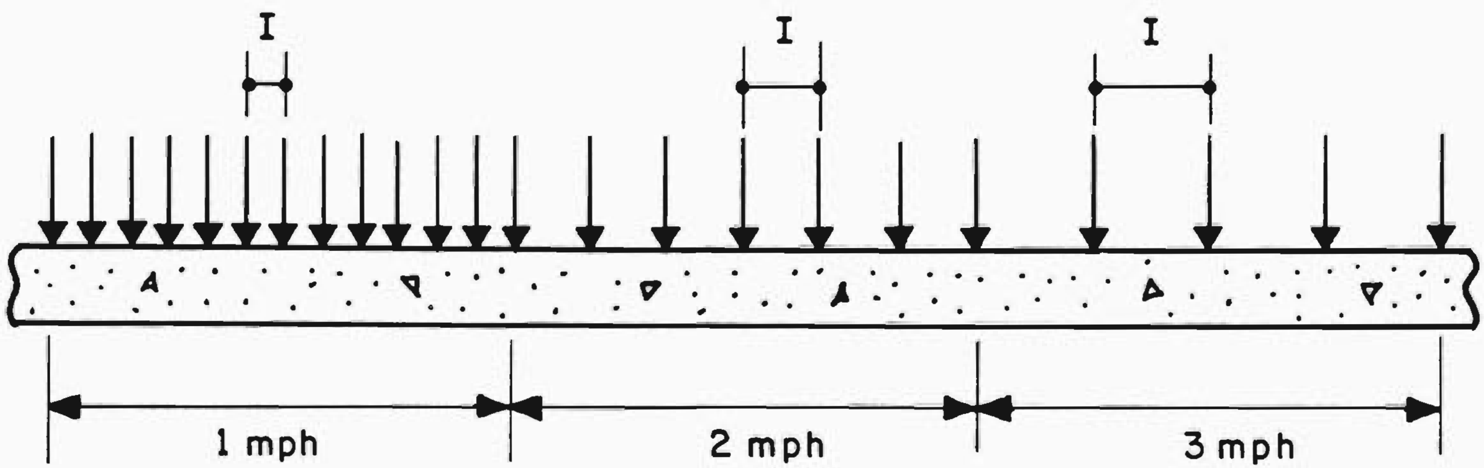


Figure 16.18. Effect of roller speed on impact spacing.

is about the maximum speed that a roller should travel. Roller speed will be governed by the lateral displacement or tenderness of the asphalt concrete mix. If the mixture moves excessively under the rollers, the speed of the compaction equipment should be reduced.

For vibratory compactors, roller speed also affects the impact spacing (Fig. 16.18). This spacing is important for controlling the amount of dynamic compaction energy applied to the mix and also for obtaining the proper surface smoothness. The spacing should be from 1.5 to 1.2 inches, or 8 to 10 impacts per foot. In some cases, an impact spacing of 1 inch has been recommended for thin lifts and a spacing equal to the mat thickness for thick lifts.

