PART II

Hot-Mix Asphalt Plant Operations

SECTION

5 Types of Asphalt Plants: Overview

The purpose of an HMA plant is to blend aggregate and asphalt cement together at an elevated temperature to produce a homogeneous asphalt paving mixture. The aggregate used can be a single material, such as a crusher run aggregate or a pit run material, or it can be a combination of coarse and fine aggregates, with or without mineral filler. The binder material used is normally asphalt cement but may be an asphalt emulsion or one of a variety of modified materials. Various additives, including liquid and powdered materials, can also be incorporated into the mixture. Indeed, with Superpave the use of additives is becoming more common. Use of additives can result in a need for more binder storage tanks, as well as silos for adding mineral materials.

There are three basic types of HMA plants currently in use in the United States: batch, parallel-flow drum-mix, and counter-flow drum-mix. All three types serve the same ultimate purpose, and the asphalt mixture should be essentially similar regardless of the type of plant used to manufacture it. The three types of plants differ, however, in operation and flow of materials, as described in the following sections.

BATCH PLANTS

The major components of a batch plant are the cold-feed system, asphalt cement supply system, aggregate dryer, mixing tower, and emission-control system. A typical batch plant is depicted in Figure 5-1; the major plant components are shown in Figure 5-2. The batch plant tower consists of a hot elevator, a screen deck, hot bins, a weigh hopper, an asphalt cement weigh bucket, and a pugmill. The flow of materials in a batch tower is illustrated in Figure 5-3.

The aggregate used in the mix is removed from stockpiles and placed in individual cold-feed bins. Aggregates of different sizes are proportioned out of their bins by a combination of the size of the opening of the gate at the bottom of each bin and the speed of the conveyor belt under the bin. Generally, a feeder belt beneath each bin deposits the aggregate on a gathering conveyor located under all of the cold-feed bins. The aggregate is transported by the gathering conveyor and transferred to a charging conveyor. The material on the charging conveyor is then carried up to the aggregate dryer.

The dryer operates on a counter-flow basis. The aggregate is introduced into the dryer at the upper end and is moved down the drum by both the drum rotation (gravity flow) and the flight configuration inside the rotating dryer. The burner is located at the lower end of the dryer, and the exhaust gases from the combustion and drying process move toward the upper end of the dryer, against (counter to) the flow of the aggregate. As the aggregate is tumbled through the exhaust gases, the material is heated and dried. Moisture is removed and carried out of the dryer as part of the exhaust gas stream. The hot, dry aggregate is then discharged from the dryer at the lower end.

The hot aggregate is usually transported to the top of the plant mixing tower by a bucket elevator. Upon discharge from the elevator, the aggregate normally passes through a set of vibrating screens into, typically, one of four hot storage bins. The finest aggregate material goes directly through all the screens into the No. 1 hot bin; the coarser aggregate particles are separated by the different-sized screens and deposited into one of the other hot bins. The separation of aggregate into the hot bins depends on the size of the openings in the screen that is used in the screen deck and the gradation of the aggregate in the cold-feed bins.

The heated, dried, and resized aggregate is held in the hot bins until being discharged from a gate at the bottom of each bin into a weigh hopper. The correct proportion of each aggregate is determined by weight.

At the same time that the aggregate is being proportioned and weighed, the asphalt cement is being pumped from its storage tank to a separate heated weigh bucket located on the tower just above the pugmill. The proper amount of material is weighed into the bucket and held until being emptied into the pugmill.

The aggregate in the weigh hopper is emptied into a twin-shaft pugmill, and the different aggregate fractions are mixed together for a very short period of time—usually less than 5 seconds. After this brief dry-mix time, the asphalt cement from the weigh bucket is discharged

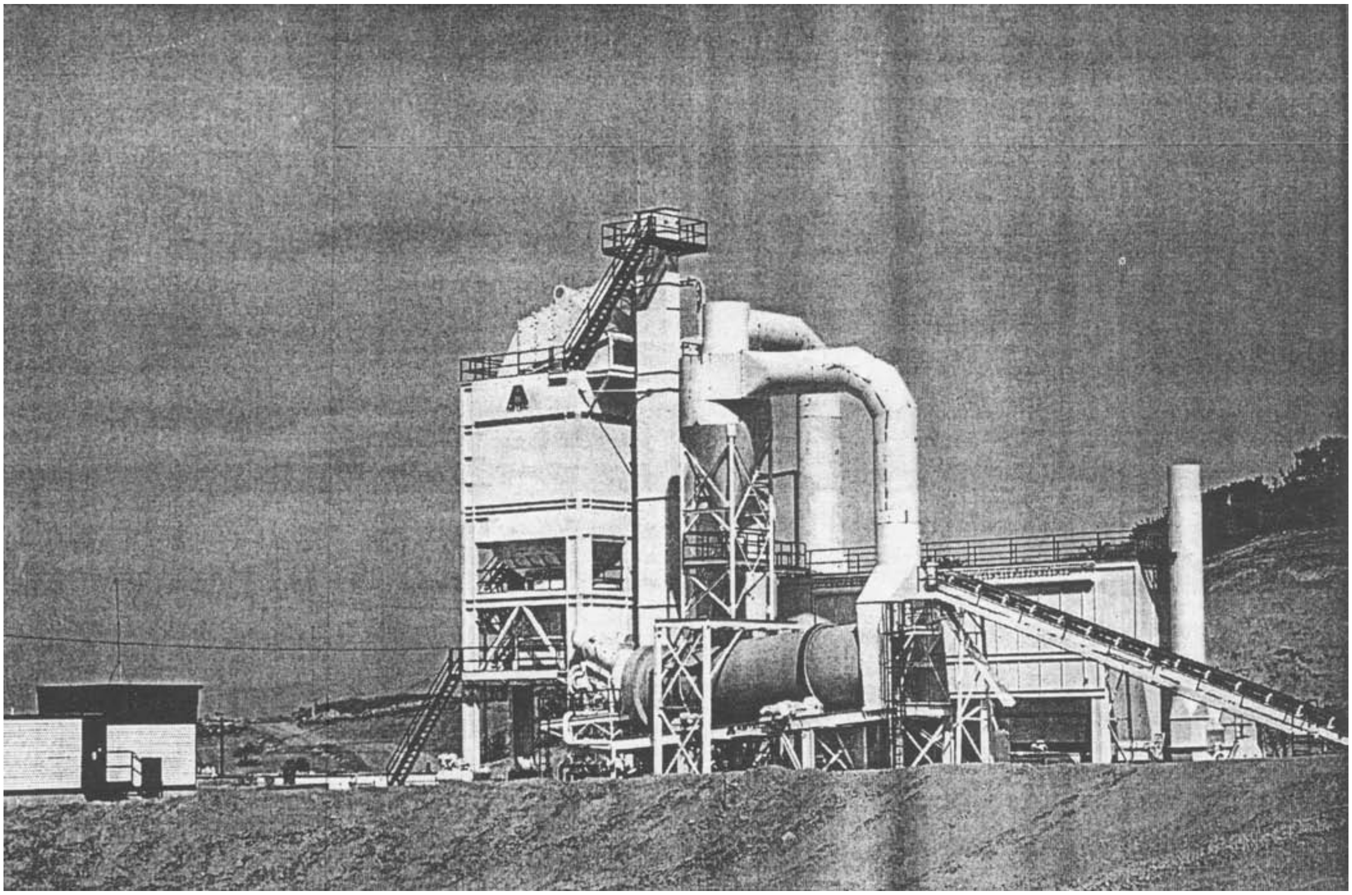


FIGURE 5-1 Typical HMA batch plant.

into the pugmill, and the wet-mix time begins. The mixing time for blending of the asphalt cement with the aggregate should be no more than that needed to completely coat the aggregate particles with a thin film of the asphalt cement material—usually in the range of 25 to 35 seconds, with the lower end of this range being for a pugmill that is in good condition. The size of the batch mixed in the pugmill can be in the range of 1.81 to 5.44 tonnes (2 to 6 tons).

When mixing has been completed, the gates on the bottom of the pugmill are opened, and the mix is discharged into the haul vehicle or into a conveying device that carries the mix to a silo from which trucks will be loaded in batch fashion. For most batch plants, the time needed to open the pugmill gates and discharge the mix is approximately 5 to 7 seconds. The total mixing time (dry-mix time + wet-mix time + mix discharge time) for a batch can be as short as about 30 seconds, but typically, the total mixing time is about 35 seconds.

The plant is equipped with emission-control devices, comprising both primary and secondary collection systems (see Section 12). A dry collector or knockout box is normally used as the primary collector. Either a wet scrubber system or, more often, a dry fabric filter system (baghouse) can be used as the secondary collection system to remove particulate matter from the exhaust gases that flow out of the dryer and send clean air to the atmosphere through the stack.

If RAP is incorporated into the mix, it is placed in a separate cold-feed bin from which it is delivered to the plant. The RAP can be added to the new aggregate in one of three locations: the bottom of the hot elevator; the hot bins; or, most commonly, the weigh hopper. Heat transfer between the superheated new aggregate and the reclaimed material begins as soon as the two materials come in contact and continues during the mixing process in the pugmill.

PARALLEL-FLOW DRUM-MIX PLANTS

The parallel-flow drum-mix plant is a variation of the old-style continuous-mix plant. It consists of five major components: the cold-feed system, asphalt cement sup-

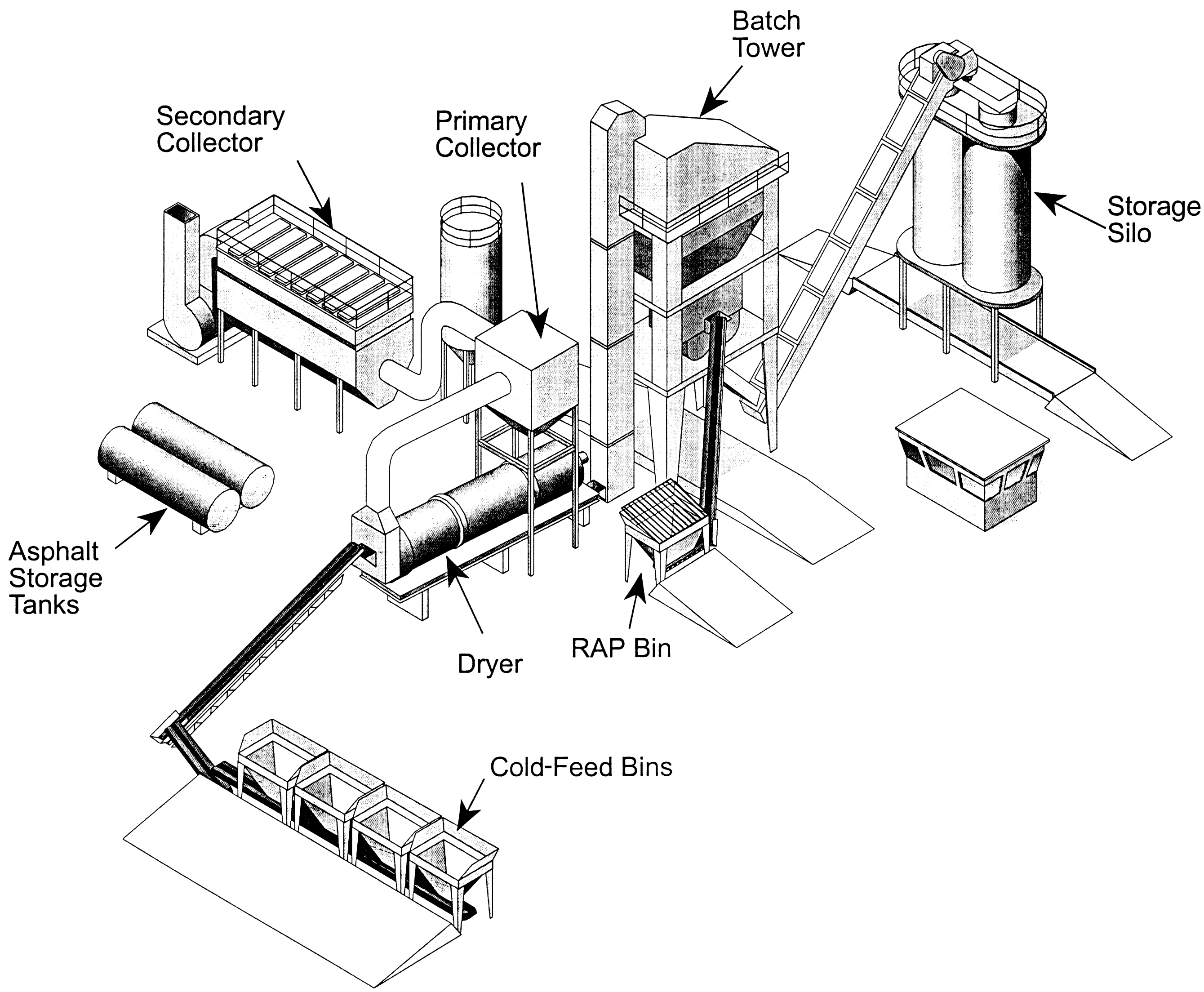


FIGURE 5-2 Major components of a batch plant.

ply system, drum mixer, surge or storage silos (see Section 11 for definitions of these silo types), and emission-control equipment. A typical parallel-flow drum-mix plant is depicted in Figure 5-4; the major plant components are shown in Figure 5-5.

The cold-feed bins are used to proportion the material to the plant. A variable-speed feeder belt is used under each bin. The amount of aggregate drawn from each bin can thus be controlled by both the size of the gate opening and the speed of the feeder belt to provide accurate delivery of the different-sized materials. The aggregate on each feeder belt is deposited onto a gathering conveyor that runs beneath all of the cold-feed bins. The combined material is normally passed through a scalping screen and then transferred to a charging conveyor for transport to the drum mixer.

The charging conveyor is equipped with two devices that are used to determine the amount of aggregate being delivered to the plant: a weigh bridge under the conveyor belt measures the weight of the aggregate passing over it, and a sensor determines the speed of the belt. These two values are used to compute the wet weight of aggregate, in tonnes (tons) per hour, entering the drum mixer. The plant computer, with the amount of moisture in the aggregate provided as an input value, converts the wet weight to dry weight in order to determine the correct amount of asphalt cement needed in the mix.

The conventional drum mixer is a parallel-flow system—the exhaust gases and the aggregate move in the same direction. The burner is located at the upper end (aggregate inlet end) of the drum. The aggregate enters the drum either from an inclined chute above

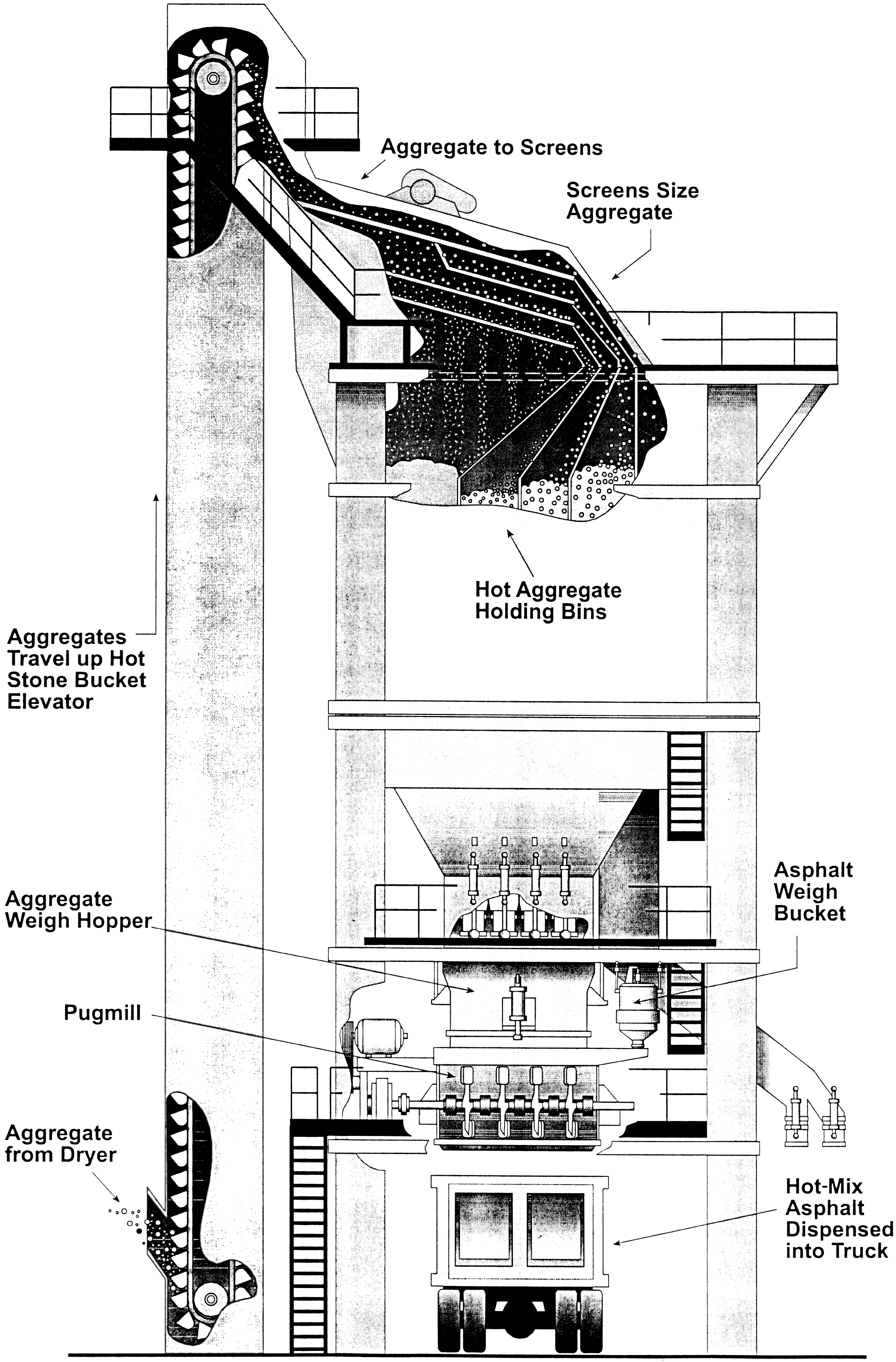


FIGURE 5-3 Flow of materials in batch tower.

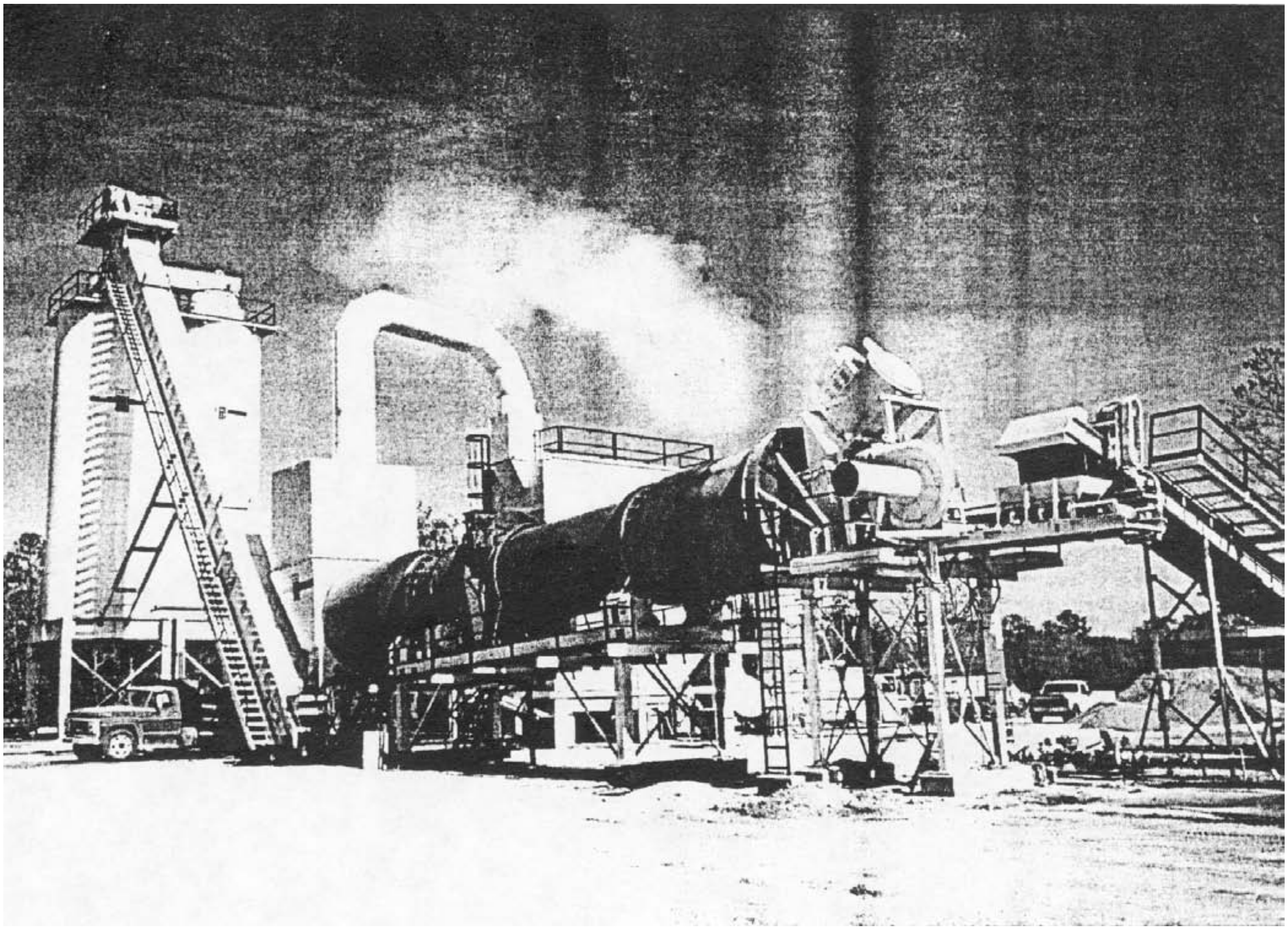


FIGURE 5-4 Typical HMA parallel-flow drum-mix plant.

the burner or on a Slinger conveyor under the burner. The aggregate is moved down the drum by a combination of gravity and the configuration of the flights located inside the drum. As it travels, the aggregate is heated and the moisture removed. A dense veil of aggregate is built up near the midpoint of the drum length to assist in the heat-transfer process.

If RAP is added to the new aggregate, it is deposited from its own cold-feed bin and gathering/charging conveyor system into an inlet located near the center of the drum length (split-feed system). In this process, the reclaimed material is protected from the high-temperature exhaust gases by the veil of new aggregate upstream of the RAP entry point. When mixes with high RAP content are used, it is more likely that the RAP will be overheated in the process. This may result in smoke being emitted from the drum or damage to the RAP.