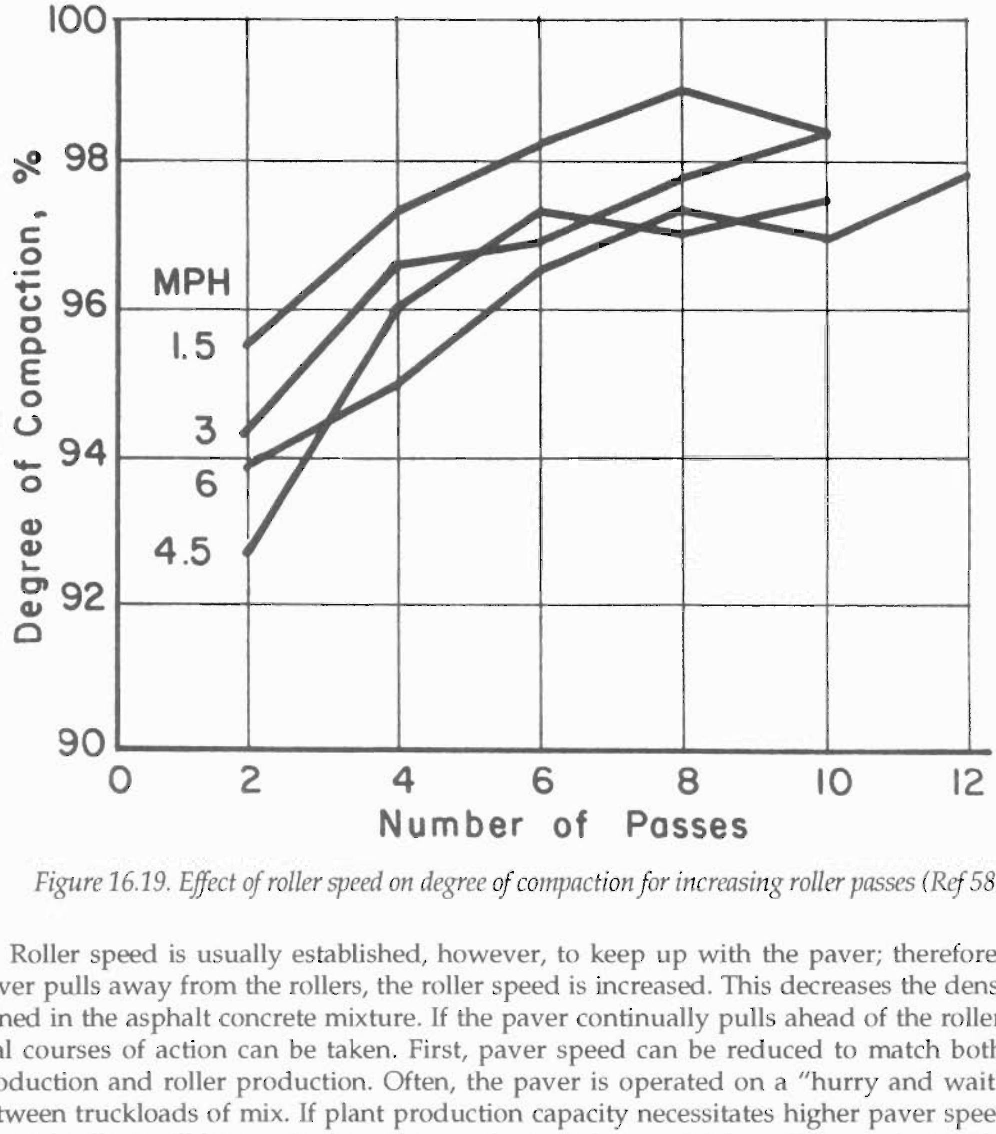


Figure 16.19. Effect of roller speed on degree of compaction for increasing roller passes (Ref 58).

Roller speed is usually established, however, to keep up with the paver; therefore, if the paver pulls away from the rollers, the roller speed is increased. This decreases the density obtained in the asphalt concrete mixture. If the paver continually pulls ahead of the rollers, several courses of action can be taken. First, paver speed can be reduced to match both plant production and roller production. Often, the paver is operated on a "hurry and wait" basis between truckloads of mix. If plant production capacity necessitates higher paver speeds, additional rollers will be required to achieve adequate density. Wider rollers can be employed, a 7 foot wide vibratory roller can be used in place of a 4-1/2 foot wide tandem roller, for example. The type of roller used can also be changed — a double drum vibratory roller in lieu of a single drum vibratory roller.

Continuously varying the speed of the compaction equipment causes variations in density. Too often, roller operators hustle along to catch up with the paver, park on the hot mat and sit and talk to the paver crew. "Slow and steady" is the key to for proper compaction.

Number of Roller Passes

To gain the target air void content in an asphalt concrete mixture, it is necessary to roll over each point in the new layer a certain number of times. The actual number of passes depends on many variables. The type of compaction equipment is one very important consideration. Three wheel steel wheel rollers have different compaction capabilities than tandem steel wheel rollers, pneumatic tire rollers, single or double drum vibratory rollers.

These capabilities vary, however, with mat thickness, mix temperature, mix design (asphalt cement content and aggregate characteristics) and environmental conditions. In addition, the number of passes required depends on the position of the rollers in the roller train. It may be possible, for example, to obtain an increase in density when a large pneumatic tire roller is switched to the breakdown roller position from the intermediate roller position.

To determine the minimum number of roller passes needed to achieve proper density levels, a test strip should be constructed at the start of any major paving project. The highest increase in density should be obtained as quickly as possible by compacting the asphalt concrete mixture while it is still hot — before it cools to 175°F (Figure 16.20).

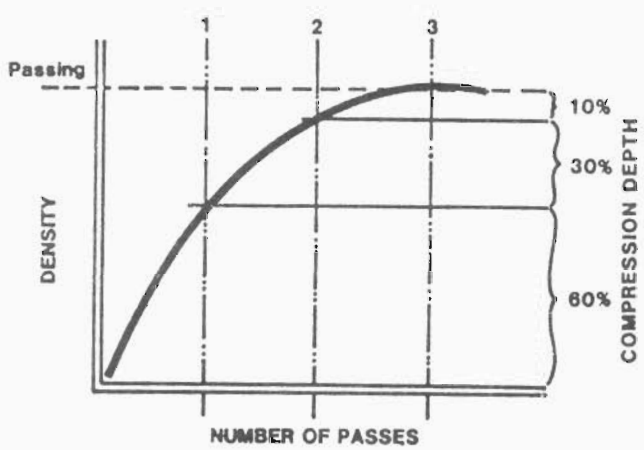


Figure 16.20. Typical compaction curve.

Roller passes must be distributed uniformly over the width and length of the mat. All too often, the center of the paver lane (the area between wheelpaths of a single lane pavement) receives adequate roller coverage while the edges of the mat and the wheelpaths where traffic runs receive considerably less roller coverage. The uniformity of the roller passes is just as important as the number of passes.

Rolling Zone

Compaction must be achieved while the asphalt cement viscosity in the mix is low enough to allow for reorientation of the aggregate particles under the action of the rollers. In other words, the mix must be hot for effective compaction to occur. The proper level of air voids must be obtained before the mix cools from the laydown temperature to 175°F. Many variables affect the rate of cooling of the mixture as previously discussed.

To reach the required density level the quickest, initial compaction should occur directly behind the laydown machine. If the stability of the asphalt concrete mixture is high enough, breakdown rolling can be carried out very close to the paver, while the mat temperature is still high. More density is usually obtained with one pass when the mix temperature is 250°F than with a similar pass when the mat is at 220°F . Thus, the rolling zone (the distance the breakdown roller operates behind the paver) should be as short as possible.

Many times a "tender mix" is placed. Because of the lack of stability in the asphalt concrete, the initial rolling is often delayed to avoid excessive shoving of the mix with the rollers. This is the wrong solution to the problem. A mix that cannot be compacted directly behind the paver needs to be changed. The rolling zone should not be arbitrarily lengthened. A tender mix cannot be properly compacted, and the rollers can not overcome a poor mix design. When a tender mix is encountered, the mix design, not the compaction process, should be changed.

Roller Patterns

Rollers are "busy" most of the time on a paving project. The question is whether they operate correctly and effectively. Generally, compactive effort is applied but not necessarily in the right place.

Numerous compaction studies have shown that the middle of the paver pass width typically receives more compaction than the edges of the pavement. This is unfortunate since traffic uses the wheelpath areas and travels near the edge of the pavement more often than the center of the lane.