The new aggregate and reclaimed material, if used, move together into the rear portion of the drum. The asphalt cement is pulled from the storage tank by a pump and fed through a meter, where the proper volume of asphalt cement is determined. The binder material is then delivered through a pipe into the rear of the mixing drum, where the asphalt cement is injected onto the aggregate. Coating of the aggregate occurs as the materials are tumbled together and moved to the discharge end of the drum. Mineral filler or baghouse fines, or both, are also added into the back of the drum, either just before or in conjunction with the addition of the asphalt cement.

The asphalt mix is deposited into a conveying device (a drag slat conveyor, belt conveyor, or bucket elevator) for transport to a storage silo. The silo converts the continuous flow of mix into a batch flow for discharge into the haul vehicle.

In general, the same type of emission-control equipment is used on the drum-mix plant as on the batch plant. A primary dry collector and either a wet scrubber system or a baghouse secondary collector can be used. If a wet scrubber system is used, the collected fines cannot be recycled back into the mix and are wasted; if a baghouse is

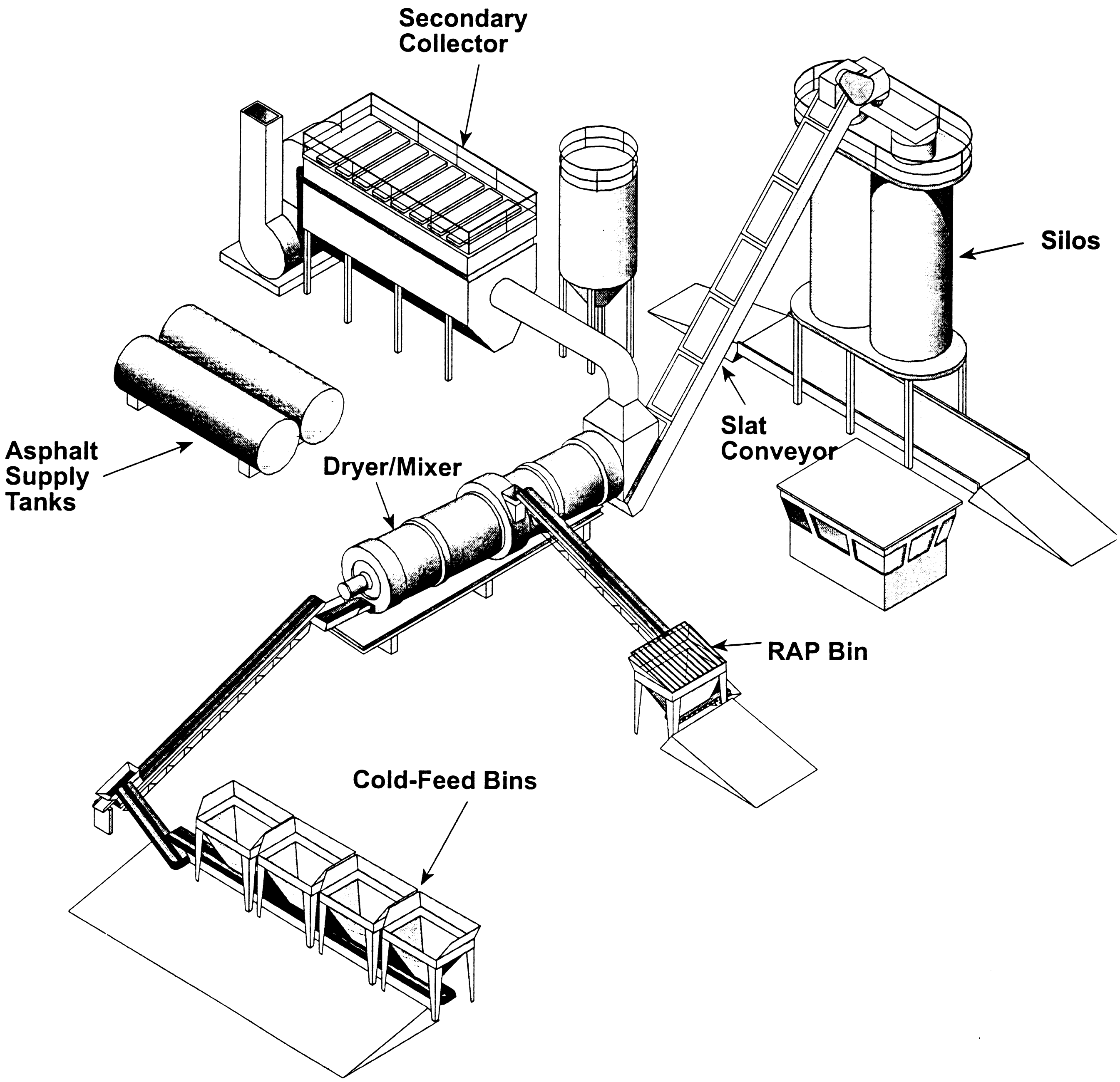


FIGURE 5-5 Major components of a parallel-flow drum-mix plant.

used, the collected fines can be returned in whole or in part to the mixing drum, or they can be wasted.

In the late 1980s, a number of variations on the conventional parallel-flow drum-mix plant were introduced to the HMA industry. One of these is the coater plant. For this type of drum mixer, the asphalt cement injection pipe is removed from the drum. This modification eliminates exposure of the asphalt cement to the high-temperature exhaust gases and reduces both hydrocarbon and visible emissions from the plant. The uncoated aggregate, which is heated and dried inside the parallel-flow drum, is discharged into a single- or dual-shaft mixing chamber, where it is sprayed with asphalt cement. The blending of the asphalt cement and the aggregate takes place as the materials move from one end of the mixing unit to the other. When mixing has been completed, the material is delivered to the conveying device used to transport it to the silo. Figure 5-6 depicts the coater type of drum-mix plant. Because the number of coater parallel-flow drum-mix plants in use is currently limited, this type of plant is not discussed further in this manual.

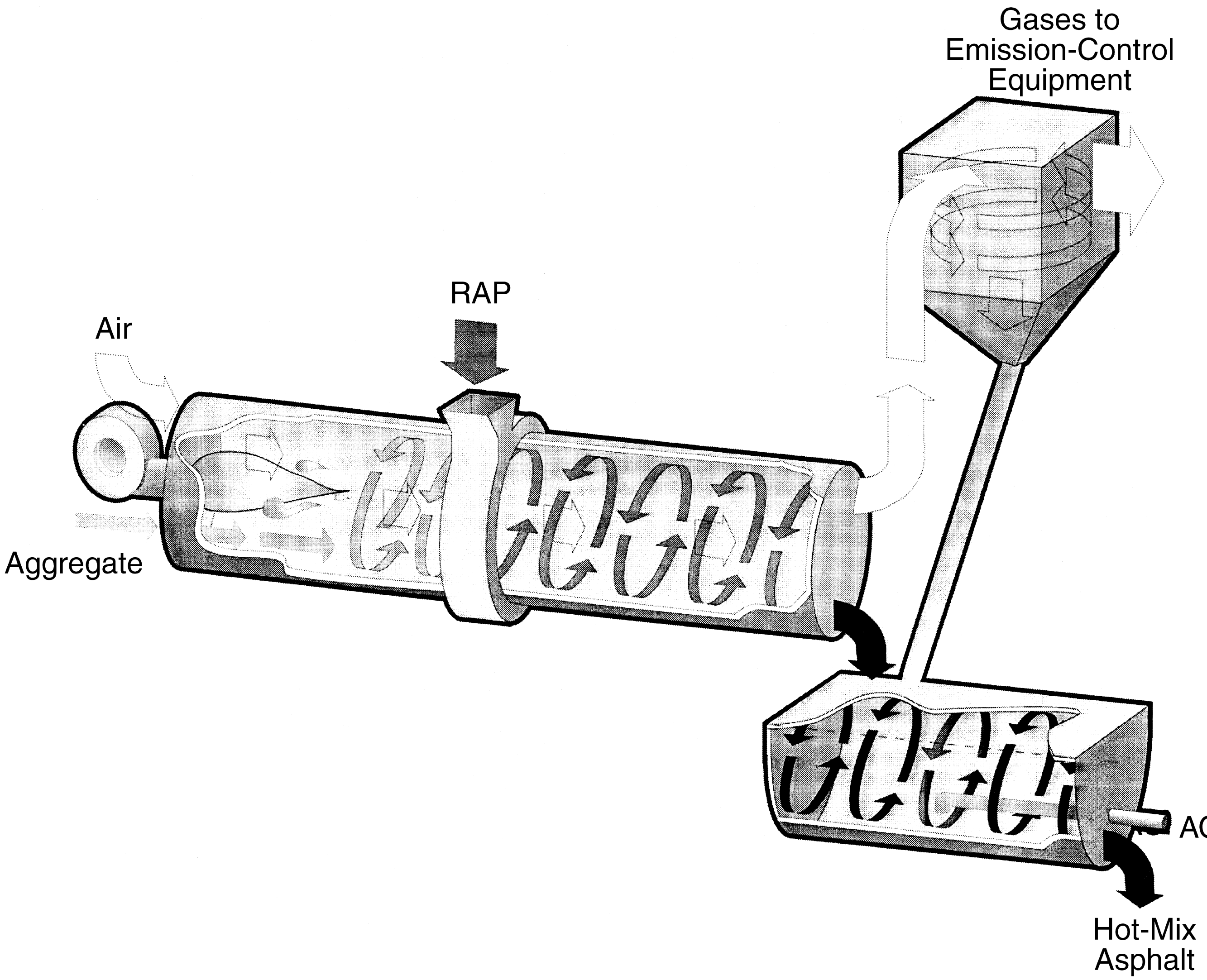


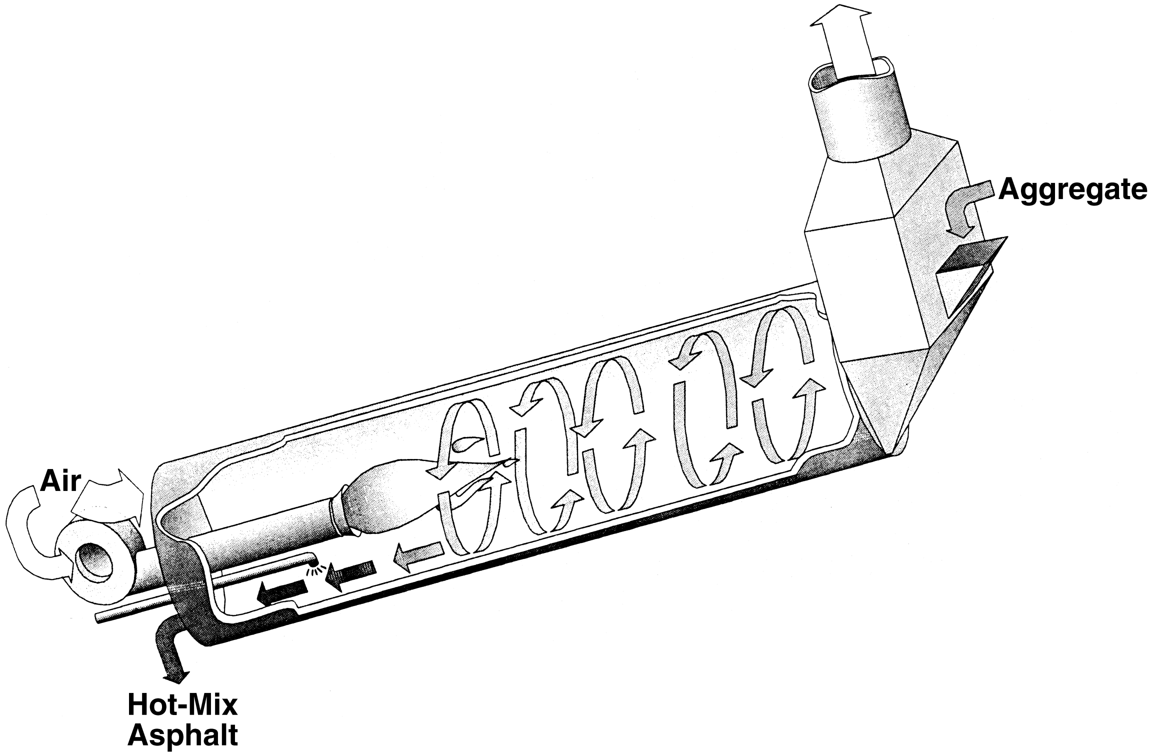
FIGURE 5-6 Drum-mix plant with coater.

COUNTER-FLOW DRUM-MIX PLANTS

A more recent development in drum-mix plant design is the counter-flow drum-mix plant. Its design represents an effort to improve the heat transfer process inside the drum and to reduce plant emissions. In the counter-flow drum-mix plant, the heating and drying of the aggregate are accomplished in a manner similar to that of a conventional batch plant dryer.

Two basic types of counter-flow drum-mix plants are in use. The first, shown in Figure 5-7, has the mixing unit extended on the end of the aggregate dryer portion of the drum. The second, shown in Figure 5-8, has the mixing unit folded back around the aggregate dryer portion of the drum. With both designs, the aggregate enters the drum from the upper end. The burner, however, is located near the lower end of the drum, similar to its position on a batch plant dryer. The aggregate moves down the drum against the flow of the exhaust gases in a counter-flow direction. No asphalt cement is introduced into the aggregate within the main (drying) portion of the drum. The mixing of the binder material with the heated and dried aggregate is accomplished completely outside of the exhaust gas stream—behind or underneath the burner.

In the counter-flow drum-mix plant design shown in Figure 5-7, the hot aggregate passes the burner into a mixing zone. At the upper end of the mixing zone, the baghouse fines or mineral filler (or both) are added to the aggregate. A short distance later, the binder material is introduced into the drum. The mixing of the aggregate and asphalt cement thus takes place behind (downstream of) the dryer in a separate mixing zone, out of contact with the exhaust gases from the burner. If RAP is used in the asphalt mix, it is introduced into the drum



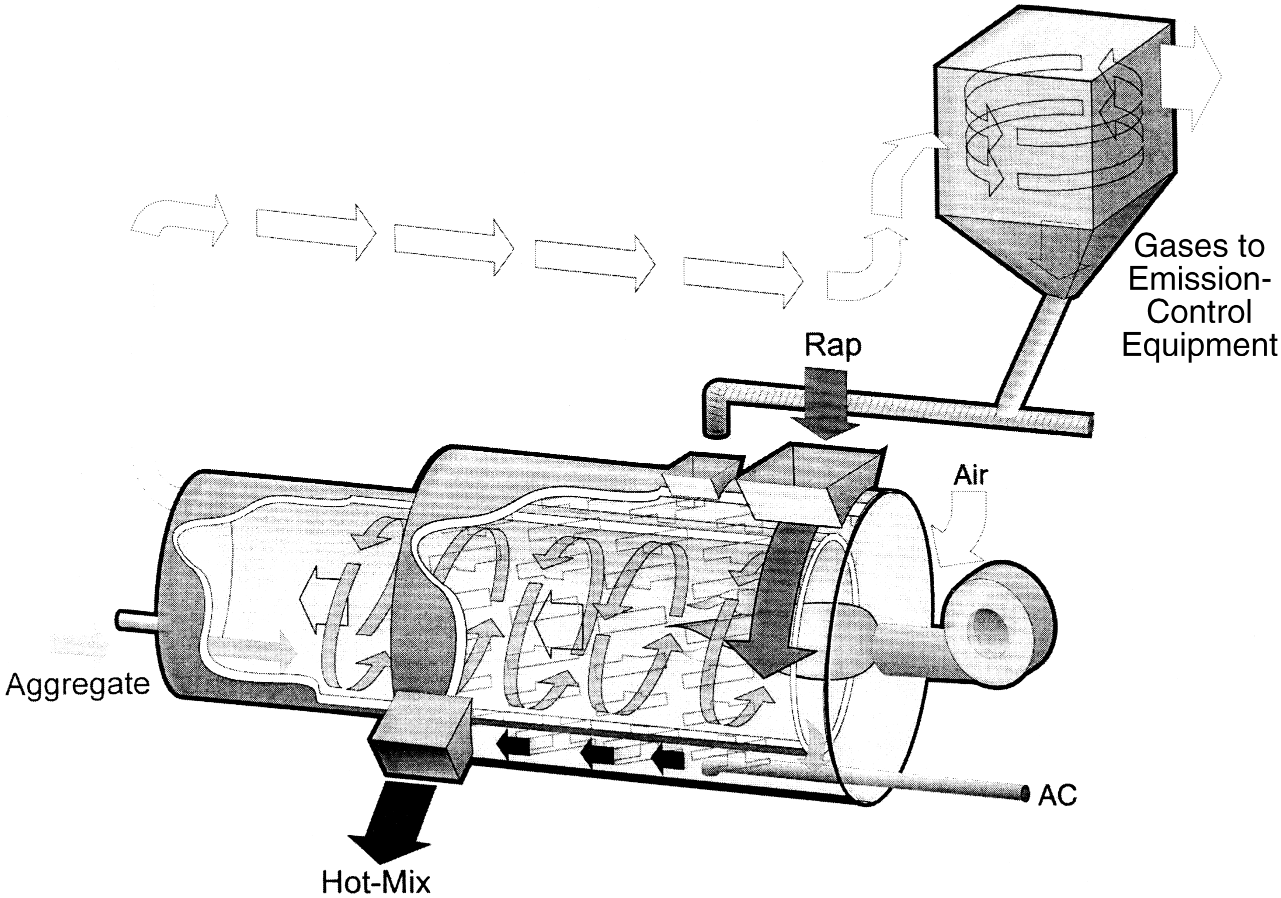


FIGURE 5-8 Counter-flow drum mixer with mixing unit folded around aggregate dryer.

downstream of (behind) the burner. Thus the RAP also does not come in contact with the high-temperature exhaust gases from the burner, and visible hydrocarbon emissions are reduced. The reclaimed material is heated by overheating the new aggregate in the upper end of the counter-flow dryer and blending the two materials together in the lower portion of the drum, between the burner and the discharge end of the mixing unit.

In the counter-flow drum-mix plant design shown Figure 5-8, the inner drum acts as an aggregate dryer, and the outer drum serves as the mixing unit. The asphalt cement is introduced into the aggregate after the aggregate has been discharged from the inner into the outer drum. The blending of the two materials occurs as the aggregate and asphalt cement are conveyed back uphill in the outer drum by a set of mixing paddles attached to the inner drum. The inner drum rotates, whereas the outer drum is stationary. This type of counter-flow drum-mix plant is known commercially as a double-barrel plant because of the double-drum setup. Any mineral filler or baghouse fines, as well as RAP material, enters the drum in the double-barrel process between the inside and outside drums. Thus, as with the design shown in Figure 5-7, the material is kept away from the exhaust gases from the burner. In particular, this protects the RAP from contact with the high-temperature exhaust gases and thus reduces the possibility that visible emissions will be generated during the recycling process.

6 Aggregate Storage and Handling

The storage and handling of both new aggregate and RAP material for use in any type of asphalt plant are addressed in this section. Proper stockpiling techniques, both for placement of the aggregate in the stockpile and for removal of the aggregate from the stockpile, are first discussed. Next is a review of the discharge of the aggregate from the cold-feed bins onto the individual feeder belts; the passage of the aggregate onto the gathering conveyor; and the delivery of the aggregate, sometimes through a scalping screen, to the charging conveyor and finally to the batch plant dryer or drum-mixer. The use of a weigh bridge system on the charging conveyor on a drum-mix plant to determine the amount of aggregate being fed into the drum is also addressed. A discussion of the delivery of RAP from its cold-feed bin to the batch or drum-mix plant is then presented. A brief review of the addition of hydrated lime to reduce moisture damage in the HMA mix is followed by a discussion of calibration of the cold-feed system, including the proper means of checking the rate of aggregate delivery from the individual cold-feed bins and over the weigh bridge system. The final subsection provides a summary of the key operating factors to be considered when monitoring the storage and handling of new aggregates and RAP.

AGGREGATE STOCKPILES

Quality control of HMA, regardless of whether a batch or drum-mix plant is used to manufacture the mix, begins with the stockpiles of aggregate that are to be processed through the plant and incorporated into the mix. The aggregate should be stored on a sloped, clean, stable surface, with the different sizes of coarse and fine aggregate kept separated. Care should be exercised during both the stockpiling and removal processes to minimize segregation of the aggregate in each pile. (Segregation is the undesirable separation of blended aggregate into zones with improper gradation.) If segregation of a particular size of coarse or fine aggregate does occur, an effort should be made to blend the segregated materials together before the aggregate is delivered into the cold-feed bins. This is difficult to do, however, and care must be taken with this operation to keep from aggravating the segregation problem.

Building Stockpiles

Aggregate should be stockpiled on a clean, dry, stable surface and should not be allowed to become contaminated with foreign materials such as dust, mud, or grass. Fugitive dust in the aggregate stockpile area should be controlled so that the dust does not coat the surface of the aggregates and thus does not alter the gradation of the material in each stockpile. The stockpiles should be constructed to be free draining to ensure that the moisture content of the aggregate is as low as possible. Paved stockpile pads should be used to facilitate drainage and provide a solid working platform. Excess moisture, particularly in the fine aggregates (sand), increases the cost of drying the aggregates and reduces the production capacity of the plant. When using a drum-mix plant, the moisture content of each aggregate size should be determined at least twice a day and the average moisture content of the combined aggregates entered into the plant computer system.

To reduce the amount of moisture that accumulates in the aggregate, especially from rain, it is often cost-effective to cover the aggregate stockpiles. The cover typically is in the form of a roof or a shed, as seen in Figure 6-1. A tarp placed directly on top of the aggregate should generally not be used since moisture will typically collect under the tarp instead of evaporating. If only one roof is used, it should be placed on top of the fine aggregate pile since this material will typically have a higher moisture content than that of the coarser aggregate. If a second roof is used, it should be placed on top of the RAP since the moisture content of this material will directly affect the temperature of the recycled mix. If multiple roofs are available, they should then be placed over the various coarse aggregate stockpiles.

As noted, the stockpiles of the various aggregate sizes should be kept separated—by physical barriers, if necessary—at all times. The cold-feed bins and feeders are calibrated to provide a specific amount of each size of aggregate from each bin. If the various materials are

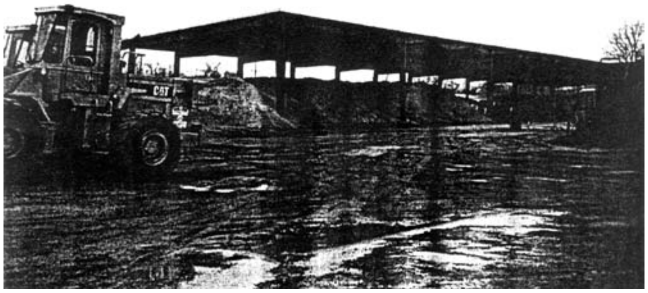


FIGURE 6-1 Covered aggregate stockpiles.

blended in the stockpiles, a combination of sizes will occur in each cold-feed bin. This blending of the aggregate will cause variations in the gradation of the HMA produced by a drum-mix plant and may cause problems with unbalanced hot bins in a batch plant.