As an example, consider an actual asphalt recycling project on an Interstate roadway. The recycled mixture was placed on a milled out section of the driving lane in a 6 inch deep trench section, 12 feet wide, in two 3 inch compacted layers. Initial or breakdown rolling was accomplished by the contractor using a 7 foot wide double drum vibratory roller. Two passes of the vibratory roller cover all the mat width, with an overlap in the center. To achieve adequate density, the breakdown roller operator had to keep the vibratory roller tight to each edge of the trench. Each roller pass needed to be made directly into and away from the paver, without ever making an attempt to roll the center of the lane.

On the job, however, the roller operator made the first pass up the left-hand side of the mat, 7 feet wide. Upon reversing when reaching the rear of the paver, the roller shifted transverse direction and progressed away from the paver by traveling down the center of the mat with 2.5 feet of free area on either side of the vibratory roller. The third pass, again toward the paver, was along the right-hand edge of the driving lane. The fourth pass (away from the paver) was once more down the center, and similar to pass number two. The final roller pass, to catch up to the paver, was a reversal of pass four, up the center of the lane. The roller operator continued to repeat this five pass pattern as the paver moved down the roadway.

Five passes of this breakdown roller were applied to the center of the 12 foot area, a point where no traffic runs. Only one pass each was provided over each wheelpath. The roller was simply not being used properly because no one had taken the time to observe the rolling pattern. Density tests were conducted by the state DOT, but all the tests were run in the center of the lane. The contractor, of course, passed the minimum density levels required with no problem. A future failure was built, however, because proper density was not obtained in the wheelpaths where traffic loads are applied.

If an adequate number of roller passes are provided on each edge of the lane being compacted, the density level in the center of the lane will always be more than enough to meet specifications. Thus, roller patterns should be structured to assure proper compaction of the outside portion of each paver pass — the center will take care of itself.

For each roller employed on a project, the mat width can be divided by the width of the compaction rolls to determine the number of passes needed to cover each transverse point in the surface. A tandem roller 4.5 feet wide would need to make at least three passes over a 12 foot wide mat. A 5.5 foot wide vibratory roller would also have to travel three times up or back to get full-width coverage.

In a longitudinal direction, the rollers should not stop at the same transverse end point with each pass of the roller. The reversal points should be staggered to prevent shoving of the mix. A slight change in direction or "hook" is often used at each reversal spot to further reduce the tendency of the mix to shove under the compactor.

A roller should not sit and wait while parked on the hot mat. A long delay, due to lack of haul trucks at the paver or due to filling the compactor with water, allows the roller to "settle into" the new mat. Once the mat has cooled, it is generally impossible to roll out these indentations.

Vibration Frequency

Vibratory rollers have two additional variables that must be controlled during the compaction process. The first is the frequency of the vibration. Most vibratory rollers have a range of frequencies available to the operator. With very few exceptions, the maximum frequency setting available should be used. This rule of thumb allows for more compaction to be applied by a given roller. Rarely should vibratory rollers be operated at frequency settings under 2,000 vpm. Many vibratory rollers operate at a frequency of 2,400 or 3,000 vpm.

Speed, in combination with frequency, plays a significant part in the effectiveness of a vibratory roller. As shown in Figure 16.21, an increase in roller speed from one to three miles per hour significantly decreases the number of impacts per foot. The more impacts per foot, (the slower the roller speed at a given vibration frequency), the greater the density level per pass.

Vibration Amplitude

Regardless of project conditions, many vibratory rollers are operated at a constant amplitude setting — usually the setting on the equipment when it left the factory. But the amplitude setting is important in obtaining the required density level as quickly and efficiently as possible (Fig. 16.22).

Basically, and somewhat oversimplified, the amplitude used depends on the asphalt mix characteristics and on mat thickness. Greater compaction, or greater amplitude setting, is needed when (a) the asphalt cement used in the mix is of higher viscosity or lower penetration; (b) an angular or crushed aggregate is used in the mix, (c) a coarse gradation is used rather than a fine grading; (d) a larger top size coarse aggregate is used in the mix; and (e) a stiffer mix is produced — one containing a higher mineral filler content.