Segregation is a major concern with stockpiled aggregate. Many aggregate problems are caused by mishandling of the aggregate during stockpiling and load-out operations. Whenever possible, aggregate should be stockpiled by individual size fractions. A well-graded or continuously graded material should not be contained in one stockpile. Aggregate of larger sizes, particularly when combined with that of smaller sizes, has a tendency to roll down the face of a stockpile and collect at the bottom, leading to segregation.

Prevention of segregation begins with the construction of the stockpile. If possible, stockpiles should be constructed in horizontal or gently sloping layers. If trucks are used to carry the incoming aggregate to the plant site, each load should be dumped in a single pile, as seen in Figure 6-2. Any construction procedure that results in the aggregate being pushed or dumped over the side of the stockpile should be avoided because these practices may result in segregation. Trucks and loaders should be kept off the stockpiles since they can cause aggregate breakage, fines generation, and contamination of the stockpile.

Aggregate coming off the end of a stacking conveyor or radial stacker can be segregated in one of three ways. First, if the particle sizes are small and if the wind is strong, the coarser particles can fall straight down, and the finer particles will be carried to one side of the pile by the wind. Second, and more commonly, even if there is no wind and aggregate is dropped straight down, it will still segregate. Sand particles have less energy, and they do not roll far when they

FIGURE 6-2 Horizontal stockpiles.

land. Larger pieces have more energy and will roll to the outside edge of the pile. Third, if the speed of the conveyor belt is high, the coarser particles will be thrown farther from the top of the conveyor, and the finer particles will drop more directly into the stockpile. An example of the use of a conveyor to create a RAP stockpile is shown in Figure 6-3.

Removing Aggregate from Stockpiles

Proper operation of the front-end loader used to load haul trucks or charge the cold-feed bins of the asphalt plant will help in avoiding problems with aggregate segregation and gradation variation. The outside edge of the stockpile will generally be coarser than the interior because, as noted, the larger aggregate particles have a tendency to roll down the side of the pile. Significant changes in gradation may result from the way the stockpile was produced. The loader operator

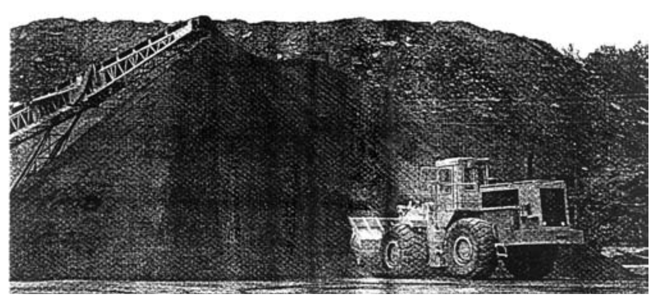


FIGURE 6-3 RAP stockpile using radial stack.

should remove the aggregate in a direction perpendicular to the aggregate flow into the pile and should work the entire face of the stockpile. This practice will minimize aggregate gradation changes and variation in the moisture content of the mix produced by the asphalt plant.

When cleaning the edges of the stockpile, the loader operator should be careful not to push or dump yard material that would contaminate the stockpile. When loading out of a stockpile, the loader operator should ensure that the loader bucket is up high enough to be in the stockpile and not in the yardstone.

When loading from a stockpile built in layers, the loader operator should try to obtain each bucket load by entering the lower layer at the approximate midpoint of the height of that layer and scooping up through the overlying layer. This practice results in half the aggregate being from each layer; it also reblends the aggregate, which in turn reduces segregation. Removal of aggregate from a stockpile should be planned so that a minimum amount of aggregate is disturbed with each bucket load. Removal of aggregate from the bottom of a large stockpile will often result in the above-noted problem of coarser aggregate particles rolling down the face of the pile and gathering at the bottom, increasing possible segregation problems.

Besides working the face of the stockpile, the loader operator should use sound stockpile management techniques. A good practice is to rotate stockpiles so that the first material put into the stockpile is removed first. Areas of the stockpile that are segregated should be reblended by the loader operator at the stockpile. The operator should not feed one or two loads of coarse aggregate and then one or two loads of fine aggregate into the cold-feed bins in an attempt to blend the aggregate. Doing so will cause significant problems in achieving the required aggregate gradation in the mix, regardless of what type of plant is used to produce the mix. It should be noted that the best approach to minimizing segregation is always to use proper stockpiling techniques in the first place, as discussed above, and not to rely on the loader operator to reblend segregated materials adequately.

Generally, RAP should be stockpiled using the same techniques described for aggregate. If the RAP is delivered to the stockpile in large pieces or slabs, it must be crushed before it is used in the plant. If the RAP has been produced by cold milling, this finer material will have a tendency to retain more moisture from rainfall while stockpiled than will RAP maintained in larger pieces.

Segregation of RAP into larger particles and smaller pieces will generally occur more readily than with aggregate because the reclaimed material will usually contain a greater variety of particle sizes than is typical of aggregate stockpiles. Normally this is not a problem because the RAP pieces will usually break down inside the drum mixer or in the batch plant pugmill during the heating, drying, and mixing processes. If a significant amount of large chunks of RAP [pieces greater than 50 mm (2 in.) in size] is fed into the plant at one time, however, those chunks may not be properly heated and mixed with the new aggregate and asphalt binder material. Thus care should be taken to ensure that the RAP material fed into the plant is as consistent in gradation as possible. It is often necessary to screen out and then crush the largest pieces of RAP to ensure proper heat transfer and mixing of the RAP and new aggregate inside the drum mixer.

COLD-FEED SYSTEMS FOR NEW AGGREGATE

Typically the cold-feed systems on HMA batch and drum-mix plants are similar. Each consists of cold-feed bins, feeder conveyors, a gathering conveyor, and a charging conveyor. On most drum-mix plants and on some batch plants, a scalping screen is included in the system at some point. If RAP is also being fed into the plant to produce a recycled mix, an additional cold-feed bin or bins, feeder belt and/or gathering conveyor, scalping screen, and charging conveyor are necessary to handle the extra material.

Cold-Feed Bins and Feeder Conveyors

The flow of aggregates through a plant begins at the cold-feed bins, as seen in Figure 6-4. The plant is equipped with multiple bins to handle the different sizes of new aggregate used in the mix. Most cold-feed bins are rectangular in shape, have sloping sides, and have a rectangular or trapezoidal opening at the bottom. A bulkhead or divider should be used between each cold-feed bin to prevent overflow of the aggregate from one bin into another. The resulting commingling of aggregate sizes can significantly alter the gradation of the mix being produced, particularly in a drum-mix plant, where no screens are used to resize the aggregate after it is dried. If bulkheads are not in place between the cold-feed bins and mixing of the different-sized aggregates is a problem, these devices should be installed.

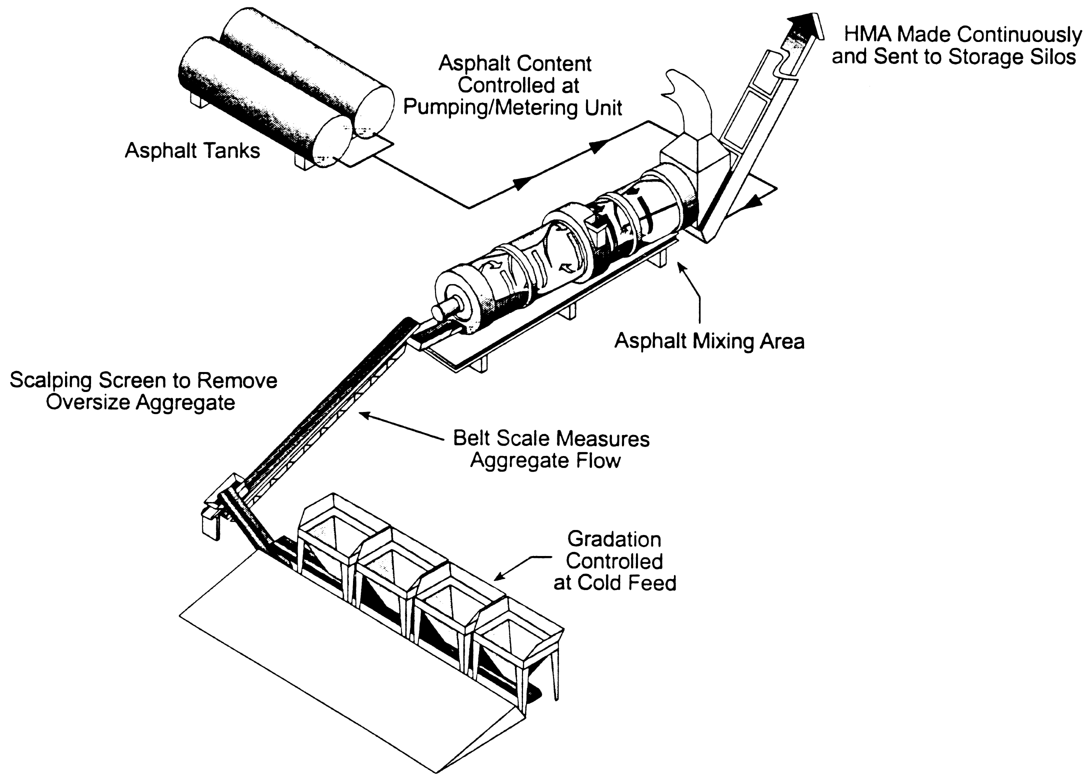


FIGURE 6-4 Flow of material through a drum-mix plant (continuous-flow facility).

Care should be taken not to pile aggregate higher than the top of the bulkheads, again to prevent aggregate in one bin from spilling over into the adjacent bin. If bins overflow, the resulting contamination of aggregate materials will lead to a difference in the gradation of the produced HMA mix.

Each cold-feed bin is equipped with a gate to control the size of the discharge opening on the bin and a feeder belt to draw aggregate out of each bin at a controlled rate. On some plants, the speed of the feeder belt under the bin is not variable; the amount of aggregate that is withdrawn from the bin is determined by the setting of the gate opening. The degree of control exercised over the amount of aggregate withdrawn from each bin is thus governed by the number of possible gate settings on each feeder gate. The size of the gate opening is set by raising or lowering the gate using a manual or electric-powered crank or wheel, or by unbolting, moving, and rebolting a sliding plate on one end of the bin.

Most cold-feed bins are equipped with variable-speed feeder belts under each bin, as shown in Figure 6-5. The gate opening and the feeder belt speed for each bin are set to deliver an amount corresponding to the desired proportion of that aggregate needed in the mix. The more a particular aggregate is required, the larger is the opening of the bin discharge gate. The speed of each belt is then set in accordance with the exact amount of material withdrawn from the bin. If a small change is needed in the amount of material to be delivered from a bin, the speed of the feeder belt can be increased or decreased to accommodate that change. Theoretically, it is possible to withdraw aggregate from a bin using the full range of the belt speed, from 1 to 100 percent of the maximum speed. In practice, only 20 to 80 percent of the maximum belt speed (ideally closer to 50 percent) should be used when adjusting the rate of aggregate feed. This practice allows the plant operator some leeway to vary the production rate of each feeder for changes in operating conditions without having to change the settings of the gate openings.

If a large change is needed in the feed rate for a particular size of aggregate, however, the gate opening at the discharge end of the bin will need to be adjusted. The speed setting of each feeder belt is displayed on the operator's console in the plant control trailer and is typically shown as a percentage of the maximum belt speed. If the feeder belt under a given cold-feed bin is operating at less than 20 percent or more than 80 percent of maximum speed, the gate setting may need to be changed so that the belt can operate closer to the middle of its speed range for the selected production rate.

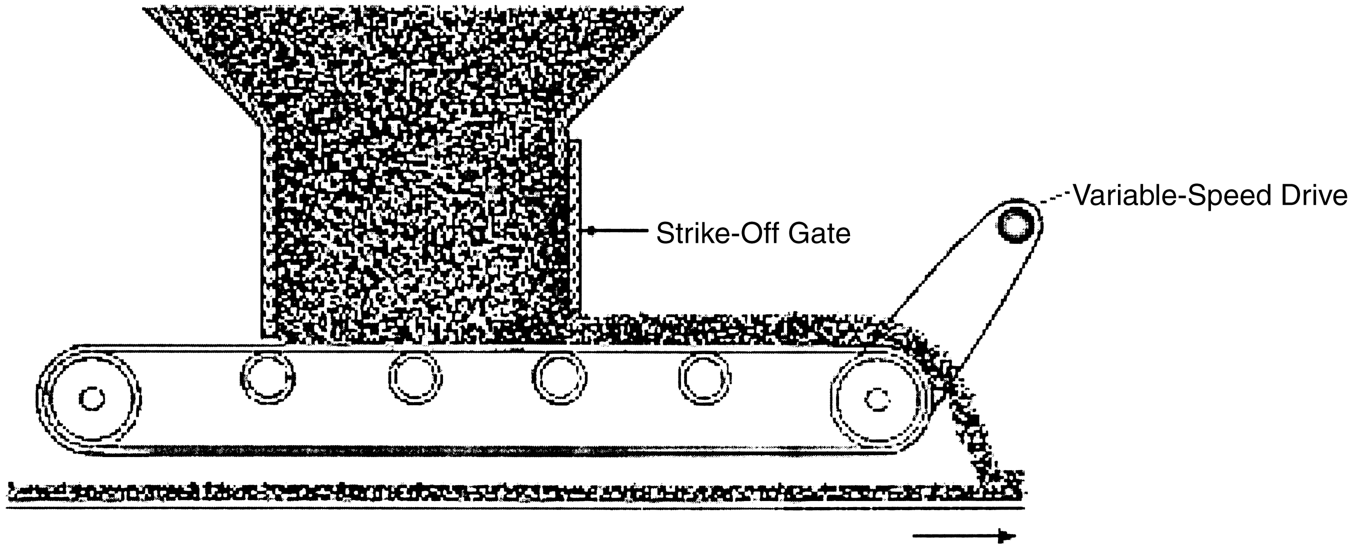


FIGURE 6-5 Continuous feeder belt.

The speed setting for each feeder belt is adjusted independently to allow the proper amount of aggregate to be pulled from each bin. Once determined, the speed of all the feeder belts is synchronized so that a change in the speed of one is proportional to the change in the speed of all the others. Thus if the production of the plant is increased from 225 to 320 tonnes (250 to 350 tons) per hour, a change in the master control setting causes a corresponding change in the speed of all the feeder belts.

Each cold-feed bin and its companion feeder belt should be equipped with a no-flow sensor (typically a limit switch) that will alert the operator when no aggregate is coming out of the cold-feed bin. If the bin is empty or the aggregate has bridged over the discharge opening in the bin, and no material is being discharged onto the collecting conveyor, the no-flow sensor will indicate the condition by sounding an audible alarm or automatically shutting down the plant after a preset time.

Collecting Conveyor

As shown in Figure 6-6, aggregate deposited from each feeder belt is dropped onto a collecting conveyor, located beneath all of the individual feeder conveyors, that collects the aggregate discharged from each of the bins. The speed of the conveyor is constant. The amount of aggregate deposited on this conveyor is thus a function of the size of the gate opening and the speed of the feeder conveyor under each cold-feed bin.

To reduce the amount of buildup that may occur on this conveyor, particularly when the various aggregates are wet, the coarser aggregates should be placed on the belt first. The sand, which typically has the higher moisture content, may stick to the conveyor belt if placed on the belt first and may need to be continually removed. This may, in turn, affect the gradation of the aggregate in the mix.

Scalping Screens and Devices

On drum-mix plants it is desirable to insert a scalping screen into the cold-feed system to prevent oversized material from entering the mixer. Scalping can sometimes be accomplished by placing a screen over the top of the cold-feed bins. In many cases, however, this screen is only a grizzly type of device with relatively large openings. Because of the large volume of aggregate that is delivered at one time from the front-end loader to a cold-feed bin, a screen with small openings

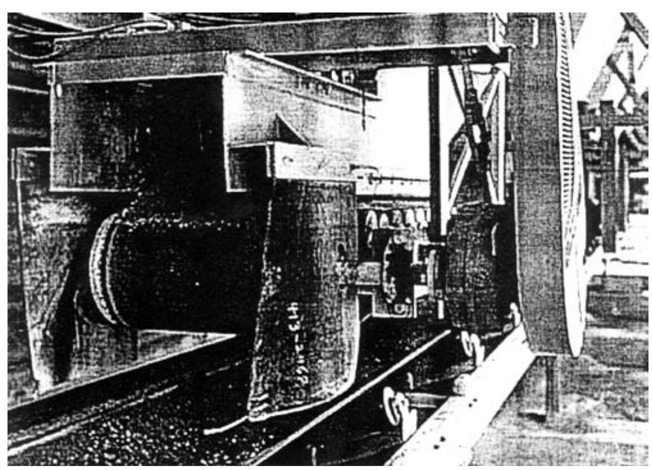


FIGURE 6-6 Collecting conveyor under cold-feed bins.

cannot properly handle the flow of aggregate from the loader bucket to the bin. Thus, scalping screens employed on top of the cold-feed bins are normally used only for the larger-sized coarse aggregate and for RAP.

A scalping screen is used to remove larger-sized deleterious materials such as tree roots, vegetable matter, and clay lumps, as well as oversized aggregate, from the aggregate material. As shown in Figure 6-7, the scalping screen is most often placed somewhere between the end of the collecting conveyor and the drum. While it is not always necessary to pass quarry-processed aggregates through a scalping screen, it is good practice to do so to prevent any extraneous oversized material from entering the drum and thus the mix. A scalping screen should be used as part of the cold-feed system on a batch plant if the screens have been removed from the mixing tower or if the screens are bypassed. The openings in the scalping screen (the bottom screen if a double-deck screen is being used) are typically slightly larger than the maximum-sized aggregate used in the mix.

Scalping devices can be tailored to the needs of the individual plant. Typically only a single-deck scalping screen is used. Some plants, however, employ a double-deck scalping screen, which controls two different top-size aggregates without requiring changing of the screen (see Figure 6-8). If both screens are being used, a flop gate at the lower end of the second screen is employed to redirect the aggregate caught on the bottom screen to the charging conveyor. The flop gate can be operated either manually or automatically. The openings in the screen can be either square or slotted. The advantage of the slotted screen is that a smaller screen area can be used to handle a given volume of material.

Some scalping screens are equipped with a bypass chute. This device allows the aggregate on the collecting conveyor to be deposited directly on the charging conveyor without passing through the screen. This procedure is sometimes used when quarry-processed aggregate or aggregate known to be free of deleterious material is fed to the plant.

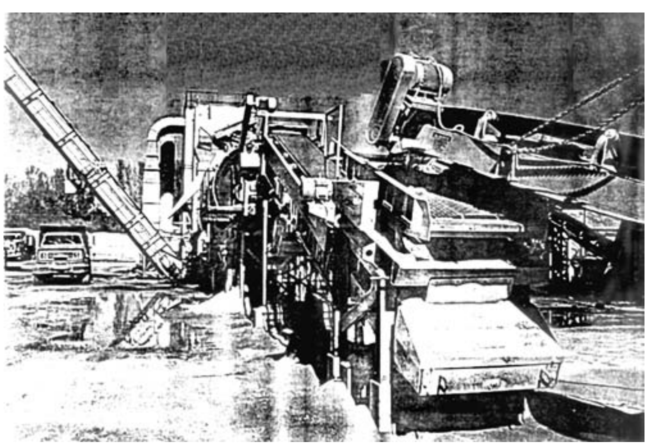


FIGURE 6-7 Single-deck scalping screen on drum-mix plant.

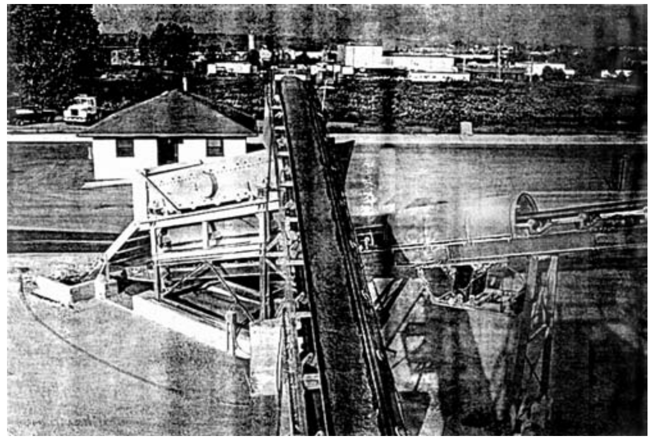


FIGURE 6-8 Double-deck scalping screen on drum mixer with air-operated deck selector.

One make of cold-feed bins includes a small scalping screen under each cold-feed bin instead of a scalping screen at the end of the collecting conveyor. The aggregate from a particular bin falls off the feeder belt and onto the scalping screen. Material of the proper size passes through the screen and onto the collecting conveyor. Oversized pieces are rolled down the screen into a reject chute that deposits this aggregate in a pile beside each bin for subsequent disposal. Because these individual bin scalping screens are very small, the proper amount of aggregate will not pass through the screen onto the charging conveyor if they become blinded or clogged. Thus the operation of such scalping screens should be monitored on a regular basis.

Charging Conveyor

Batch Plants

The combined coarse and fine aggregates are discharged from the gathering conveyor onto the charging conveyor for transport to the drum. For a batch plant, this conveyor delivers the aggregate to the inclined chute at the upper end of the dryer. The charging conveyor is a simple belt that operates at a constant speed but carries a variable amount of aggregate, depending on the volume of aggregate delivered from the cold-feed bins. The conveyor should normally be equipped with a device such as a scraper blade or brush, located on the underside of the belt, to clean off the belt as it revolves. This device will prevent any buildup of aggregate on the belt. If a significant amount of fine aggregate (sand) continually builds up on the belt and must be removed, the order of aggregate placed on the gathering conveyor from the cold-feed bins should be changed, if necessary, so that the coarser aggregates are placed on that belt first.

Drum-Mix Plants

For a parallel-flow drum-mix plant, the charging conveyor carries the aggregate 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. For a counter-flow drum-mix plant, the charging conveyor carries the aggregate to an inclined chute at the upper end of the drum. For both types of plant, the charging conveyor contains a weigh bridge system (shown in Figure 6-9) that measures the amount of aggregate, in tonnes (tons) per hour, being fed to the drum mixer. The weigh bridge, or belt scale, determines the weight of aggregate passing over the weigh idler. The charging conveyor operates at a constant speed that is independent of the speed of the other conveyors. The weigh bridge itself is located near the midpoint of the length of the charging conveyor.

A weigh idler, as shown in Figure 6-10, is the heart of the weigh bridge system. 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 is recorded as an electrical signal in the computer control system. The weight value by itself is meaningless, however, because it covers only an instant of time. Thus the charging conveyor is also equipped with a belt speed sensor, as shown in the figure. This device, usually located on the belt takeup pulley, is a tachometer, which, coupled with the diameter of the pulley, is used to measure the actual speed of the conveyor belt.

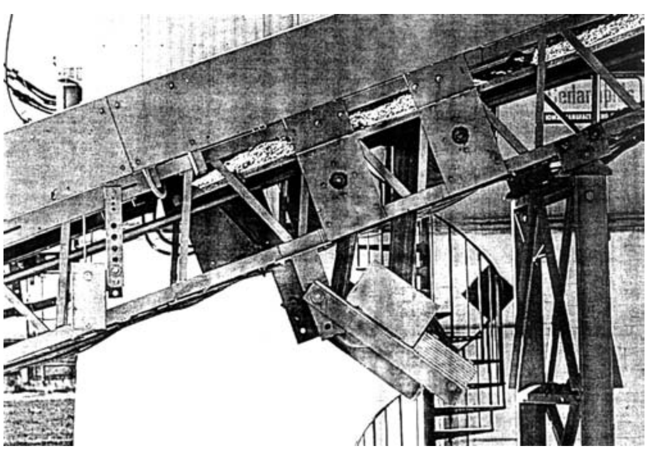


FIGURE 6-9 Weigh bridge.

To obtain an accurate belt speed reading, it is essential that the charging conveyor belt be tight around the gravity takeup pulley, as shown in Figure 6-10. Any slippage of the belt over the speed sensor will result in an erroneous reading and an incorrect wet aggregate weight input to the drum mixer. Some conveyors are equipped with an air-actuated takeup system, located on the tail shaft pulley, that operates in a manner similar to that of the gravity takeup system. The purpose of this system is to keep the belt tight and eliminate the potential problem of inaccurate belt speed sensor readings.

The information from the weigh idler on the belt scale and from the belt speed sensor is combined to determine the actual weight of the aggregate in tonnes (tons) per hour. This value is the wet weight and includes the moisture in the aggregate. The wet weight is converted to dry weight by the plant computer so that the proper amount of asphalt cement will be added to the mix. The average moisture content in the combined coarse and fine aggregates is input manually.

The moisture content of each of the aggregates being fed into the plant should be checked regularly and the average amount of moisture in the incoming aggregate determined. This determination should be made whenever the moisture content of the aggregate stockpiles has changed, such as after it has rained, or a minimum of twice a day. This frequency can be reduced to a minimum of once a day during periods of consistent dry weather conditions. An erroneous moisture content input into the computer system will result in an inaccurate amount of binder material being added to the mix. If the actual moisture content of the incoming aggregate is higher than the value input to the computer, slightly less aggregate dry weight is actually being introduced into the drum, and a higher-than-desired amount of asphalt cement is being added to the aggregate. Conversely, if the actual moisture content of the incoming aggregate is lower than the value input to the computer, more aggregate is being introduced into the mixing drum, and a slightly lower binder content will result. The difference in the asphalt content, of course, will depend on the difference between the actual and input moisture values.

If the aggregates being carried on the belt are relatively dry, all the aggregates that pass over the weigh bridge will enter the drum. As discussed earlier, however, if the moisture content of the aggregates is high, some of the fine aggregate may stick to the charging

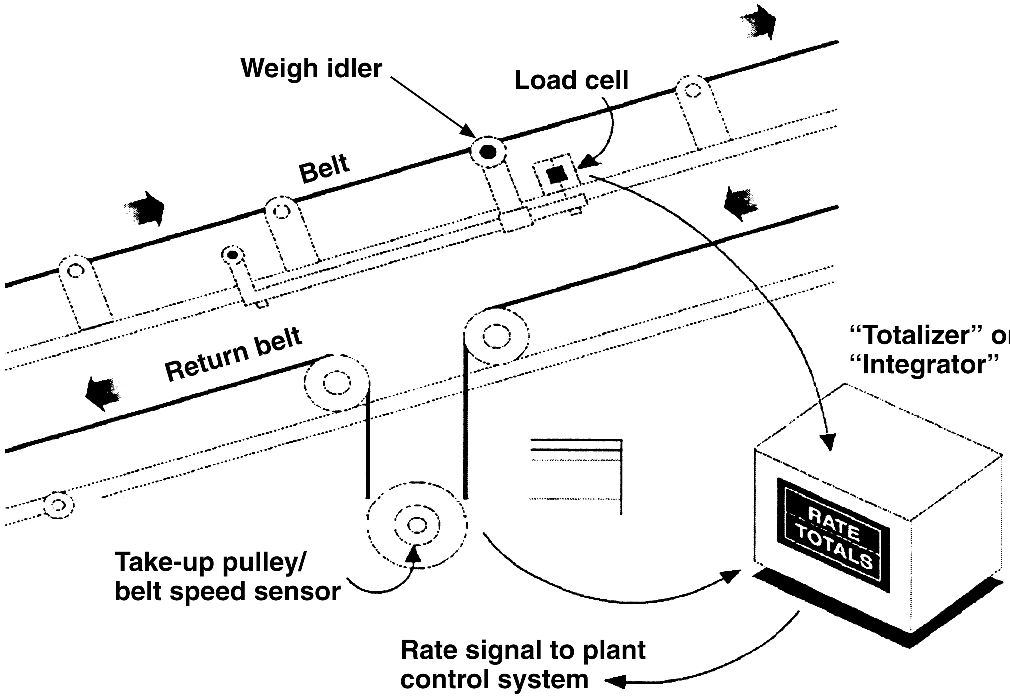


FIGURE 6-10 How a weigh bridge works.

conveyor belt. This "extra" material will not be fed into the drum but will remain on the belt. If not removed by a scraper or brush, this material will continually be detected by the weigh bridge, and the plant computer will calculate a greater weight of aggregate entering the drum than is actually occurring. The computer will in turn signal the asphalt pump to deliver more asphalt cement to the plant to allow for the additional aggregate. Thus the belt scraper or brush should be in place, continually cleaning the charging conveyor belt as it carries aggregate to the mixing drum. As discussed previously, the amount and gradation of the fine aggregate removed by the scraper will change the gradation of HMA mix produced by the plant.

Individual Bin Weigh Bridges

On a few plants, the individual cold-feed bins may be equipped with weigh bridge systems located on the individual feeder belts. In this arrangement, the belt under each individual cold-feed bin must be longer than feeder belts without a weigh bridge. Usually a plant with individual cold-feed weigh bridges will not have a weigh bridge installed on the last feeder belt, closest to the drum mixer. Another standard weigh bridge is installed, however, on the charging conveyor. This latter system provides data on the combined weight of all the aggregates, as does the weigh bridge system on most drum-mix plants.

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

COLD-FEED SYSTEMS FOR RECLAIMED ASPHALT PAVEMENT

The cold-feed system for handling RAP is essentially the same as the conventional cold-feed system for new aggregate. On most plants, as shown in Figure 6-11, a separate cold-feed bin is used. The bin (or bins) is similar to the cold-feed bins used for aggregate except that all four sides of the RAP feed bins are usually much steeper. The steeper sides allow the asphalt-coated aggregate to be discharged from the bins more easily. This is particularly important in hot or wet weather, when the RAP can

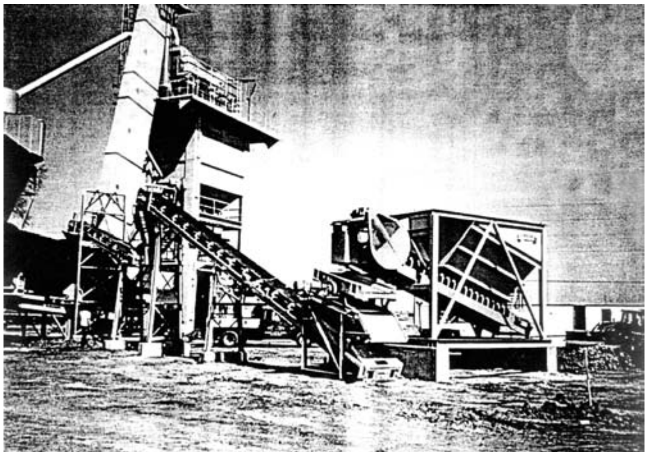


FIGURE 6-11 Inclined RAP feeder.

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, there is normally a variable-speed feeder belt under each bin. The bins also have a gate that can be set at various openings. The RAP, typically delivered to the bin by front-end loader, is discharged onto the feeder belt. If only one cold-feed bin is used, the RAP on the feeder belt is transferred to a charging conveyor. If more than one cold-feed bin is employed, the feeder belt under each bin delivers the RAP to a gathering conveyor and then to the charging conveyor.

The RAP should then be passed through a scalping screen to remove any oversized pieces of asphalt mixture or deleterious material. An alternative arrangement is to place a scalping screen or fixed-bar grizzly over the cold-feed bin and thereby remove any oversized and foreign material before it enters the bin. Still another alternative is to place a small crusher in the system between the cold-feed bin and the charging conveyor to reduce the size of any oversized RAP pieces.

After exiting the scalping screen, the RAP is dropped onto the inclined conveyor for transport to the plant. If it is being carried to a batch plant, the material can be delivered to the boot (bottom) of the hot elevator, to one of the hot bins at the top of the plant, or to the weigh hopper. If the RAP is being transported to a drum-mix plant, the charging conveyor will be equipped with a weigh bridge system that measures the weight of the material passing over it, as well as the speed of the belt. This weight, in tonnes (tons) per hour, includes the moisture in the RAP. The average moisture content value is input manually to the plant controls, and the dry weight of the RAP is calculated by the plant computer. The information determined from the weigh bridge system on the RAP charging conveyor is combined with the data from the weigh bridge system for the aggregate to determine the plant input tonnage.

For most parallel-flow drum-mix plants, the charging conveyor delivers the RAP into the center rotary inlet located on the mixing drum, as discussed below and in Section 9. For some counter-flow drum-mix plants, the charging conveyor delivers the RAP into the upper portion of the mixing chamber or drum, just ahead of the asphalt cement injection point, as discussed below and in Section 10. For other counter-flow drum-mix plants, the RAP is delivered to an outer drum where the aggregate, RAP, and new asphalt cement are blended.

Single-Feed Drum-Mix Plants

A very limited number of drum-mix plants have only one set of cold-feed bins. Some of the bins are used to hold the new aggregate, and the others are used to handle the RAP. For one type of plant still in use but no longer manufactured, the new and reclaimed aggregates are fed into the burner end of the drum-mix plant at the same time. In this case, the RAP is handled in the same way as aggregate. It can be deposited underneath or on top of the aggregate, depending on which cold-feed bins are selected to hold the asphalt-coated aggregates. The reclaimed material is often deposited on top of the aggregate so that it can be exposed to a water spray (used to reduce potential emission problems) when traveling up the charging conveyor.

Split-Feed Drum-Mix Plants

Most parallel-flow and counter-flow drum-mix plants are equipped with a split-feed system to handle the RAP. Typically, a separate cold-feed bin and conveyor system is used to feed this material into the drum mixer through a rotary center inlet.

On some older plants, however, a separate cold-feed bin is not used for the RAP. Rather, the material is placed in one or more of the conventional cold-feed bins. The gathering conveyor under the bin or bins is modified, however, by being divided into two different belts, moving in different directions. The gathering conveyor under the feeder belts for the new aggregate 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 RAP transports the RAP to a separate charging conveyor that carries it to an inlet location near the midpoint of the length of the mixing drum on a parallel-flow drum-mix plant and to the upper end of the mixing unit or to the outer drum on a counter-flow drum-mix plant.

Regardless of which cold-feed bin system is used for the RAP, a weigh bridge and speed sensor are employed to measure the amount of reclaimed material moving up the charging conveyor and into the drum. Although using the same cold-feed bin system to handle both new and reclaimed material saves the cost of a separate cold-feed bin or bins for the RAP, there is a greater chance of bridging the opening at the bottom of the bin because of the shallower angle of the sides of the conventional cold-feed bins.

ADDITION OF HYDRATED LIME

To reduce the occurrence of moisture damage in the HMA mix, hydrated lime is sometimes added to the mix at a rate of 1 to 2 percent by weight of aggregate. This material may be added in one of two different forms—as a dry powder or as a slurry. If a slurry is used, it is typically proportioned as one part hydrated lime to three parts water. The lime can be added by being mixed with the aggregate on the cold-feed belt or by being introduced into the rear of the drum, similar to what is done with a conventional mineral filler. The addition of lime as a mineral filler is discussed in Sections 9 and 10.

The dry lime or slurry is often added to the aggregate as it moves along the gathering conveyor or up the charging conveyor. The lime is normally placed on top of the aggregate and is then mixed with the aggregate either when the aggregate passes through the scalping screen, when it passes through a set of plows or mixing paddles on the belt, or in an in-line pugmill placed in the cold-feed system between the gathering conveyor and the charging conveyor. The amount of mixing of the lime that occurs as aggregate passes through the scalping screen, however, is normally not enough to ensure that all of the aggregate particles are adequately coated with lime. Therefore, this method should generally not be used. If the lime is to be mixed with the aggregate on the gathering or charging conveyor, a set of plow blades should be used to move the aggregate and the lime back and forth as the material moves up the belt. An even better way to ensure that the hydrated lime is properly mixed with the coarse and fine aggregate is to place a twin-shaft pugmill in the cold-feed system. This latter method distributes the lime more uniformly throughout the aggregate particles.

CALIBRATION

The rate of aggregate flow from each cold-feed bin should be determined to ensure that the proper proportion of each aggregate is being delivered from the bin to the plant, so that the mix will have the proper gradation. The method used to calibrate the cold-feed bins depends on the type of plant being used and on the type of feeder belt under each bin.

Each cold-feed bin should be calibrated at a flow volume that will be within the range of material to be delivered from the bin during mix production. Ideally, the bin should be checked at rates that are approximately equal to 20, 50, and 80 percent of the estimated operational flow rate.

If a cold-feed bin is equipped with a constant-speed feeder belt, the only way to change the amount of aggregate delivered from the bin is to vary the size of the gate opening. In this case, the size of the gate opening at which the calibration procedure is conducted depends on the proportion of aggregate to be drawn out of the bin. If, according to the mix design information, 25 percent of the total amount of aggregate in the asphalt mix should come out of a given bin, that bin should be calibrated at the gate opening size that will typically provide this rate of flow. In addition, the calibration procedure should be completed at both the next-largest and next-smallest gate settings to allow for small changes in production rate. If significant changes in production rate are anticipated, the cold-feed bins should be calibrated at whatever gate openings are needed to provide the proper amount of that size of aggregate to the plant.

Many cold-feed bins on batch plants and the vast majority of the cold-feed bins on both parallel-flow and counter-flow drum-mix plants are equipped with a variable-speed feeder belt in addition to a means of changing the size of the gate opening under the bin. The gate opening on the cold-feed bin should be set at that level which will deliver the proper amount of aggregate for the desired plant production rate. In addition, the bin should be calibrated at three different feeder belt speeds: 20, 50, and 80 percent of the range of speed of the feeder belt. The optimum operating condition is for the cold-feed bin to provide the proper amount of aggregate from the preset gate opening with the feeder belt operating at approximately 50 percent of its maximum speed. Doing so allows the plant operator some latitude to increase or decrease the production rate of the plant without having to change the setting of the gate opening at the bottom of the cold-feed bins.

The calibration of each cold-feed bin is accomplished by drawing aggregate out of a bin for a specific period of time and determining the weight of the aggregate delivered during that time. In most cases, a truck's empty (tare) weight is determined. Aggregate is withdrawn from the cold-feed bin and delivered, usually by means of a diverter chute on the charging conveyor, into the truck. After a set period of time, the flow of the aggregate is stopped, and the truck is weighed to determine the amount of aggregate delivered. For cold-feed bins equipped with only a constant-speed feeder belt, the weighing process is accomplished for a variety of gate opening settings. For cold-feed bins that are equipped with variable-speed feeder belts, the calibration process may be repeated at different gate opening settings, with at least three different belt speeds per gate opening.

On a drum-mix plant, the weigh bridge must also be calibrated. This is accomplished by running aggregate over the charging conveyor and thus the weigh idler for a given period of time. Instead of being delivered to the drum mixer, the aggregate is diverted into an empty (tared) truck. After the selected time period has passed, the aggregate flow is terminated, and the truck is weighed to determine the amount of aggregate delivered. The weight thus determined is compared with the weight of aggregate calculated by the plant computer system. The two weights should be within the tolerance band set by the agency and typically within 1.0 percent of each other (assuming that the weigh bridge and the truck scale are both accurate to 0.5 percent). It must be noted that both methods used to weigh the material—the conveyor weigh bridge and the truck scale—must usually meet a tolerance of 0.5 percent of the true weight. Since one weight is being compared against the other and each has a tolerance of 0.5 percent, the two weights should be within 1.0 percent of each other.

For many drum-mix plants, the weigh bridge should be calibrated at a production rate that is near the estimated normal production rate for the plant. If the drum mixer is going to run at 90 percent of capacity, the calibration of the weigh bridge should be completed at three production rates: 70, 85, and 100 percent of capacity. This calibration, however, will probably not be correct if the plant is run at a much lower capacity, such as 60 percent. In this case, the calibration procedure should be repeated at the lower production rate (bracketing the estimated rate with one rate above and one rate below the most probable production level).

Because of the differences in the operating procedures of different makes and models of cold-feed bins and asphalt plants, it is difficult to generalize the exact calibration procedure to use. The calibration instructions provided with the plant should be followed.

SUMMARY

Several key factors should be considered in the storage and handling of aggregate and RAP, both when in the stockpile and when being fed into a batch or drum-mix plant:

- The stockpiles should be built on a clean, dry, and stable foundation. Positive drainage for each pile should be provided. Aggregate of different sizes should be separated.
- The moisture content of each aggregate should be determined at least twice a day and more often if moisture conditions change, such as after rainfall. The average moisture content of the aggregate coming into the plant dryer or drum mixer should be input to the plant control system to permit proper setting of the burner controls, calculation of the dry weight of the incoming aggregate, and determination of the plant production rate.
- Covering the aggregate piles—particularly those of fine aggregate—with a roof should be considered to reduce the moisture content of the stockpiled aggregate.
- Stockpiles should be built in horizontal or gently sloping layers. Any stockpiling procedure that results in aggregate being pushed or dumped over the side of a stockpile should be avoided to prevent segregation. Travel on stockpiles by trucks and front-end loaders should be minimized to prevent aggregate breakage and the generation of fines.
- The front-end loader should work the full face of the stockpile, removing the aggregate in a direction perpendicular to the flow of the aggregate into the stockpile. The operator of the front-end loader should go straight into the stockpile, roll the bucket up, and then back out instead of scooping up through the stockpile. Doing so will minimize segregation caused by the larger-sized aggregate rolling down the face of the stockpile. The operator is the key to providing a consistent gradation of material to the plant and minimizing segregation.
- If the coarser-aggregate stockpiles are segregated, the loader operator should not place a bucketful of coarse material and then a bucketful of finer material into the cold-feed bins. The segregated materials should be preblended by the loader (or by other means) before the material is introduced into the cold-feed bins.

■ Cold-feed bins that are kept relatively full of aggregate should be separated by bulkheads between bins, located at the top of the bins, so aggregate that is supposed to be in one bin cannot overflow into another.

■ The discharge end of the feeder belt should be equipped with a "no-flow" device to indicate to the plant operator when an inadequate amount of aggregate is being delivered from a cold-feed bin.

■ If the plant is equipped with variable-speed feeder belts, they should be run at a speed that is between 20 and 80 percent of their maximum speed. Ideally, the speed of the feeder belts should be in the middle of their speed range to allow for small increases and decreases in plant production capacity without the need to change the settings of the cold-feed bin gate openings. The feeder belts should be calibrated at the speed at which they will typically run.

■ A scalping screen should be placed in the cold-feed charging system of a drum-mix plant or a batch plant operated without screens to remove any oversized and deleterious material from the aggregate.

■ For drum-mix plants, the weigh bridge should be checked to see whether the weigh idler is free to move and the conveyor belt is tight around the gravity takeup pulley to ensure an accurate belt speed sensor reading.

■ The cold-feed bin(s) used for RAP should have steep sides to prevent the material from bridging the gate opening at the bottom of the bin.

■ The RAP feed system on both a batch and a drum-mix plant should include a scalping screen over the cold-feed bin or at some other point in the material flow.

■ Cold-feed bins should be calibrated. For bins equipped with constant-speed feeder belts, the flow of aggregate from the bins should be determined at three different gate opening settings: one at the estimated plant production rate, one above that rate, and one below that rate.

■ For cold-feed bins equipped with variable-speed feeder belts, the bins may be calibrated at up to three different gate openings, as well as at three different belt speeds—approximately 20, 50, and 80 percent of the range of belt speeds.

■ The weigh bridge on the charging conveyor of a drum-mix plant must also be calibrated. This should be accomplished by collecting and weighing the amount of aggregate that passes over the weigh bridge in a set amount of time and comparing that weight with the weight determined by the plant computer system. For the weigh bridge to be calibrated properly, the two weights should be within 1.0 percent of each other.

7 Asphalt Cement Supply System

The asphalt cement supply system consists of two major components. The first comprises one or more tanks used to store the asphalt cement until it is needed by the mixing plant. The second is a pump and meter system used to draw asphalt cement from the storage tank in proportion to the amount of aggregate being delivered to the batch plant pugmill or drum mixer. In this section these two components, as well as the use of liquid antistrip materials and calibration of the pump and meter system, are reviewed. The section ends with a summary of key operating factors to be considered when monitoring the operation of the asphalt cement supply system.

STORAGE TANKS

Figure 7-1 shows a typical arrangement of multiple horizontal asphalt cement storage tanks. All asphalt cement storage tanks must be heated to maintain the correct temperature of the asphalt cement so its viscosity will be low enough that it can be pumped and mixed with the heated and dried aggregate. Most asphalt cement storage tanks are heated by a hot-oil system and are equipped with a small heater to heat and maintain the temperature of the oil. The hot oil is circulated through a series of coils inside the storage tank, as shown in Figure 7-2, and the heat is then transferred from the oil, through the coils, to the asphalt cement. This heat transfer process reduces the viscosity of the asphalt cement, causing it to flow upward and circulate or roll, and causing new, lower-temperature asphalt cement to come in contact with the heating oils. Thus the hot-oil system, through a set of thermocouples and solenoid valves, maintains the proper temperature of the asphalt cement, generally in the range of 150°C (300°F) to 180°C (350°F), depending on the grade and type of asphalt cement being used.

Another common approach is to use electric heating elements to heat the asphalt tanks directly. Heating elements that can be removed for servicing are submerged directly into the tank. Scavenger coils may be installed in the asphalt tank to heat oil for asphalt lines and other parts of the plant requiring heat.

A less commonly used, much older style of asphalt cement storage tank is the direct-fired tank. In this system, the asphalt cement is heated by direct heat exchange from the combustion source, through a series of heat tubes, to the asphalt cement. Care needs to be used with this type of tank to prevent overheating of the asphalt cement immediately adjacent to the heat tubes.

All storage tanks should be completely insulated and heated, and all the lines for both asphalt cement and heating oil should be insulated to prevent loss of heat. Both the line used to fill the tank from the asphalt cement transport truck or railcar and the discharge line from the tank to the plant should be located near the bottom of the tank. The return line from the pump should be located so that the asphalt cement enters the tank at a level beneath the surface of the asphalt cement stored in the tank and does not fall through the air. This practice reduces the oxidation of the asphalt cement during the circulation process.