The amplitude setting is also a function of layer thickness and material behavior. In general, thick lifts require a greater amplitude than thin lifts. A high amplitude setting on a thin lift (less than 2 inches) will typically cause the vibratory roller to bounce, making it difficult to obtain the desired air void content levels.

Vibration can be used on thin lifts, providing the roller operator limits the number of vibratory passes and maintains a consistent roller pattern. The economic benefit of vibrating very thin lifts (less than 1 inch) is marginal in most cases, but again, it depends on the mix characteristics and behavior. Vibrartory compaction of thin layers of asphalt concrete may cause fracture of the aggregate in the mix.

Direction of Travel

When using a single drum rigid frame roller, the equipment should normally be operated with the driven drum toward the laydown machine and with the steering drum trailing. This assures maximum compactive effect due to the additional weight of the drive drum. In addition, this method of operation provides a more stable mat to reduce tearing or displacement of the mix caused by the steering drum. A single drum, articulated frame roller should also be operated with the driven drum toward the laydown machine. Again, this assures maxi-

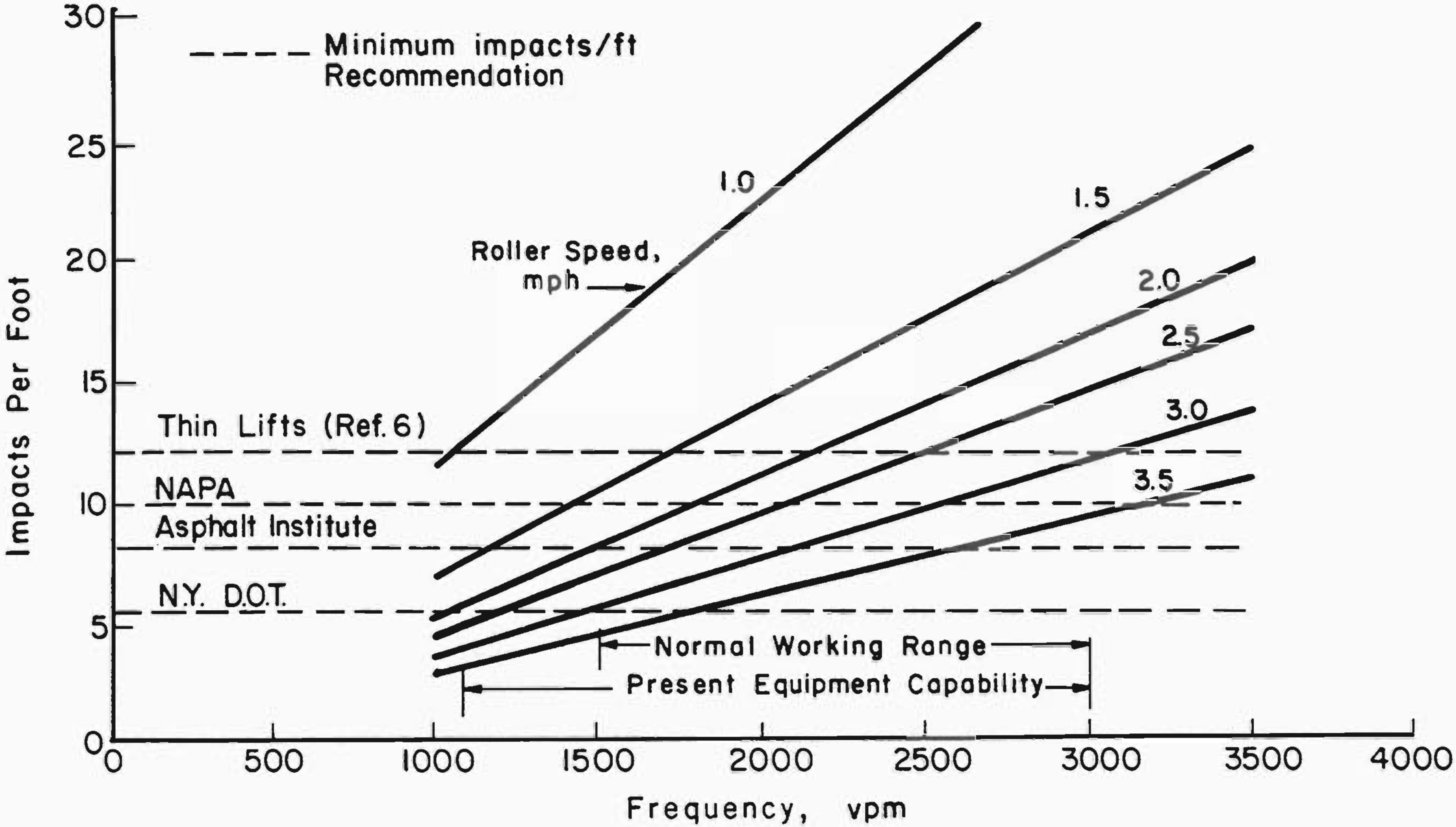


Figure 16.21. Relationship between impact spacing, roller speed, and frequency.

LOWER AMPLITUDES			HIGHER AMPLITUDES
Parameter Level	PARAMETER	Parameter Level	
Thin* < 2" ←	MAT THICKNESS	→ Thick 2"	
Rigid ←	BASE SUPPORT	→ Flexible	
Low ←	AC VISCOSITY	→ High	
Rounded ←	AGGREGATE	→ Angular	
Smooth ←	AGGREGATE SURFACE TEXTURE	→ Rough	
Poorly Graded ←	AGGREGATE GRADATION	→ Dense	
High ←	TEMPERATURE MIXTURE BASE AIR	→ Low	

*For very thin lifts, especially on rigid base supports, vibration is not recommended.

Figure 16.22. Guidelines for selecting the amplitude of vibration.

mum compaction due to the additional weight of this drum and minimizes distortion of the mix.

Double drum, rigid frame rollers should also be operated with the driven drum near the laydown machine and the steering drum trailing. Double drum, articulated frame rollers operate in the same manner in either direction so that direction of travel of the roller is not a consideration.