On most asphalt storage tanks, the discharge line to the batch or drum-mix plant is located at a point closest to the plant to minimize the amount of pipe required. The return line for the asphalt cement not used by the plant (depending on the particular plant pump and meter setup, as discussed below) is typically located on the same end of the storage tank. If it is desired to circulate the contents of the tank in order to keep the material blended, the return line should be relocated to the opposite end of the tank. Otherwise, only the material located at the end of the tank that contains the discharge and return lines will be circulated.

If the HMA plant is equipped with more than one asphalt cement storage tank, the capability should exist to pump material from one tank to another. It is important that the plant operator know from which tank material is being pulled, especially if different grades or types of asphalt cement are being stored in different tanks.

All asphalt cement storage tanks contain a “heel” of material at the bottom of the tank. This material, located beneath the heating coils, usually 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

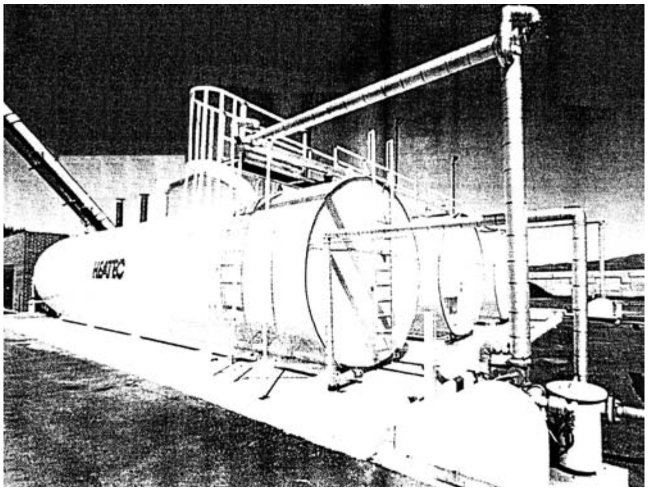


FIGURE 7-1 Typical horizontal asphalt cement storage tanks.

last cleaned. It is recognized, however, that some asphalt cement will typically remain in the bottom of an "empty" tank. Therefore, placing asphalt cement of one type or grade into a tank that previously contained a different type or grade can cause an alteration of the properties of the asphalt cement to the point that it no longer meets specifications.

The capacity of an asphalt cement storage tank is a function of its diameter and length. The amount of material in the tank can be determined using a tank "stick." The stick measures the distance from the top of the dome or the top of the tank down to the level of the asphalt cement in the tank (the point at which the tank stick just touches the top of the material). This distance is noted, and the amount of asphalt cement in the tank below this level is determined from the tank manufacturer's calibration chart.

When asphalt cement is delivered from a transport vehicle into a storage tank, it is important to ensure either that the tank is clean or that it already contains the same type of material as that being pumped into the tank. If it is empty at the time the new material is being added, the tank should be checked to ensure that no water has accumulated in the bottom. If asphalt cement is loaded on top of an asphalt emulsion or on top of a layer of water in the tank, violent foaming of the asphalt cement may occur, creating a serious safety problem. Care should be taken to ensure that all valves are in the proper position to prevent pressure from building up in the lines and causing an explosion.

Most asphalt storage tanks are horizontal, as in Figure 7-1. Increasingly, however, vertical tanks are being used. Vertical tanks minimize separation of modifier in asphalt cement and result in less overall area needed for storage.

PUMP AND METER SYSTEM

Batch Plants

Batch plants typically employ one of two systems to transfer asphalt cement from the storage tank to the weigh bucket near the pugmill. The type of system used depends on the location of the return line—whether one or two asphalt cement lines are present from the pump to the weigh bucket.

In the single-line process, two lines extend from the storage tank to the pump, but only one line extends from the pump to the weigh bucket. The pump is a constant-volume, constant-speed unit that runs continuously. Asphalt cement is always being pulled from the storage tank through the pump and circulated back to the tank. When asphalt cement is needed in the weigh bucket, a valve on the end of the line at the top of the weigh bucket opens, and material is discharged into that bucket. When the proper amount of asphalt cement is in the bucket, as determined by weight, not volume, that valve is shut, and a pressure relief valve at the pump is opened. The asphalt

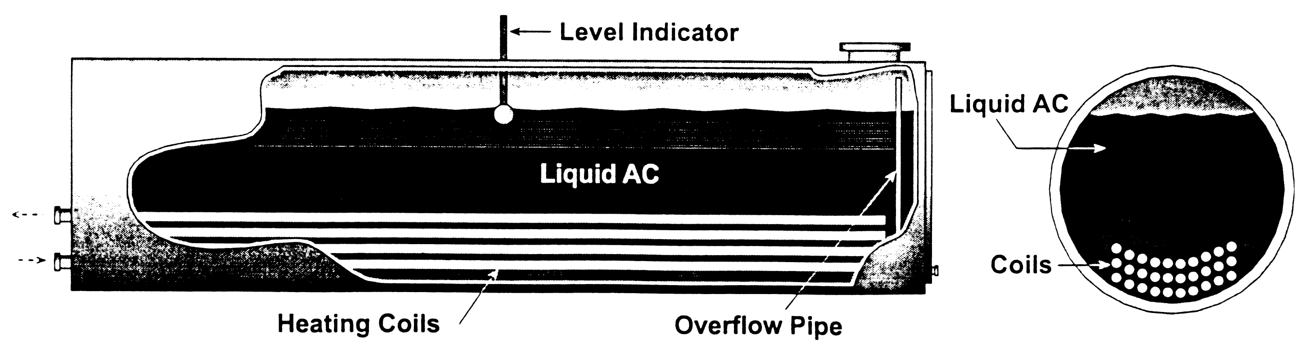


FIGURE 7-2 Heating of horizontal storage tank.

cement then passes through the pump, but is recirculated back to the storage tank, in the second line, instead of being sent to the plant. A variation on this system allows the asphalt cement to circulate through the pump itself instead of being returned back to the storage tank. In the dual-line process, one line is used to deliver asphalt cement to the weigh bucket, and the second line is used to return the "excess" asphalt cement back to the storage tank. The asphalt cement passes through the pump to a three-way valve at the weigh bucket. When asphalt cement is needed in the weigh bucket, the valve opens, and the material is discharged into the bucket. When the preselected weight is reached, the valve closes, and the asphalt cement is recirculated in the second line back to the storage tank.

Because the amount of asphalt cement used in almost all batch plants is measured by weight, no correction is needed for the temperature of the asphalt cement. On a few older batch plants, however, the amount of asphalt cement delivered is determined by volume. In this case, the amount of asphalt cement delivered to the pugmill must be corrected in accordance with both the temperature and the specific gravity of the asphalt cement. This can be accomplished using the procedure given in ASTM Specification D4311.

Drum-Mix Plants

Asphalt Cement Delivery

Most drum-mix plants employ one of three systems to pull the asphalt cement from the storage tank, meter it, and pump it to the plant: (*a*) a variable-volume pump with a constant-speed motor, (*b*) a constant-volume pump with a variable-speed motor, or (*c*) a constant-volume pump with a constant-speed motor with a metering valve. The use of a particular pump and meter system is dependent on the make, model, and date of manufacture of the plant and the choice of the plant owner.

With a system that uses a variable-volume pump driven by a constant-speed motor, the amount of asphalt cement pulled from the storage tank is controlled by changing the volume of asphalt cement being pumped. The volume needed at the pump is determined by the plant computer in proportion to the amount of aggregate being fed into the plant. As the amount of aggregate entering the drum mixer increases, the volume of asphalt cement pulled through the pump also increases. When the plant is not using asphalt cement, the material continually passes through the pump and meter and through a three-way valve that is set to circulate the asphalt cement back to the storage tank instead of to the plant.

A second system incorporates a fixed-displacement (constant-volume) pump driven by a variable-speed motor. The quantity of asphalt cement delivered to the meter is varied by changing the speed of the motor. The amount of material sent to the plant is also dependent on the aggregate feed rate. A three-way valve in the system downstream of the meter allows the asphalt cement to be recirculated back to the tank when not needed by the plant.

The third system consists of a constant-volume pump driven by a constant-speed motor. In this arrangement, 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 recirculating line to the storage tank. The system also has a valve downstream of the meter that allows the asphalt cement sent through the meter to be recirculated to the tank. This valve is used during the warm-up period for the meter and during the calibration process. Again, the position of the proportioning valve is determined by the rate of aggregate feed into the drum mixer, both of which are controlled by the plant computer. A constant-volume, constant-speed system is shown in Figure 7-3.

With parallel-flow drum-mix plants, the asphalt cement line typically enters the drum from the rear, and the binder material is discharged into the drum at a point normally one-quarter to one-third the length of the drum, from the discharge end of the drum. With one type of counterflow drum-mix plant, the asphalt cement pipe is placed in the mixing unit portion of the drum, behind or below the burner, and the binder material is added shortly after the aggregate passes out of the exhaust gas stream. In another type of counter-flow drum-mix plant, the asphalt cement is added to the heated aggregate in the outer drum away from the burner.

Temperature Compensation

Most asphalt meters measure the flow of asphalt by volume and convert this volume to weight using the specific gravity and temperature of the asphalt. Asphalt cement expands when heated. Thus the volume of asphalt cement at 180°C (350°F) will be somewhat greater than its volume at 150°C (300°F). This latter volume will be more than the volume at 15°C (60°F), which is the standard temperature for determining the volume of asphalt cement using conversion charts based on the specific gravity of the asphalt cement. If the specific gravity of the as-

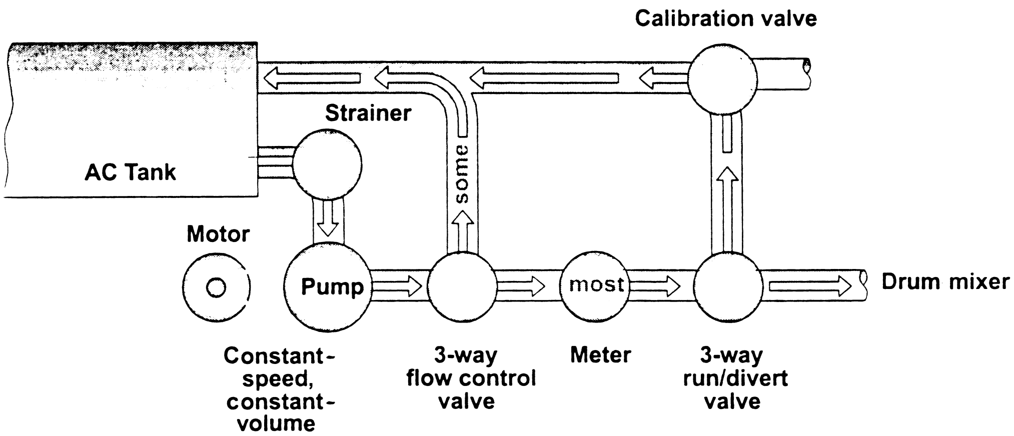


FIGURE 7-3 Asphalt metering system for drum-mix plants with constant-volume, constant-speed pump and flow control valve.

phalt cement and its temperature are known, however, the volume measured at the elevated temperature can easily be converted to the standard volume at 15°C (60°F) using the procedure given in ASTM Specification D4311.

The volume of asphalt cement moving through the meter likewise changes with temperature. Some meters are set to measure the temperature of the asphalt cement moving through the system and send that information, together with the volume data, to the plant computer. The specific gravity of the asphalt cement is set manually on the controls. The computer then calculates the volume of asphalt cement being fed into the plant at the standard temperature of 15°C (60°F) and converts that amount to a weight that is displayed on the plant console.

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, on the basis of the specific gravity of the asphalt cement, calculates the volume, at 15°C (60°F), passing through the meter. This corrected volume (and corresponding weight) is then sent to the plant console for display.

Regardless of the particular arrangement employed, the asphalt pump system must be capable of changing the volume of asphalt cement passed through the meter in direct response to the demand of the aggregate supply. The response of the pump system 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 at 15°C (60°F). At this standard reference temperature, the weight of the asphalt cement can be determined in terms of tonnes (tons) of material per hour, as with the aggregate feed rate. The total of the aggregate input (new aggregates plus RAP) and the weight of the asphalt cement provides the production rate for the drum mixer, in tonnes (tons) of HMA per hour. As production rates are adjusted, the asphalt pump system is timed so that the increase or decrease in asphalt cement reaches the drum at the same time that the increased or decreased material flow reaches that point in the drum.

Another type of asphalt meter, called a "mass-flow meter," measures the flow of asphalt by weight and, therefore, does not require temperature corrections.

CALIBRATION

The pump and meter system on a batch or drum-mix plant must be calibrated to ensure that the proper amount of asphalt cement is being delivered to the mix. For a batch plant operation, the amount of asphalt cement needed is measured by weight (although a few older batch plants measure the asphalt cement by volume), with the asphalt cement being placed in the plant weigh bucket. For a drum-mix plant, the amount of asphalt cement is measured by volume as it is pumped through a meter into the rear of the drum.

For a drum mixer, the amount of asphalt cement is calibrated by pumping the material into an empty container, the tare weight of which is known. Most often, an asphalt distributor truck is used for this purpose. The actual weight of the material delivered to the container is determined. The weight of the material indicated by the metering system as having been delivered is then determined by multiplying the corrected volume delivered from the meter totalizer by the specific gravity of the asphalt cement. With some systems, this calculation is done automatically. The actual weight is compared

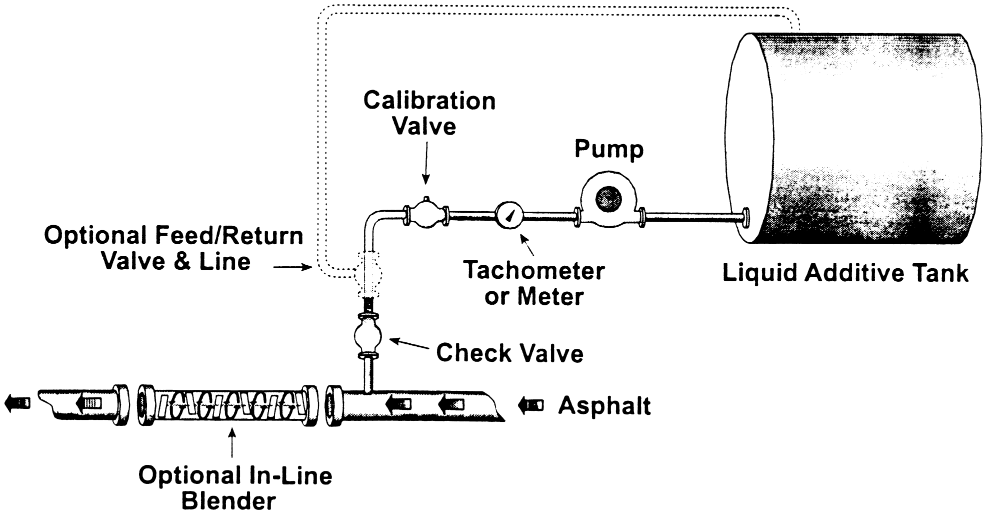


FIGURE 7-4 Typical asphalt additive tank system.

with that calculated by the metering system. To be in proper calibration, the values should be within the required tolerance band (typically 1.0 percent) for the asphalt cement supply system.

ADDITION OF LIQUID ANTISTRIP MATERIALS

Liquid antistrip additives are typically added to the asphalt cement to improve the adhesion of the binder material to the surface of the aggregate and increase resistance to moisture damage. The additive can be blended with the asphalt cement at several different locations. It can be in-line mixed with the asphalt cement as that material is pumped out of the tank truck or tank car and into the tank. It can also be added to the asphalt cement in the tank, with the two different materials being circulated together before the treated asphalt cement is sent to the drum mixer. The most common method, however is to add the liquid antistrip material to the asphalt cement, using an in-line blender, as the binder material is pumped from the storage tank to the rear of the drum-mix plant. A typical liquid antistrip additive tank system is illustrated in Figure 7-4.

SUMMARY

The following factors should be considered when monitoring the operation of the asphalt cement supply system, composed of the storage tank and the pump and meter system:

- The asphalt cement in the storage tank should be kept at a constant temperature, normally between 150°C (300°F) and 180°C (350°F). The tank should be properly insulated. All hot-oil lines should be insulated and the asphalt cement lines jacketed and insulated.
- The asphalt cement fill, discharge, and recirculation lines should enter the tank so that all charging and discharging of asphalt cement occurs below the surface of the material in the tank. Ideally, the binder return line should be located at the opposite end of the tank from the discharge line.
- The volume of asphalt cement in the tank must be converted to a standard volume at 15°C (60°F) when a tank stick is used to check the amount of material in the tank.
- The amount of asphalt cement used in a batch plant is measured by weight, so that no volume correction for temperature is needed.
- A correction for temperature must be made when calculating the volume of asphalt cement binder passing through a volumetric meter on a drum-mix plant if the meter is not equipped with an automatic temperature-compensating device. This correction is based on both the actual temperature of the asphalt cement and its specific gravity at 15°C (60°F).
- The asphalt cement supply system should be calibrated by weighing the amount of material delivered in a known amount of time. The corrected amount is determined in conjunction with knowledge of both the temperature and the specific gravity of the asphalt cement.

S E C T I O N

8 Batch Plants

In this section the operation and components of an HMA batch plant (depicted earlier in Figures 5-1 through 5-3) are described in detail. Aggregate handling, the asphalt cement supply system, aggregate heating and drying, screening and storage of hot aggregate, mixing of aggregate and asphalt cement, production of recycled mix, loading of the mix in truck or silo, emission control, and, finally, calibration are reviewed in turn. The section ends with a summary of key operating factors to be considered when monitoring the operation of a batch plant.

AGGREGATE HANDLING

Aggregate Stockpiles

The stockpiling techniques used for handling aggregate in a batch plant mixing operation are no different from those in a parallel-flow or counter-flow drum-mix plant (see Sections 9 and 10, respectively; see also the discussion of aggregate storage and handling in Section 6). Proper stockpiling techniques are as important for batch plant operations as they are for drum-mix plant operations. In particular, care needs to be taken to keep the various aggregate sizes separate and to prevent segregation of each size of aggregate in the stockpile.

It is sometimes assumed that the screens in the batch plant tower will overcome any problems with variation in the gradation of the incoming new aggregate. If the proper proportion of each size of aggregate is not delivered from the cold-feed bins, however, the amount of aggregate in the hot bins will be out of balance. As a result of lack of separation of the aggregate stockpiles or segregation of the aggregate in one or more stockpiles, one or more of the hot bins may be either starved or overflowing with material.

Cold-Feed Systems for New Aggregates

Some older batch plant cold-feed bins are equipped with a constant-speed feeder belt under each bin (see also Section 6). The amount of aggregate withdrawn from each bin is thus controlled by the size of the gate opening at the bottom of the bin. Most plants, however, have cold-feed bins that are equipped with a variable-speed feeder belt beneath each bin. The amount of aggregate withdrawn from each bin is regulated by the size of the gate opening and the speed of the conveyor belt. The aggregate is discharged from each feeder belt onto the collecting conveyor, which runs underneath all of the bins and delivers the aggregate to a scalping screen, if one is used. After the aggregate passes through the scalping screen, it is deposited onto the charging conveyor for delivery to the dryer. If no scalping screen is included in the system (which is normally the case because the screens at the top of the plant tower are used to remove any oversized material), the aggregate is transferred directly from the collecting conveyor to the charging conveyor.

Cold-Feed Systems for Reclaimed Asphalt Pavement

RAP is usually held in a separate, steep-sided cold-feed bin that is equipped with either a variable-speed or constant-speed feeder belt. The material from the bin is deposited on the feeder belt or onto a collecting conveyor for transport to a scalping screen. After passing through the scalping screen, the RAP is deposited on a charging conveyor for delivery to the plant. An alternative method is to use a scalping screen at the transfer point between the collecting conveyor and the charging conveyor so that the RAP passes through the screen as it is being placed in the cold-feed bin.

The RAP cannot be heated in the dryer because it will generate visible hydrocarbon emissions (blue smoke) when exposed to the high-temperature exhaust gases from the burner. Thus the feed of the RAP must be separated from the feed of the new aggregate. The RAP can enter the plant at one of three primary locations downstream of the dryer: the bottom of the hot elevator; one of the hot bins at the top of the tower; or the weigh hopper, which is the preferred location for most batch plant operations.

Addition of Hydrated Lime

Hydrated lime can be added to the aggregate in a batch plant mixing operation in one of two ways: it can be placed on the aggregate, in either dry or slurry form, similar to the method of addition for a drum-mix plant (see Sections 9 and 10), or it can be added in dry form to the aggregate, similar to a mineral filler. If the hydrated lime is added to the aggregate in slurry form, the water in the slurry will have to be removed during the drying process inside the aggregate dryer. This will both increase the cost of drying the aggregate and reduce the production rate of the plant.

ASPHALT CEMENT SUPPLY SYSTEM

Storage Tanks

The storage tank used for the asphalt cement for a batch plant operation is the same as that used for a drum-mix plant. The material is generally stored at temperatures between 149°C and 177°C (300°F and 350°F), depending on the grade or viscosity (or both) of the asphalt cement. The binder material must be fluid enough to mix properly with the aggregate in the pugmill.

Pump System

The asphalt content of the mix is determined by weight, not volume (except for a very few old batch plants). Thus no meter is used to proportion the amount of asphalt cement needed in the mix. The pump, which runs continuously, pulls the asphalt cement from the storage tank and either delivers it to the weigh bucket or recirculates it to the tank, depending on the opening of the control valve at the weigh bucket. When the valve is open to the weigh bucket, the binder material is pumped into the bucket until the correct weight is reached. At that time, the valve is closed, and the asphalt cement is recirculated back to the storage tank.

Addition of Liquid Antistrip Additives

Liquid antistrip additives are added to the asphalt cement in the batch plant in a manner similar to that for a drum-mix plant. The additive can be blended with the asphalt cement as that material is pumped out of the delivery vehicle or as it is pumped from the storage tank to the weigh bucket. Alternatively, it can be blended with the asphalt cement in the storage tank by circulating the two materials together for a period of time before the treated material is pumped to the asphalt cement weigh bucket.

AGGREGATE HEATING AND DRYING

The dryer on a conventional batch plant operates on a counter-flow principle. Its operation is similar to that of a counter-flow drum-mix plant (although, since the aggregate dryer was in use before the modern counter-flow drum-mix plant, it is more correct to say that the counter-flow drum-mix plant operates similarly to a conventional aggregate dryer). The aggregate is charged into the dryer at the upper end of the drum and flows through the dryer by the action of the rotating flights and gravity. The burner is located at the lower or discharge end of the dryer. The exhaust gases move toward the upper end of the dryer, counter to the direction of the flow of the aggregate. This process is shown in Figure 8-1.

The dryer is a rotating drum that is generally 1.5 to 3.0 m (5 to 10 ft) in diameter and 6 to 12 m (20 to 40 ft) in length. The length of the drum is normally propor-

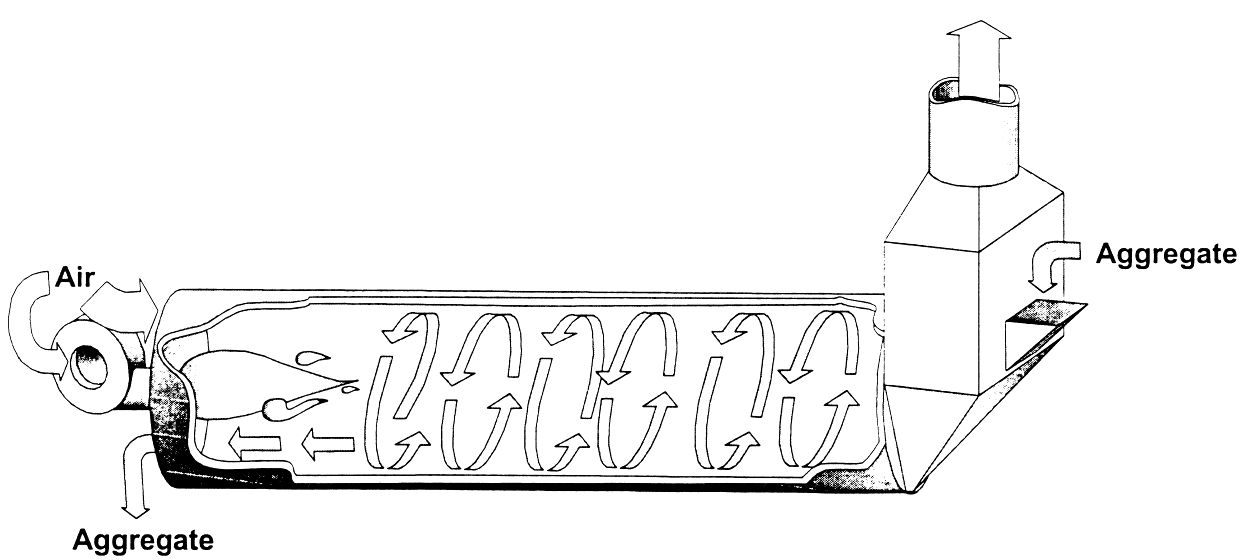


FIGURE 8-1 Typical counter-flow dryer.

tional to the diameter at a ratio of 4 : 1. Thus a dryer with a diameter of 2.4 m (8 ft) would typically be 9.7 m (32 ft) in length. The function of the dryer is to remove the moisture from the aggregate and to heat the material to the desired discharge temperature, generally in the range of 138°C to 163°C (290°F to 325°F). The moisture content of the aggregate upon exiting the dryer should be less than 0.5 percent and ideally less than 0.2 percent.

The aggregate is fed into the dryer from the charging conveyor by means of either a charging chute at the top of the dryer or, occasionally, a Slinger conveyor at the bottom of the dryer. The flights inside the dryer, shown in Figure 8-2, are used to lift and tumble the material in a veil across the diameter of the dryer. As the aggregate flows down the dryer, it is heated by the exhaust gases from the burner, and the moisture is driven off. The burner flame, which generally has a much longer, thinner shape than the short, bushy flame of the burner on a parallel-flow drum-mix plant, extends into the dryer to penetrate the aggregate veil. The aggregate is heated and dried by the exhaust gases from the burner by means of conduction, convection, and radiation. Because of the higher efficiency of the counter-flow system, a batch plant dryer typically uses less fuel to heat and dry a given amount of aggregate than does the mixing drum on a parallel-flow drum-mix plant.

The dwell or residence time of the aggregate inside the dryer is a function of the length of the drum, the design and number of flights, the speed of rotation, and the slope of the dryer [typically 2.5 to 6.0 deg, or 26 to 63 mm/m ($\frac{5}{16}$ to $\frac{3}{4}$ in./ft)]. If more than 0.5 percent remains in the aggregate upon discharge from the dryer, the density of the veil of aggregate inside the drum must be increased, typically by lowering the slope of the dryer or by changing the number or type of flights used in the dryer. Both of these procedures will increase the dwell time of the aggregate inside the dryer, and both may be difficult and costly to perform.

Because the aggregate typically makes up between 92 and 96 percent of the weight of the asphalt mix, it governs the temperature of the mix produced in the pugmill. Excessive heating of the aggregate may cause excessive hardening of the asphalt cement in the mixing process. If a recycled mix is to be produced, however (as discussed in a later section), the new aggregate must be superheated in the dryer to accomplish the necessary heat exchange in the pugmill. In this case, the required temperature of the new aggregate is dependent on the amount of RAP and its moisture content.

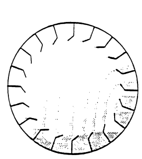


FIGURE 8-2 Proper veiling.

SCREENING AND STORAGE OF HOT AGGREGATE

Hot Elevator

New Aggregate

The heated and dried aggregate is discharged from the dryer through a chute into the bottom of the bucket elevator. The hot material is transported by the continuously moving buckets up to the top of the batch plant tower, as illustrated earlier in Figure 5-1. From the hot elevator, the aggregate is delivered to the screen deck at the top of the tower.

RAP

It is not generally advisable to add the RAP into the plant at the bottom of the hot elevator, particularly when the amount of RAP exceeds approximately 10 percent of the mix. The RAP should be fed, if possible, into the new-aggregate discharge chute from the dryer so that it is on top of the hot new aggregate and is directed into the center of the buckets. If that is not feasible, the reclaimed material should be deposited into a separate steep-sided chute located above the new-aggregate entry at the bottom of the hot elevator. The RAP must be placed in the buckets after the new aggregate to prevent the asphalt-coated material from sticking to the buckets as it is heated by contact with the superheated new aggregate.

There is a limit to the amount of RAP that can be fed into the bottom of the hot elevator, and this limit is related to the heating process as the material travels to the top of the tower. Depending on the percentage of RAP used in the mix, the moisture content of the RAP, and environmental conditions, the reclaimed material can be sufficiently heated while traveling up the hot bucket elevator with the new aggregate to stick to the screens instead of passing through them. The result may be clogging (blinding) of the screens and a consequent change in the gradation of the new aggregate in each of the hot bins as material that should be in a given bin passes over that bin and ends up in another, coarser-gradation bin. If the screens become clogged enough, shutdown of the plant may eventually result. It is recommended that if more than 10 percent RAP is to be added to the mix and if the RAP is to be introduced into the plant at the bottom of the hot elevator, the screens at the top of the tower be either removed or bypassed. If this is done, all of the new and reclaimed aggregate will be delivered into the No. 1 hot bin.

Screen Deck

The aggregate is discharged from the hot elevator buckets onto a set of vibrating screens that are used to separate the material into different sizes. Four screen decks typically are used, arranged as shown in Figure 8-3. The top screen is generally a scalping screen used to remove any oversized material from the aggregate flow and reject it to a bypass or overflow chute. The remaining three screen decks divide the aggregate into four different fractions. The amount of material in each fraction is dependent on the size and shape of the openings in the screens. Each screen deck may have several different screen sizes in order to improve screening efficiency and protect the smaller screens from oversized aggregate.

The screens can have square (most common), rectangular, or slotted openings. For example, in a typical batch plant used to manufacture base, binder, and surface course mixes, the openings in a square screen might be 32 mm (1¼ in.) for the top deck, 14 mm (9⁄16 in.) for the second deck, 8 mm (5⁄16 in.) for the third deck, and 4 mm (5⁄32 in.) for the bottom deck. The sand-sized aggregate, smaller than 4 mm (5⁄32 in.) in diameter, would pass directly through all of the screens and be deposited into the No. 1 hot bin. Aggregate that was larger than 4 mm (5⁄32 in.) but no larger than 8 mm (5⁄16 in.) would be carried over the first screen and then dropped into the No. 2 hot bin. For any particular mix, the proper screens need to be used in the screen deck to produce the required gradation in the asphalt mix. If mix gradations change significantly, it may be necessary to change the screen sizes used at the top of the mixing tower. Different-sized screens than those in the above example may be used for various combinations of aggregate to meet particular agency specifications.

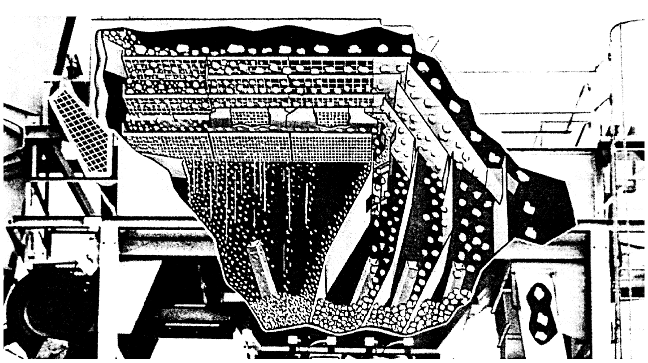


FIGURE 8-3 Cutaway illustration of screening process.

Many screen decks use a split-screen setup in which screens with two different-sized openings are placed at the same level (in the same deck). For example, the top deck might employ a screen with an opening of 8 mm (5⁄16 in.) for the half of the deck nearest to the hot elevator and a screen with an opening of 32 mm (1¼ in.) for the half of the deck over the No. 3 and 4 hot bins. This arrangement will improve the efficiency of the screening operation.

Not all of the material that should be in a particular bin always ends up in that bin. The term "carryover" refers to finer aggregate that fails to pass through the larger screens and is deposited in bins intended for larger-sized material. A small amount of carryover, generally less than 10 percent, from one bin to the adjacent bin is often found. The carryover is caused by the flow of aggregate moving across instead of through the screens. The amount of carryover is increased as the openings in the screens become clogged or blinded with aggregate and as the amount of aggregate being delivered by the hot elevator is increased. The primary problem occurs when the amount of carryover is variable over time, causing the gradation of the aggregate found in each of the hot bins to change. This situation is often due to continued variation in the rate of feed of the aggregate from the cold-feed bins.

Moreover, if a screen develops tears or holes, some of the aggregate that should be deposited in another bin will pass through the screen and end up in a bin with smaller-sized material. Thus screens at the top of the tower should be checked regularly to ensure that there are no holes and that the screens are not clogged or blinded with aggregate. Analysis of hot-bin gradations will help identify where tears or holes exist.

In some locations, batch plants are routinely operated without screens; the screen deck is removed, or a screen bypass chute is used. All of the aggregate that is transported up the hot elevator is deposited directly into the No. 1 bin. Without screens, the batch plant is operated in much the same manner as a counter-flow drum-mix plant, and the final gradation of the mix is determined by the consistency of the gradation of the aggregate in the cold-feed bins. Because no screening is done to separate the aggregate into different sizes, the various gradations that are proportioned out of the cold-feed bins (unless only one aggregate blend is used to make the mix) are deposited directly into the No. 1 hot bin upon discharge from the hot elevator. All of the aggregate used in the mix is drawn from this one hot bin into the weigh hopper and then into the pugmill.

Hot Bins

New Aggregate

The total capacity of the hot bins is usually proportional to the size of the pugmill. The capacity of each of the hot bins, however, is not the same. The No. 1 (sand) bin has the greatest capacity. Generally about 40 to 50 percent by weight of the aggregate delivered by the hot elevator passes through the screens and into this bin. The typical capacity (percentage of total hot-bin capacity) of each of the remaining three bins is 25 to 30 percent for bin No. 2, 15 to 20 percent for bin No. 3, and 10 percent for bin No. 4.

Some segregation of the aggregate occurs in each hot bin, particularly in the No. 1 (sand) bin. This segregation is caused by the finer material in each size fraction passing through the screens more directly than the coarser material of the same fraction. Thus the aggregate on the side of each hot bin that is closest to the hot elevator will generally be finer in gradation than the aggregate on the opposite side of the same hot bin.

The partitions between the hot bins should be checked regularly to ensure that no holes have developed and that aggregate in one bin is not flowing into another. The overflow pipes at the top of each bin should be open. Fines sometimes build up in the corners of the No. 1 bin. When the level of aggregate in the bin is low, the collected fines can break loose, and a slug of that material can enter the weigh hopper. If this is a continuing problem with a particular plant, fillets can be welded in the corners of the No. 1 bin to reduce the buildup of the fine material, or a plate can be used at the top of the No. 1 bin to deflect the fines and direct that material into the center of the bin.

Even though the screens on the batch plant are used to regrade the aggregate that is fed into the plant from the cold-feed bins, the proportion of material delivered from each cold-feed bin must be correct, or one of the hot bins will either run out of material or overflow. Because all the aggregate that is discharged from the cold-feed bins will end up in the mix, it is very important that the aggregate placed in the cold-feed bins be graded consistently. The screens should not be used to attempt to overcome a problem with a variable incoming aggregate gradation, as discussed below.

RAP

Although the practice is not recommended, in the operation of some batch plants RAP is deposited directly into one of the hot bins on the plant. A separate charging conveyor or bucket elevator is used to carry the reclaimed material to the top of the plant. The RAP is deposited through a screen bypass directly into the No. 1 hot bin with the sand, or into the No. 4 hot bin if no other aggregate is in that bin (when a surface course mix is being produced, and no large aggregate is needed). Further, if the RAP is placed in the No. 1 hot bin, the heat transfer process between the superheated sand and the ambient-temperature RAP can begin while both are together in that hot bin. If the asphalt-coated material is placed in the No. 4 bin, no such heat advantage is realized because of a lack of heated new aggregate in the bin.

The disadvantage of placing the RAP in either the No. 1 or the No. 4 bin is that some of the asphalt-coated particles will stick to the walls of the bin. This can be a major problem, particularly if the amount of reclaimed material used in the mix and the moisture content of that material are both high. If superheated new aggregate is in the bin adjacent to the RAP, a significant amount of the RAP will stick to the partition between the two bins.

Weigh Hopper

New Aggregate

If a base course mix is being produced, all four of the hot bins may be filled with aggregate. If a binder or surface course mix is manufactured, only two or three of the hot bins will normally be needed. The aggregate in the hot bins can be discharged into the weigh hopper in any order; however, a coarse aggregate is typically discharged into the weigh hopper before the fine aggregate is deposited. This is done to prevent the finest aggregate particles from leaking out through the gates at the bottom of the weigh hopper if the sand (No. 1 bin material) is emptied into the weigh hopper first.

Normally the gate at the bottom of the No. 3 hot bin is opened, and the aggregate is discharged into the weigh hopper until the correct weight is reached. The gate on the No. 3 bin is then shut, and the gate on the No. 2 hot bin is opened and the weigh hopper filled with that material until the correct cumulative weight (combined weight of the No. 3 and No. 2 bin material) is reached. The aggregate in each of the last two hot bins (No. 1 and No. 4) is added to the weigh hopper in the same manner. The weighing of each aggregate is accomplished in about 5 seconds. It is important that the aggregate delivered from each hot bin be deposited as near the center of the weigh hopper as possible so that the hopper is not unbalanced on the scale and spillage of the aggregate does not occur.

If mineral filler is needed in the mix, it is normally added to the aggregate already in the weigh hopper. The filler is delivered pneumatically or mechanically from a storage silo to a small holding hopper typically located on the plant tower just above the weigh hopper. It is then added to the weigh hopper by means of a horizontal screw conveyor. On some batch plants, the filler is weighed separately from the other aggregate and then augered into the main aggregate weigh hopper after the aggregate from the hot bins has been weighed. On other plants, the filler is weighed as a fifth aggregate as it is added to the material already in the hopper.

Most batch plants are operated in automatic or semiautomatic mode. The different aggregate materials temporarily held in the hot bins are weighted out one at a time. If there is not enough aggregate in a particular hot bin to attain the required weight in the weigh hopper, the weighing system waits until enough of that size aggregate is available before the aggregate from the next hot bin is weighed. Thus if the plant is to be kept running efficiently and not continually waiting for aggregate to weigh, it is important that the proper aggregate gradations be delivered consistently to the plant from the cold-feed bins. Even though the batch plant is normally equipped with screens, control of the aggregate gradation must be achieved at the cold-feed bins.

If the material delivery from the cold-feed bins is not consistent, one or more of the hot bins at the top of the batch plant tower will eventually run out of aggregate or another hot bin will contain too much material and overflow, or both. In such cases, there might be a tendency for the plant operator to switch the plant to the manual processing mode and to rebalance the aggregate flow by adding or subtracting certain aggregate sizes from the aggregate blend for a short period of time. This procedure, of course, changes the aggregate gradation in the HMA mix. To eliminate the need for such procedures, the plant operator must control the amount of each size of aggregate being delivered from the cold-feed bins, just as control is needed at the cold-feed bins to achieve a consistent aggregate gradation for a drum-mix plant, whether parallel-flow or counter-flow.

RAP

The most common location for adding RAP to a batch plant is in the weigh hopper. Once the aggregate from the hot bins has been deposited in the hopper and weighed, the reclaimed material is usually fed into the hopper as a fifth aggregate (or a sixth aggregate, if mineral filler is used in the mix), although it can actually be added to the weigh hopper in any order except first. The charging conveyor used to deliver the RAP to the weigh hopper, shown earlier in Figure 5-2, must be oversized in this case because it does not run continuously. The RAP must be deposited into the weigh hopper in approximately 5 seconds.

The RAP must be discharged from the charging conveyor into a steeply angled chute and thence into the center of the weigh hopper. The steep angle prevents the RAP from collecting in the chute. If this material is deposited on one side of the weigh hopper so that the hopper is unbalanced, an accurate weight will not be determined. The charging chute should be equipped with a flop gate to prevent the escape of fugitive dust from the weigh hopper area when the aggregate is emptied into the pugmill.

MIXING OF AGGREGATE AND ASPHALT CEMENT

The aggregate and the asphalt cement binder are blended together in a twin-shaft pugmill. Mixing paddles, shown in Figure 8-4, are attached to two horizontal shafts that rotate in opposite directions. The aggregate is first discharged from the weigh hopper into the pugmill and is mixed for a very brief time (dry-mix time) before the asphalt cement is introduced into the pugmill and the wet-mix time begins. When the mixing has been completed, the asphalt mix is discharged from the pugmill directly into a haul truck or into the conveying device for transport to the silo.

Pugmill Capacity

The size of the batch produced depends on the size of the pugmill. Some batch plants have a pugmill capacity as little as 0.9 tonne (1 ton). The pugmill of most batch plants, however, has a capacity of 1.8 to 4.5 tonnes (2 to

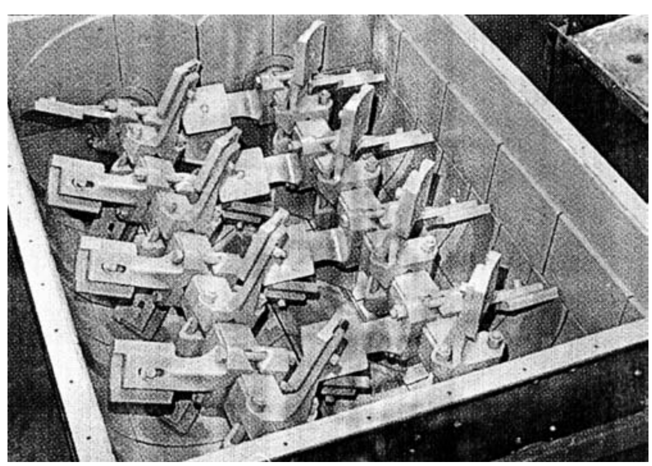


FIGURE 8-4 Interior of pugmill.

5 tons). One of the largest batch-plant pugmills made can mix 10.4 tonnes or 10 400 kg (11.5 tons or 23,000 lb) of mix in a single batch. The total mixing time for the various batch sizes is the same—typically as short as 35 seconds per batch. The only difference is the size of each batch, not the time needed to produce it.

Nominal pugmill capacity is determined by the dimensions of the live zone. If too much aggregate is placed in the pugmill, the material above the paddle tips will tend to stay on top and not be mixed with the other aggregate. If too little aggregate is deposited into the pugmill, the material will be thrown around and up into the air by the paddles instead of getting mixed. These two conditions are illustrated in Figure 8-5.

Batch size should not be varied from batch to batch; consistent batch size is one of the keys to a consistent mix. The optimum approach is to select a batch size at or slightly below the nominal capacity of the pugmill and produce all batches at that tonnage. If the plant is equipped with a 2.7-tonne (3-ton) pugmill and the average haul truck being used can hold 12.5 tonnes (14 tons) of mix, the batch size selected should be 2.5 tonnes (2.8 tons) [12.5 tonnes (14 tons) per truck, divided by five batches]. The plant operator should not attempt to produce four batches of 2.7 tonnes (3 tons) each and a fifth batch of only 1.8 tonnes (2 tons).

RAP

Pugmill recycling is gaining in popularity. By adding an additional weigh hopper to the batch facility, the RAP is conveyed into and weighed in its own hopper while the asphalt and virgin aggregates are being weighed. The same heat-transfer, steam-release, and practical limits apply to this approach as apply to the weigh-box method of batch plant recycling, as shown in Figure 8-6. The advantages of this method include the following:

- During long production runs of recycled pavement, an increase in the production rate per hour can be achieved with the slightly shorter batch cycle time.
- There is less wear and tear on the equipment from abrupt starting and stopping.
- The weighing process can be done more slowly and accurately with a separate weigh hopper that is undisturbed by instant steam release.

Typically, a high-speed Slinger conveyor is used to convey the RAP from the RAP weigh hopper to the pugmill. A chute or high-speed screw conveyor can also be used.

Mixing Time

Dry-Mix Time

Dry-mix time starts when charging of the aggregate into the pugmill begins and ends when asphalt injection begins. Dry-mix time should be minimal—normally no more than 1 or 2 seconds. Although the aggregate in the weigh hopper is layered, the different-sized aggregates can be blended adequately during the wet-mix cycle and do not need to be premixed during the dry-mix cycle. The main purpose of the dry-mix time is to allow some aggregate to enter the pugmill before the asphalt cement is discharged so that the liquid cement does not run out of the gates at the bottom of the pugmill.

Increasing dry-mix time decreases the plant production rate without benefiting the mix and causes unnecessary wear on the pugmill paddles and liners. In addition, any increase in the dry-mix time raises the cost of producing the mix. The dry-mix time should thus be kept as short as possible; 1 second is normally adequate.

Wet-Mix Time

While the aggregate is still being discharged from the weigh hopper into the pugmill, the addition of the asphalt cement commences. This material is fed into the pugmill by gravity flow or pressure spray and is added either through one pipe in the center of the pugmill or through two pipes, one over each of the two mixing shafts. The wet-mix time starts when the asphalt enters the pugmill. Typically 5 to 10 seconds is required for all the asphalt cement to be discharged from the weigh bucket. Pressure injection systems can be used to reduce this time.

Wet-mix time should be no longer than is necessary to coat the aggregate completely with asphalt cement. If the paddle tips and pugmill liners are in good condition and if the pugmill is full, the wet-mix time can be as short as 27 seconds. If the paddle tips are worn, the wet-mix time will be extended somewhat, but typically should not be more than 33 seconds. Because the condition of the paddle tips affects the amount of wet-mix time, it should be checked regularly and the tips changed when necessary. As a general rule, a 30-second wet-mix time is more than adequate to uniformly distribute the asphalt cement and coat the aggregate.