Selection of Frequency, Impact Spacing, and Roller Speed

Frequency, impact spacing, and roller speed are interrelated, as shown in Figure 16.21, and there is no universally accepted criteria for the selection of the optimum operating values for the three parameters. General recommendations are summarized below.

Frequency. Generally, the frequency of vibration should be as high as possible regardless of mat thickness, mixture characteristics, or underlying base support. A high level of frequency will reduce the impact spacing and increase the compactive effort applied by the vibratory roller. The impact spacing should be from 1.5. to 1.2. inches (8 to 10 impacts) per lineal foot.

Roller Speed. Based on the above recommendations, the maximum roller speed should be no greater than 3.5 mph. A better maximum speed, however, is probably 2.5 mph. At lower vibratory frequencies, the maximum speed permitted would be less for a given impact spacing (Fig. 16.21). Final roller speed should be selected based on the density obtained from a test strip on the actual project. Generally, the best roller speed should be slow enough to achieve density but high enough to meet production requirements — subject to the maximum speed for optimum impact spacing. If production requirements cannot be satisfied, additional rollers will be required. Consideration should be given to the use of two breakdown rollers working side-by-side in lieu of an additional roller operating behind the breakdown roller (in the intermediate position).

Selection of Amplitude

In general, a higher amplitude should be used on thicker layers of asphalt concrete mix. For layers from 1-1/4 to 2 inches in compacted thickness, a low amplitude setting should normally is used. For layers between 2 inches and 4 inches in compacted thickness, a medium amplitude setting is appropriate. For thick layers (4 inches or more), a high amplitude setting can be used. For very thin layers of mix, less than 1-1/4 inches in compacted thickness, the vibratory roller should be operated in the static mode — without vibration. A stiffer mix will require more compactive effort and thus a greater amplitude setting can be used on the vibratory roller. General guidelines for amplitude setting selection are contained in Figure 16.22.