The mixing time should be as short as possible to avoid excessive hardening of the asphalt cement in a thin film around the aggregate particles as a result of exposure to high temperatures. The required wet-mix time can be established using the Ross count procedure to

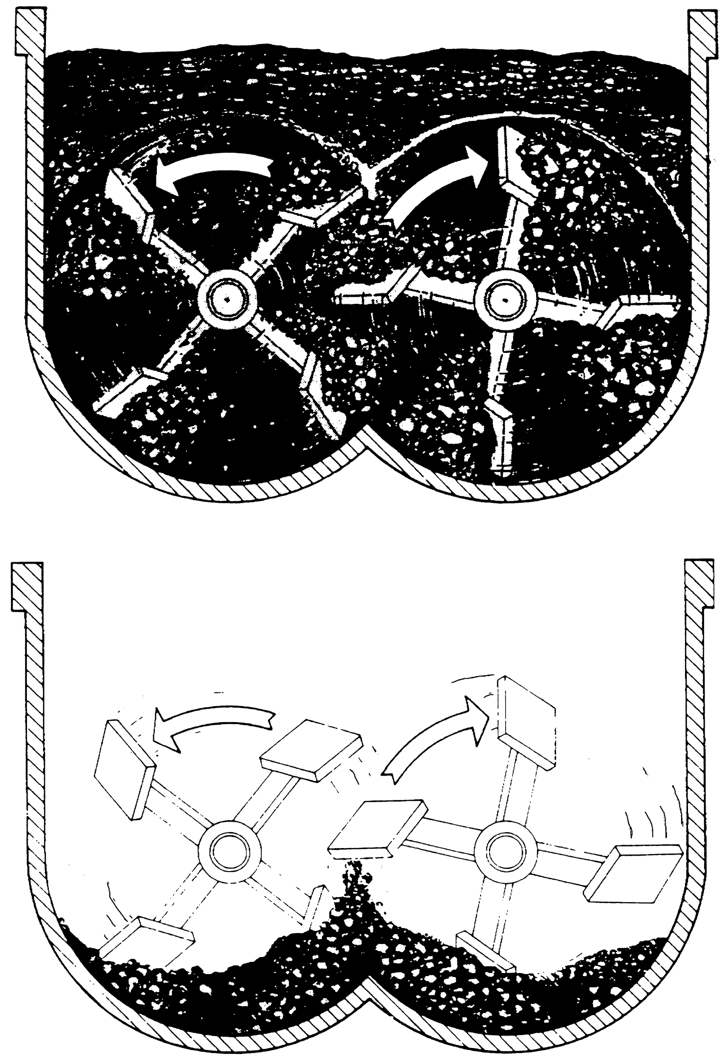


FIGURE 8-5 Overfilled and underfilled pugmills.

determine the degree of particle coating of the coarse aggregate in the mix, as given in ASTM D2489. Once the asphalt cement has been properly distributed, additional wet-mix time does not improve the degree of coating but only oxidizes (hardens) the asphalt cement by continuing to expose the binder material to air.

Coating of the aggregate in a pugmill occurs first with the smallest-sized aggregate particles. If wet mixing is done for only 10 seconds and the material is discharged from the pugmill at the end of that time, only the smaller fine aggregate [the material finer than the 0.600-mm or 0.425-mm (No. 30 or No. 40) sieve] will typically be coated with the asphalt cement; the coarser aggregate particles will be only partially coated with asphalt. If wet-mixing time is extended to 20 seconds and the material is discharged from the pugmill at the end of that time, only the aggregate of 4.75-mm (No. 4) sieve size and smaller will typically be coated with asphalt cement; the coarser aggregate particles will remain uncoated. Complete coating of all the coarse aggregate in the mix usually takes about 26 to 28 seconds of wet-mixing time in a pugmill with paddle tips and lining in good condition. Thus the Ross count procedure, which looks only at the degree of asphalt coating on the coarse aggregate particles [larger than the 4.75-mm (No. 4) sieve], is an effective way of determining the minimum amount of wet-mix time needed to distribute the asphalt cement properly throughout the aggregate.

Total Mix Time

Mixing time has a direct effect on the production capacity of a plant. If a 1-second dry-mix time and a 27-second wet-mix time are used, proper mixing of the two materi-

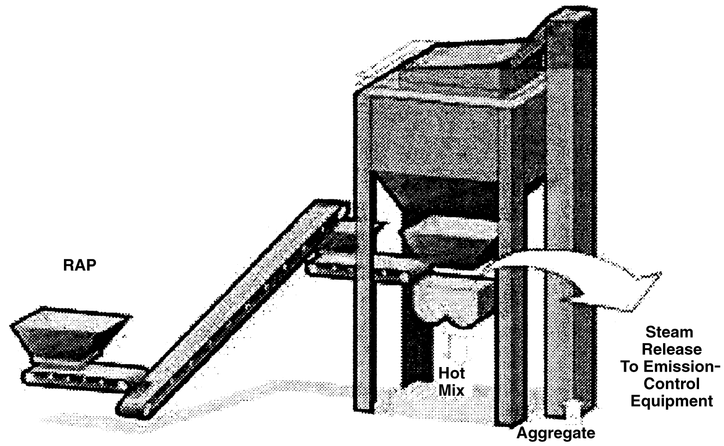


FIGURE 8-6 Weigh-box method of batch plant recycling.

als can be accomplished in 28 seconds. Given approximately 7 seconds more to open the gates at the bottom of the pugmill, discharge the mix, and close the gates, the total cycle time required to produce a batch of HMA is 35 seconds. This time is the same whether the batch size is 1.8 tonnes (2 tons) or 4.5 tonnes (5 tons). Theoretically, if a plant with a pugmill capacity of 4.5 tonnes (5 tons) is run continuously for 1 hour, 465 tonnes (514 tons) of asphalt mix can be manufactured.

If a 5-second dry-mix time and a 35-second wet mix time were required by specification, the total cycle time to produce the mix would be 47 seconds (assuming a 7-second gate-opening, mix-discharge, and gate-closing time). This increased cycle time (47 compared with 35 seconds) would decrease the amount of mix produced in a pugmill with a capacity of 4.5 tonnes (5 tons) from 465 tonnes (514 tons) to 348 tonnes (383 tons) per hour. If a 60-second total cycle time were used, the production rate for the same plant would be reduced to only 270 tonnes (300 tons) per hour. Thus the dry- and wet-mix times have a significant effect on the amount of mix produced by a given plant and the cost of producing that mix.

If the plant is not equipped with a silo, there will be times when the plant production may have to be interrupted because of a lack of available haul trucks. This problem must be monitored by the plant operator. In no case should the plant mixing time be extended during the wet-mix cycle. If the asphalt cement has been added to the aggregate and the wet-mix time is extended to 40 or 50 seconds or longer, excessive hardening of the asphalt cement will occur. This extended wet-mix time can be highly detrimental to the long-term performance of the mix on the roadway.

If trucks are not available, the plant should be idled with no material in the pugmill—the paddles should be “mixing air.” The second, much less desirable, choice is to let the plant wait during the dry-mix time; the aggregate is in the pugmill, but the asphalt cement has not been added. This can be done only for a short period of time; otherwise excessive breakdown of the aggregate may occur. Again, the plant should not be idled during the wet-mix time.

Several factors may reduce the supply of incoming aggregate, such as high moisture content or insufficient screen capacity, which extend drying time. The production rate of the plant will be reduced (total cycle time increased) while waiting for dry aggregate. If this problem occurs, the plant operator must not increase the total cycle time by arbitrarily increasing the wet-mix time. Rather, the total cycle time should be increased by delaying the discharge of the aggregate from the weigh hopper into the pugmill and thus “mixing air” instead of aggregate (increased dry-mix time) or asphalt mix (increased wet-mix time).

PRODUCTION OF RECYCLED MIX

Recycling Variables

The temperature of the new aggregate and the moisture content of the RAP govern the amount of reclaimed material that can be introduced into a recycled mix produced in a batch plant. For the heat transfer to take place from the heated new aggregate to the ambient-temperature RAP, the new aggregate must be superheated—heated to a temperature above that needed to produce a conventional HMA. This heat transfer can take place in the hot elevator, in the hot bins, in the weigh hopper, or in the pugmill, depending on where the RAP is introduced into the plant. For most dryers, the maximum new-aggregate temperature upon discharge from the dryer should be about 260°C (500°F) in order not to reduce the life of the dryer and to keep from driving off internal moisture in the aggregate.

The three primary variables that determine the temperature to which the new aggregate must be heated to accomplish the necessary heat transfer are the moisture content of the reclaimed material, the discharge temperature of the final recycled mix, and the amount of reclaimed material used. Depending on the values for these variables, up to 50 percent RAP may be blended with new aggregate to manufacture a recycled HMA. Very rarely, however, is it feasible to use that amount of RAP in an HMA mix produced in a batch plant.

Moisture Content

As the moisture content of the reclaimed material increases, the required new-aggregate temperature increases significantly. This is illustrated in Table 8-1. If 20 percent RAP is used in the mix, if the moisture content of that material is 1 percent, and if the required mix discharge temperature is 127°C (260°F), the temperature to which the new aggregate must be heated is 177°C (350°F), as seen in Section B of the table. If the same RAP has a moisture content of 4 percent, however, the temperature of the new aggregate must be increased to 199°C (390°F) for the same amount of reclaimed material and the same mix discharge temperature.

Mix Discharge Temperature

Using Section C of Table 8-1 as an illustration, the amount of RAP incorporated into the mix is 30 percent. If the moisture content of this material is 3 percent as it is delivered to the plant, the new-aggregate temperature must be at least 196°C (385°F) when the mix discharge temperature is only 104°C (220°F). If the discharge temperature is 138°C (280°F), however, the temperature of the new aggregate must be increased to 246°C (475°F). Thus a higher mix discharge temperature for the recycled mix from the pugmill requires an increase in the new-aggregate temperature from the dryer.

Amount of RAP

As the amount of RAP in the recycled mix increases, the new-aggregate temperature must also increase. If only 20 percent RAP is used and if the moisture content of that material is 4 percent for a mix discharge temperature of 138°C (280°F), the new-aggregate discharge temperature must be 213°C (415°F), as determined from Section B of Table 8-1. Increasing the mount of RAP to 50 percent, using Section E of the table and for the same value of moisture content (4 percent) and mix discharge temperature [138°C (280°F)], the new-aggregate temperature must be raised to 405°C (760°F) to accomplish the heat-transfer process. This latter temperature significantly exceeds the recommended maximum new-aggregate temperature of 260°C (500°F).

Dryer Operation

If the temperature of the new aggregate exiting the dryer exceeds approximately 260°C (500°F), the cost of operating and maintaining the dryer can increase significantly. Because of extremely high aggregate temperatures and the reduced volume of aggregate in the dryer when a large percentage of RAP is used in the recycled mix as compared with a normal mix, the veil of aggregate inside the dryer will typically not be adequate. This lack of veil will increase the temperature of the dryer shell and may necessitate increased maintenance on the inside of the dryer, especially on the discharge flights.

If the mix production is stopped for a long period of time because of a lack of haul trucks or mechanical problems, the superheated new aggregate will lie in the bottom portion of the dryer. If the temperature of this material is greater than about 260°C (500°F), warping of the drum shell can occur, and the dryer will be out of round. Further, at the end of each production cycle, the dryer should be allowed to run empty with the exhaust fan operating for a reasonable cooling-down period after aggregate feed shutdown. This cooling procedure will protect against possible warping of the dryer shell and the flights.

Visible Emissions

When the RAP is deposited on top of the superheated new aggregate in the weigh hopper and when the two materials are mixed together in the pugmill, emissions of both moisture and dust can occur. These emissions are caused by escape of the moisture, in the form of steam, from the RAP. The amount of moisture vapor, as well as blue smoke, released can be quite large. For a mix containing 50 percent reclaimed material in a 2.7-tonne (3-ton) batch of recycled mix, with a moisture content of 3 percent, 40 kg (90 lb) of water, which will convert to approximately 422 m^3 (14,900 ft^3) of water vapor, will be released in about 5 seconds. This release of vapor usually

TABLE 8-1 Required Aggregate Temperature

Reclaimed Material Moisture Content (%)	Recycled Mix Discharge Temperature, °F			
	220°F	240°F	260°F	280°F
A. Ratio: 10% RAP/90% Aggregate				
0	250	280	305	325
1	260	290	310	335
2	270	295	315	340
3	280	300	325	345
4	285	305	330	350
5	290	315	335	360
B. Ratio: 20% RAP/80% Aggregate				
0	280	310	335	360
1	295	320	350	375
2	310	335	360	385
3	325	350	375	400
4	340	365	390	415
5	355	380	405	430
C. Ratio: 30% RAP/70% Aggregate				
0	315	345	375	405
1	335	365	395	425
2	360	390	420	450
3	385	415	445	475
4	410	440	470	500
5	435	465	495	525
D. Ratio: 40% RAP/60% Aggregate				
0	355	390	425	460
1	390	425	460	495
2	425	460	495	530
3	470	500	535	570
4	500	535	570	610
5	545	575	610	645
E. Ratio: 50% RAP/50% Aggregate				
0	410	455	495	540
1	465	515	550	590
2	520	580	605	650
3	575	620	660	705
4	640	680	715	760
5	690	735	775	820

NOTE: 20°F loss between dryer and pugmill assumed in these calculations. °C = (°F – 32)/1.8.
SOURCE: National Asphalt Pavement Association, *Hot Recycling in Hot Mix Batch Plants* (IS-71), page 2.

causes carryout of dust particles from the weigh hopper and the pugmill areas.

One way to control the particulate emissions is to reduce the amount of moisture or reduce the amount of RAP used in the recycled mix, or both. The moisture content of the reclaimed material can be kept low by not crushing this material until just before it is needed and by keeping the RAP under a roof to prevent rain from falling on it. Another common approach is to adequately vent the weigh hopper and pugmill into the emission-control system on the plant. (See also the discussion of emission control in Section 12.)

LOADING IN TRUCK OR SILO

If the mix discharged from the pugmill is loaded directly into the haul truck, each batch should be deposited into a different location on the truck. The first batch should be placed in the front portion of the bed. The driver should then move the truck forward so that the second batch is placed into the rear section of the truck bed, adjacent to the tailgate. The remaining batches should be discharged into the center of the bed, with the position of the truck under the pugmill changing for each batch. This procedure will minimize the distance the coarse aggregate particles can roll in the bed, thereby reducing the possibility of segregation of the mix.

If the mix is to be stored in a silo temporarily, it should be discharged from the pugmill into the center of a hopper and then into a conveying device, which can be a drag-slat conveyor, a belt conveyor, or a bucket elevator. The silo should be operated in a manner similar to the silo used with a drum-mix plant (see Sections 9 and 10; see also the discussion of silos and truck loading techniques in Section 11).

EMISSION CONTROL

Because the asphalt cement is not added to the aggregate inside the dryer, the amount of dust carryout from a batch plant dryer is generally greater than that from a parallel-flow drum mixer. The operation of the emission-control equipment—wet-scrubber system or baghouse (fabric filter)—is the same, however, regardless of the type of plant used.

If the baghouse fines are fed back into the mix, they should be fed into a filler metering system before being introduced into the weigh hopper on the tower. This procedure will ensure that the baghouse fines are delivered uniformly into the mix. On some plants, the fines are transported to the bottom of the hot elevator and deposited on top of the new aggregate that is discharged from the dryer. As long as the fines are delivered consistently, this method of fines return is acceptable, particularly if the aggregate will pass through the screen deck. If screens are not used, however, small lumps of fines can be deposited into the No. 1 hot bin and possibly end up in the mix without being broken up. Thus returning the baghouse fines to the hot elevator is probably not as good a practice as placing them directly into the weigh hopper.

If the plant is equipped with a baghouse and a recycled asphalt mix with a high percentage of RAP is being produced, the temperature of the exhaust gases from the dryer to the baghouse should be monitored continuously to ensure that the bags in the fabric filter are not damaged by excessive heat. The higher the temperature to which the new aggregates must be heated, the greater is the chance for problems with the baghouse operation. (See Section 12 for a full discussion of emission control.)

CALIBRATION

The calibration procedure for a batch plant involves checking the accuracy of the scales, both for the aggregate weigh hopper and for the asphalt cement weigh bucket. This is usually accomplished by adding a known amount of weight to each scale and reading the weight shown on the scale dial. For this purpose, a set of ten 22.6-kg (50-lb) weights is normally used.

The aggregate scale is unloaded and set to a zero reading. The ten 22.6-kg (50-lb) weights are hung from the scale, and the reading on the dial is recorded. The weights are removed, and 226 kg (500 lb) of aggregate is then added to the weigh hopper. The ten weights are again hung from the scale, and the next reading on the dial [452 kg (1,000 lb)] is recorded. The weights are removed once again, and an additional 226 kg (500 lb) of material is added. The weights are placed on the scale, and the next dial reading is recorded [678 kg (1,500 lb)]. This process continues [adding the weights, recording the dial reading, removing the weights, adding 226 kg (500 lb) of aggregate to the weigh hopper, and then repeating the sequence] until the capacity of the aggregate scale has been reached.

The same process is used for the asphalt cement weigh bucket, except that only one 22.6-kg (50-lb) weight is typically used. First the weigh bucket is unloaded and the scale set to a zero reading. Next, one 22.6-kg (50-lb) weight is hung from the scale, and the dial reading is recorded. Asphalt cement to a weight of 22.6 kg (50 lb) is then introduced into the weigh bucket. The 22.6-kg (50-lb) weight is placed back on the scale again, and the dial reading is recorded. An additional 22.6 kg (50 lb) of asphalt cement is added to the weigh bucket [for a total of 45.2 kg (100 lb)]. The procedure continues [adding the weight, recording the dial reading, removing the weight, adding 22.4 kg (50 lb) of asphalt cement, and then repeating the sequence] until the capacity of the asphalt cement weigh bucket scale has been reached.

For both scales, the actual dial reading after each set of weights has been added to the scale and the "theoretical" scale reading are compared. If the two readings are the same (within 0.5 percent), the scale is in calibration. If the two readings differ by more than that amount, the scale must be adjusted. Adjustments are made using the procedures provided by the scale manufacturer.

SUMMARY

The following factors should be considered when monitoring the operation of a batch plant:

- The moisture content of the aggregate when discharged from the dryer should be less than 0.5 percent and ideally less than 0.2 percent.
- The amount of carryover of the aggregate from one hot bin to the next should be relatively constant and generally less than 10 percent. Significant changes in the amount of carryover from one bin to the adjacent bin may result in a major change in the aggregate gradation in the HMA being produced.
- The screens should be checked regularly for holes and blinding.
- The pugmill should be operated at nominal capacity. Both overloading and underloading of the pugmill with aggregate will decrease the efficiency of the mixing process significantly. Batch size should be consistent from batch to batch. The paddle tips and the pugmill lining should be checked periodically to ensure that they are in good condition.
- The dry-mix time for the aggregate in the pugmill should be minimal—usually no more than 1 or 2 seconds.
- The wet-mix time for blending the asphalt cement and the aggregate should be no longer than needed to coat the aggregate properly and completely. For most batch plants, the wet-mix time can be as short as 27 seconds.
- Increasing the wet-mix time over the minimum needed to completely coat the coarse aggregate particles in the HMA increases the aging (oxidation or hardening) of the binder material, increases the wear on the pugmill components, reduces the production rate of the plant, and increases the cost of producing the mix.
- The plant operator must not idle the plant during the wet-mix cycle and should not do so during the dry-mix time. When the plant is waiting for trucks, there should be no material in the pugmill; the pugmill should "mix air."
- The total mix cycle time to produce and discharge a batch of mix, regardless of the size of the pugmill, may (and generally should) be as short as 35 seconds.
- If RAP is introduced into the plant at the bottom of the hot elevator, it should be placed on top of the superheated new material and not in the bottom of the buckets.
- If reclaimed material is charged into the weigh hopper, it should be placed in the center of the weigh hopper so that the hopper is balanced and an accurate weight can be determined.
- The temperature to which the new aggregate must be heated to obtain adequate heat transfer to the reclaimed material is a function of the amount of RAP used in the recycled mix, the amount of moisture in the RAP, and the mix discharge temperature. To prevent potential damage to the dryer, the new aggregate generally should not be heated to a temperature greater than 260°C (500°F). If the temperature of the new aggregate (as found in Table 8-1) is greater than this value for the amount and moisture content of the RAP, it will be necessary to reduce the percentage of RAP added to the recycled mix.

9 Parallel-Flow Drum-Mix Plants

This section is concerned with the processing of aggregate and asphalt cement in a parallel-flow drum-mix plant. The methods used to introduce the aggregate into the drum are first reviewed, followed by the operation of the burner system and the three-step heating, drying, and mixing process that occurs as the aggregate moves down the drum. The importance of the veil of aggregate across the whole cross section of the drum is stressed. Next, methods for introducing the asphalt cement into the drum and onto the aggregate are considered, as well as the systems used to deliver both mineral filler and baghouse fines into the drum. The addition of RAP into the drum, primarily by use of a split-feed system for the new aggregate and the RAP, is then discussed, followed by information on the factors that affect the production rate of the plant. Finally, the relationship between the mix discharge temperature and the exhaust gas temperature as it exits the drum is analyzed, as this information is used to determine the efficiency of the heat transfer process inside the drum mixer. The section ends with a summary of key factors to be considered in monitoring the operation of a parallel-flow drum-mix plant.

AGGREGATE ENTRY

There are two ways to introduce new aggregate from the charging conveyor. The first is by means of a charging chute located above the burner. The aggregate is delivered into a sloped chute and slides by gravity into the drum. The chute is angled to push the aggregate away from direct contact with the burner flame and toward the rear of the drum. The aggregate can also be deposited on a Slinger conveyor belt located beneath the burner. On some plants, the speed of this conveyor can be changed so that the aggregate can be deposited farther down the drum, away from the burner flame. Figures 9-1 and 9-2 show a rotating feed and a Slinger conveyor, respectively, for a counter-flow drum.

BURNER SYSTEM

The burner heats and dries the aggregate. Burners are rated by a Uniform Burner Rating Method that is based on eight criteria: (*a*) percent excess air, (*b*) percent leakage air, (*c*) percent casing (shell) loss, (*d*) fan gas temperature, (*e*) percent moisture removed from the aggregate, (*f*) mix discharge temperature, (*g*) use of No. 2 fuel oil, and (*h*) specific heat of the aggregate. The maximum output for the burner under these conditions can be found on the rating plate attached to each burner, although the actual operating conditions for the burner may differ from those used to rate the burner.