Mode of Operation

A double drum vibratory roller can be operated in any one of three modes: (a) static mode (vibrator off), (b) dynamic mode (vibrator on), or (c) a combination mode, with one drum vibrating and the other static. The mode selection is primarily a function of mixture behavior immediately following laydown.

For very stiff or stable mixtures, initial breakdown rolling is often accomplished with both drums vibrating. Subsequent compaction passes are also made in the vibratory mode. For mixtures with normal stiffness and stability, initial breakdown rolling should be accomplished in the vibratory mode. Sometimes a combination mode — one drum static and one drum vibrating — is used for the first breakdown pass with subsequent compaction passes made in the vibratory mode. For the combination mode, the trailing drum is usually operated static to provide a smoother finish to the mat. For tender mixtures, initial breakdown rolling is usually accomplished in the static mode. Subsequent passes are usually made in the combination mode if the mixture displacement is not too great. When the vibratory roller is operated in the combination mode for tender mixtures, the front drum is run in static mode and the trailing drum is usually vibrated.

Vibratory rollers generally should not be used on thin layers of asphalt concrete, especially on pavements with rigid base support such as a thin overlay over portland cement concrete pavement. The roller should not be vibrating when it is not moving or when it is changing directions. Most modern vibratory rollers automatically stop vibrating when the roller speed drops below some value. Older rollers, however, may require that the operator manually control and shut off the vibration.

16.8 DETERMINATION OF ROLLING PATTERN

The actual rolling pattern and procedures employed should be based on the results obtained on a test strip of the mix to be placed on the actual construction project using the proposed rollers. Final decisions regarding frequency, impact spacing, and amplitude should be based on the results obtained from the test strip.

In addition to determining the operational characteristics of the rollers, the number of coverages required to produce the target density is determined from the test strip. Adjacent passes should overlap about 6 inches. During test strip rolling, the breakdown roller should operate as close to the laydown machine as possible. The rolling pattern established in the test strip should produce a final asphalt concrete mix that meets density and finish requirements of the project in an efficient and economical manner. The following is a discussion procedure that has produced favorable results (Refs 18 to 22).

Determination of Roller Type and Number

The first step in developing a rolling pattern involves selecting the number and type of rollers to be used. This decision is based on an evaluation of production requirements in terms of the width of the individual rollers and the availability of equipment.

Selecting a Test Site

The second step is to select a project site that is representative of the overall project conditions. If those conditions are highly variable with respect to sublayer support and mix confinement, a test strip should be constructed for each condition. A representative 400- to 500-foot straight section should be chosen.

The density of the compacted material should be determined after varying the following factors: (a) operation mode (vibration on or off), (b) speed, (c) amplitude and frequency, (d) number of passes, and (e) length of rolling zone. The most common method for monitoring changes in density with roller passes is with a nuclear density gauge.

Constructing the Test Strip

The third step involves actually constructing the asphalt concrete layer on the test strip. Following each roller pass, the nuclear gauge should be placed on the mix and a count taken. A graph of the relationship between density and number of roller passes should be generated. Once the target density value is achieved, rolling should cease since additional rolling could reduce density, particularly with a tender mix.

Rolling Pattern Troubleshooting

If the proposed test pattern does not achieve the required density, adjustments to the pattern should be made. An initial adjustment might be to reduce the speed of the rollers. Density readings taken after each pass will show the effect of each adjustment. Roller speed reduction may adversely affect production requirements. Therefore, roller speed can be gradually increased (not exceeding 3.5 mph) using the same pattern until density requirements are not achieved. A pattern should be selected that has the highest acceptable roller speed and still meets density requirements.

If production requirements cannot be met because of low roller speed, the number of rollers should be increased. In addition, if the mat is cooling quickly — in cool weather with thin lifts — the number of rollers should be increased to assure that the mixture is compacted at a temperature high enough to achieve the desired density and engineering properties.

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