Fuel

Most burners are designed to burn more than one type of fuel with only minor changes in the burner settings. Three types of fuel are used: gaseous, liquid, and solid. Gaseous fuels include both natural gas and liquid petroleum gas. Liquid fuels include propane, butane, No. 2 fuel oil, heavy fuel oil (Nos. 4 through 6), and reclaimed oil. Pulverized coal and pelletized biomass are examples of solid fuels.

The fuel selected should be at the proper consistency for complete atomization at the time of combustion. No. 2 fuel oil will burn at ambient temperatures, without preheating, because it has a viscosity below 100 saybolt seconds universal (SSU). For proper atomization, heavy fuel oil, such as Nos. 5 or 6, must be preheated before burning to reduce the viscosity below 100 SSU and thereby atomize the fuel properly for its complete combustion. Some reclaimed oil, which has been filtered and dewatered, burns well. Other reclaimed fuel, contaminated with heavy metals, hazardous waste, or water, burns erratically and incompletely and generally should not be used in an HMA plant burner. Incomplete combustion is not normally a problem when gaseous fuels are used.

Unburnt fuel can cause difficulty with the burner, the plant, and the mix, and is a waste of money as well. It can cause clogging of the burner nozzle, difficulties in lighting the burner, and increased maintenance costs. Incomplete combustion can result in unburnt fuel entering the emission-control equipment—coating and blinding the filter bags in a baghouse (increasing the opportunity for a baghouse fire) or covering the wastewater pond surface with fuel if a wet scrubber system is used. In-

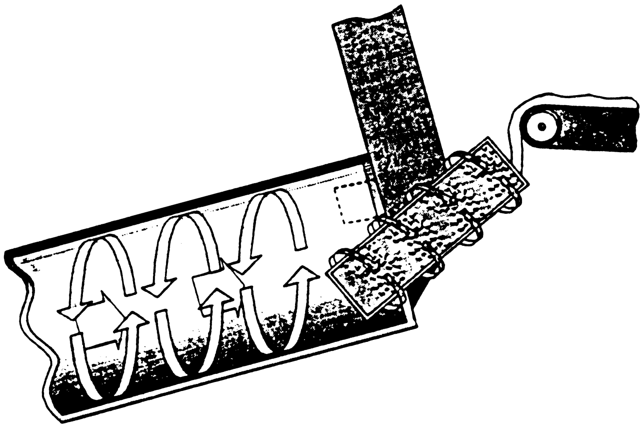


FIGURE 9-1 Typical rotating charging chute for delivery of new aggregate.

complete combustion also reduces the amount of heat available to dry the aggregate and thus increases fuel consumption and operating costs. Further, it can lower the temperature of the exhaust gases, which can result in condensation of the moisture (steam) in the baghouse.

Moreover, unburnt fuel can change the properties of the HMA. First, the fuel can decrease the viscosity of the asphalt cement binder material and reduce the amount of hardening the binder undergoes during the mixing process. The unburnt fuel can also impinge directly on the surface of the coarser aggregate particles, resulting in formation of a brown stain on the aggregate and softening of the film thickness of the asphalt cement on those surfaces. These two problems can affect the stiffness, stability, and strength of the asphalt mix produced.

Unburnt fuel problems can be recognized in several ways. A flame eye, which is an electronic device used to sense the color of the burner flame, can be employed to monitor the hue of the burner flame and shut the burner down if the color does not indicate complete combustion. A uniform, constant roar from the burner is usually a good sign (although it is possible to have a problem with unburnt fuel even when the noise of the burner is constant). In contrast, a coughing, sputtering, or spitting burner indicates possible incomplete combustion. If fuel is condensing on the filter bags, the pressure drop across the baghouse will increase, and the bags will be stained with fuel. When a wet scrubber system is used, the water in the wastewater pond surface will be covered with an oil sheen.

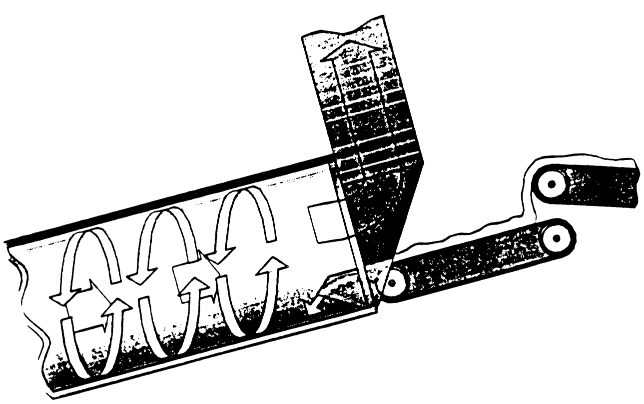


FIGURE 9-2 Typical Slinger conveyors for aggregate delivery.

Burners

The primary function of the burner is to blend the proper amounts of air and fuel to obtain complete combustion of the fuel. Two primary types of burners are used on aggregate dryers and drum mixers, either counter- or parallel-flow. First, many plants are equipped with a burner that requires from 30 to 45 percent of the air needed for combustion to be forced through the burner by a blower on the burner itself. The remaining 70 to 55 percent of the combustion air is pulled by the exhaust fan on the plant into the combustion zone around the burner. This type of equipment—a combined induced- and forced-draft burner—is shown in Figure 9-3. Some burners operate with all of the air needed for combustion being forced through the burner by a blower. This second type of burner, shown in Figure 9-4, is known as a forced-draft, total-air, or 100 percent air burner. These latter burners are generally much quieter than the first type and more fuel-efficient as well.

Some burners must be adjusted by the plant operator (*a*) as the amount of aggregate inside the dryer or drum mixer changes, (*b*) as the amount of moisture in the aggregate increases or decreases, and (*c*) as the aggregate discharge temperature is changed to control the drying and heating of the material. Most burners are equipped with an automatic device that controls the fuel input to maintain a relatively constant discharge temperature for the aggregate (or for the mix in a drum mixer).

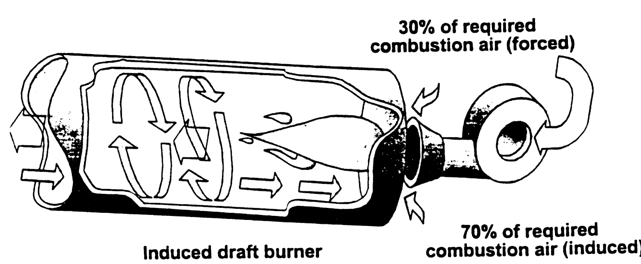


FIGURE 9-3 Combined induced- and forced-draft burner.

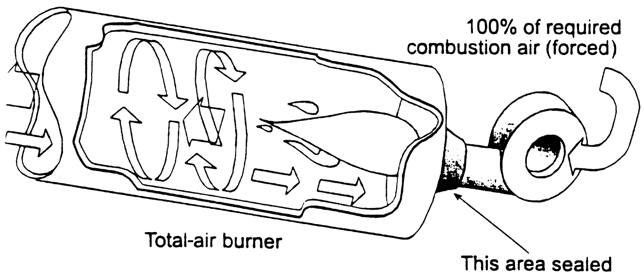


FIGURE 9-4 Forced-draft, total-air, or 100 percent burner.

A lack of either air or fuel will reduce the efficiency of the burner. Usually the availability of air is the limiting factor. The exhaust fan, besides providing the induced air, must also pull the moisture vapor (steam) created in the drying process and the products of combustion through the dryer or drum mixer. The capacity of this fan is a controlling factor in the heating and drying of the aggregate. The volume of the exhaust gases (air, moisture vapor, and combustion products) pulled by the fan is constant, depending on the setting of the damper in the system.

The efficiency of the system is also affected by air leaks. Because the fan pulls a constant volume of exhaust gases, at a constant damper setting, through the system from the burner and through the fan, any air that enters the system downstream of the burner reduces the amount of secondary air that can be pulled by the fan. Air leaks should be eliminated to provide the volume of air at the burner required to achieve complete combustion of the fuel. A damper, operated manually or automatically, should also be placed in the ductwork to control the amount of air entering the system.

HEAT TRANSFER PROCESS

Temperatures Inside the Drum

The temperature of the burner flame exceeds 1400°C (2,500°F). Exit gas temperatures for parallel-flow drum mixers are typically as much as 30°C (54°F) higher than exit mix temperatures. Exit gas temperatures higher than this could indicate improper flighting, and corrective actions should be taken. Typical temperature profiles for the exhaust gases and the aggregate along the length of the drum for parallel- and counter-flow drums are shown in Figures 9-5 and 9-6. The difference between the exhaust gas and mix discharge temperatures represents the efficiency of the heat transfer process and the amount of heat that is available to dry and heat the aggregate. Perfect heat transfer in a parallel-flow drum would require that the mix discharge and exhaust gas temperatures be equal at the point at which the mix is discharged from the plant.

Although a measure of the efficiency of the heat transfer process is obtained by comparing the mix discharge and exhaust gas temperatures at the time the gases exit the drum, it is often difficult to determine the temperature of the exhaust gases accurately at this location. The temperature differential is normally measured in the ductwork at a point between the end of the drum mixer and the entry of the exhaust gases into the emission-control equipment. This latter procedure is done by means of a thermocouple attached to the ductwork upstream of the point where the exhaust gases are drawn into the wet scrubber or baghouse system. For efficient operation of the drum mixer, the temperature of the exhaust gas before entry into the emission-control system should be within 10°C (20°F) of the mix discharge temperature.

It is generally not possible to compare the mix discharge temperature and the temperature of the exhaust gases at the point at which they exit the plant stack. If a wet scrubber is employed on the plant, the water used to impinge on the dust particles in the exhaust gases will naturally cool the gases. Moreover, for both wet scrubber and baghouse emission-control systems, any leakage air that is drawn into the ductwork and emission-control equipment between the end of the drum and the stack will reduce the temperature of the exhaust gases before they leave the stack. Thus the mix discharge and exhaust gas temperatures must be compared in the ductwork before the gases enter the emission-control equipment.

If the exhaust gas temperature in the ductwork is, say, 180°C (360°F) and the mix discharge temperature is 140°C (280°F), the veil of aggregate inside the drum is probably incomplete, and the drum is being operated inefficiently. Several problems result, including increased fuel use, possible separation of some of the very fine aggregate particles from the rest of the aggregate in the drum, and increased deterioration of the filter bags if a baghouse is used.

The temperature of the exhaust gases must also be controlled at the location where the asphalt cement is injected. Certain asphalt cements, depending on the source of the crude oil and the refining process used to produce the material, may contain small amounts of volatile material or "light ends" that can be driven off at temperatures as low as 330°C (600°F) and even much lower when moisture is present. Visible emissions can

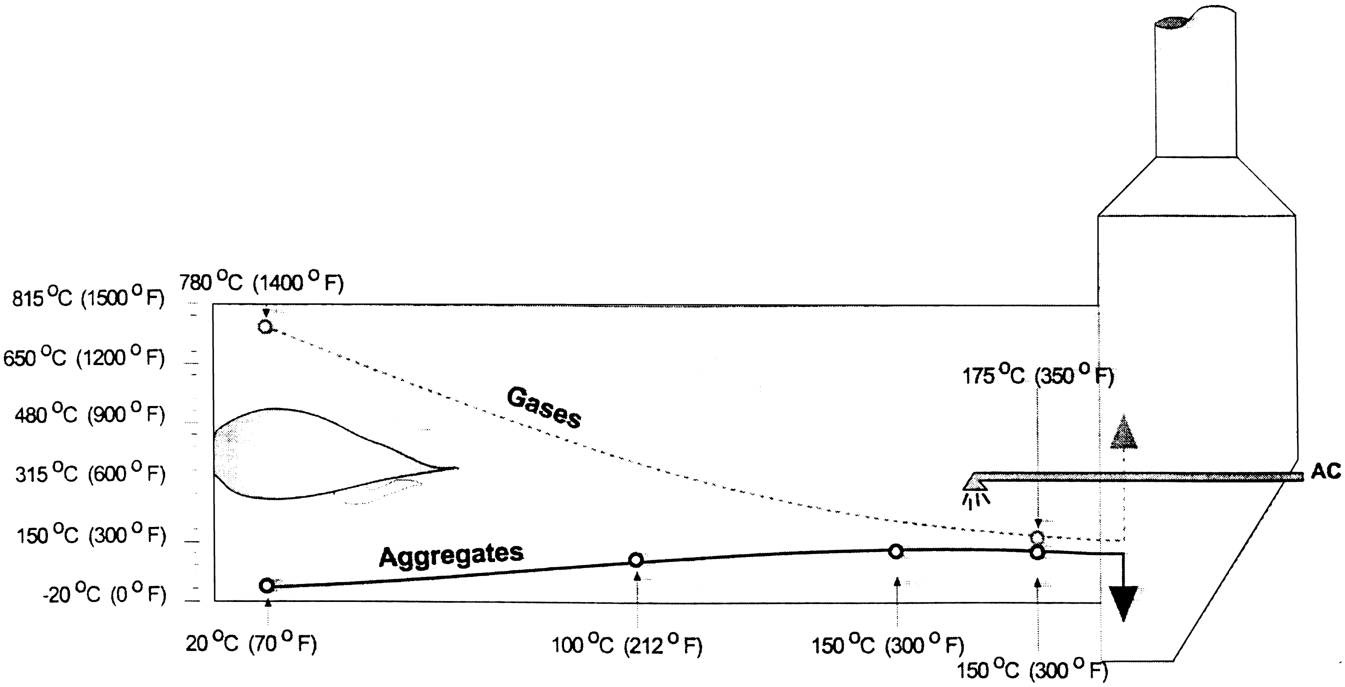


FIGURE 9-5 Temperature profile for parallel-flow drum drying aggregate.

be avoided if the temperature of the exhaust gases is below this value at the location where the asphalt cement enters the drum.

Exhaust gas temperatures will normally be higher when a recycled mix is being produced. These higher temperatures are related to the reduction in the density of the veil of aggregate upstream of the RAP entry point at the center rotary inlet and the resultant less-efficient heat transfer. The greater the amount of RAP used in the recycled mix, the less will be the amount of new aggregate, and the less complete the veil of material will be ahead of the RAP entry point. To prevent the production of visible emissions (blue smoke) during recycling, the temperature of the exhaust gases should be below

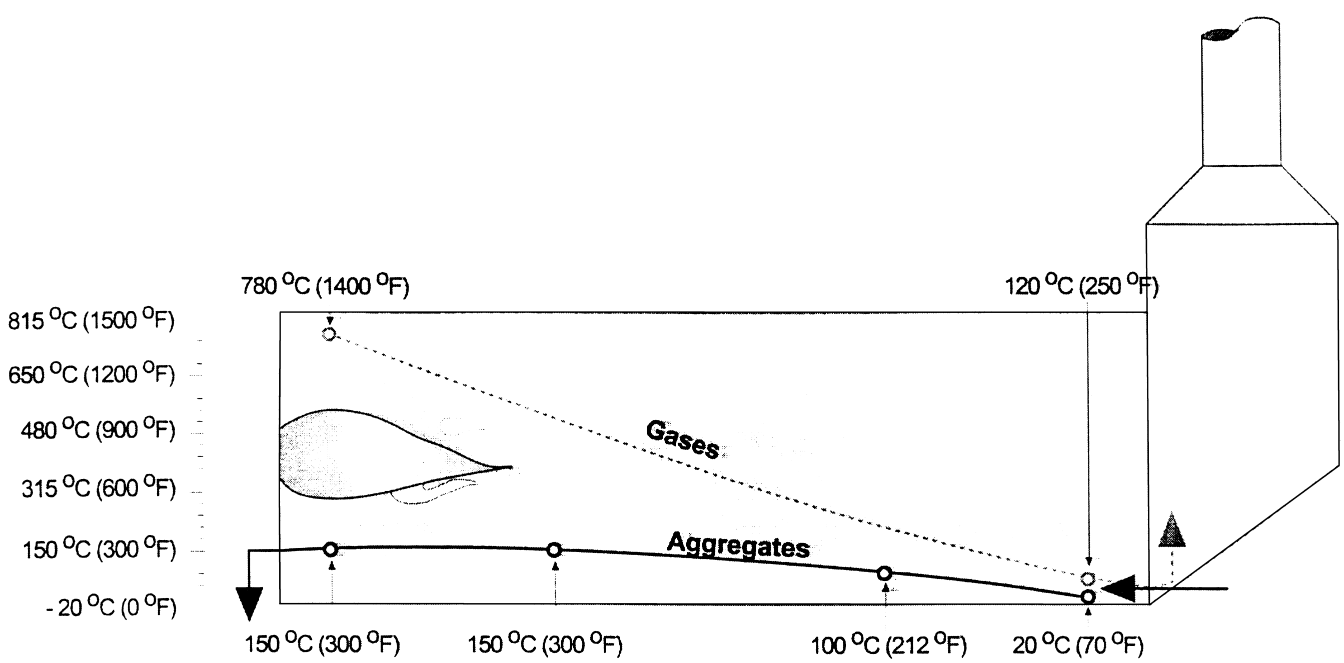


FIGURE 9-6 Temperature profile of counter-flow drum drying aggregate.

about 200°C (400°F) at the point at which the RAP enters the drum.

Flight Design

The aggregate fed into the burner end of the drum mixer moves down the length of the unit by a combination of gravity flow and the lifting flights as the drum rotates. Factors that affect the length of time required for an individual aggregate particle to pass through the drum include the length and diameter of the drum, the slope of the drum, the number and type of flights inside the drum, the speed of rotation of the drum, and the size of the aggregate particles. In general, it takes about 4 to 8 minutes for an incoming aggregate particle to reach the discharge end of the drum.

Each drum plant manufacturer uses a different pattern, shape, number, and location for the flights inside the drum. Although named differently by different manufacturers, the flights used in the various sections of the drum generally serve the same purposes: to expose the aggregate to the heat from the burner gases without dropping it through the flame, to remove the moisture from the aggregate, to coat the aggregate with asphalt cement, and to heat the coated material to the proper discharge temperature.

When a parallel-flow drum mixer is used, the burner flame should be short and bushy and not extend very far into the drum to protect the asphalt cement from high temperatures. The burner flame must have enough room, however, to expand and combust the fuel completely. The incoming aggregate cannot be deposited directly into the fire, or it will quench the flame. Thus the first flights at the upper end of the drum are used to direct the aggregate into the drum beyond the tip of the flame.

The next flights are used to lift some of the aggregate from the bottom of the drum and begin tumbling the material through the exhaust gases from the burner. As the aggregate moves down the drum, an ever greater amount of aggregate is lifted and tumbled. Near the midpoint of the length of the drum, a veil of aggregate is developed across the whole cross-sectional area. This veil is essential to accomplish the heat transfer from the exhaust gases so that the drying and heating of the aggregate can take place. The more complete the veil, the more efficient and effective the heat transfer process will be, the less fuel will be consumed, and the lower will be the particulate emissions from the plant.

Some drum mixers are equipped with devices, located near the drum midpoint, designed to retard the flow of aggregate down the drum. A ring inserted inside the drum reduces the diameter at that point. A buildup of aggregate occurs in front of the ring, creating a heavier veil of material. Some drum manufacturers install "kicker" or reverse-angle flights at this same location to intercept the aggregate and turn it back upstream, thus concentrating the aggregate in one location, increasing the density of the veil, and improving the heat transfer. Although restricting the diameter of the drum in some fashion is beneficial to increase the density of the veil of aggregate inside the drum, the reduced cross-sectional area also causes the velocity of the exhaust gases to rise, thereby potentially increasing the amount of fines carryout from the drum mixer.

Farther down the drum length, asphalt cement is injected into the drum, and mixing flights are used to combine the aggregate with the asphalt cement. These flights also allow the asphalt cement–coated particles to continue to be heated by the exhaust gases, complete the heat transfer process, and raise the mix temperature to the desired level for discharge. At the rear of the drum, discharge flights are employed to deposit the material into the discharge chute for transport to the surge silo.

As the flights wear from the abrasive action of the aggregate moving through the drum, the efficiency of the heating and drying process can be reduced. (The amount of wear on the flights depends on the operating conditions of the plant and the type of aggregate being processed.) Thus, the condition of the flights should be checked on a regular basis. Worn and missing flights should be replaced as necessary. In addition, if proper heat transfer is not being accomplished, the type and location of the flights inside the drum can be altered to improve the veil of aggregate moving across the cross section of the drum at its midpoint.

Early drum-mix plants were constructed with a 4:1 length-to-diameter ratio that was used for batch plant dryers; thus a dryer 2.45 m (8 ft) in diameter was 9.75 m (32 ft) in length. The recent trend is to use longer drums to obtain more complete heat transfer from the exhaust gases to the aggregate and reduce emission problems, particularly when a recycled mix is being produced. Some current drum mixers have length-to-diameter ratios of 5:1 and 6:1. Thus a drum mixer 2.45 m (8 ft) in diameter might be 12.19 to 14.63 m (40 to 48 ft) in length.

Increasing the Veil of Aggregate

Kicker flights, dams, donuts, or retention rings can be used to retard the flow of material down the drum and increase the density of the veil of aggregate. Another method for achieving the same effect is to lower the slope of the drum. The reduction in slope (from a maximum of 6.0 percent to a minimum of 2.5 percent) increases the dwell or residence time of the aggregate in the drum and thus provides more time to complete the heat transfer process. The additional aggregate retained in the drum because of the lower slope also causes a denser veil of material across the drum cross section, further improving the degree of heat transfer.

Lowering the slope of the drum does not normally cause a change in the plant production rate. An individual aggregate particle takes longer to travel through the drum when the slope is decreased, but the actual production rate is unchanged in terms of tonnes (tons) per hour. Power requirements for the electric motors used to turn the drum are increased 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.

Several manufacturers have developed drum mixers that change in diameter along their length: the drum is one diameter at one or both ends and a smaller diameter in the center. The change in diameter allows more room for combustion of the burner fuel and provides for development of a denser veil of aggregate in the drum by squeezing the same volume of material that was tumbling in a drum 2.60 m (8.2 ft) in diameter, for example, into a section 2.13 m (7 ft) in diameter, significantly increasing the density of the aggregate veil. In this case, the reduced diameter works in the same manner as the installation of a ring inside the drum. The heavier veil improves the efficiency of the heat transfer process. The velocity of the exhaust gases, however, also rises because of the smaller diameter, potentially increasing the amount of particulates carried out into the emission-control equipment and possibly reducing production levels as well.

Heat Transfer

While the exhaust gas temperature is being reduced as the gases move down the drum, the temperature of the aggregate is increasing as it travels in a parallel direction. The heat transfer process takes place in three ways: radiant, conductive, and convective. Radiant heat comes from the burner flame as aggregates pass under or over the flame. Conductive heat comes from contact with heated aggregate and the hot shell. Convective heat is transferred by the hot exhaust gases. The primary method of heat transfer is convective.

The aggregate enters the drum at ambient temperature, and radiant heat from the flame strikes the aggregate, which immediately begins to dry and heat. As the material moves down the drum, its temperature is increased until it reaches a point upstream of the drum midpoint, where its temperature remains relatively constant because the heat from the exhaust gases is being used to evaporate the moisture in the aggregate. The amount of time the aggregate temperature remains constant depends in part on the amount of moisture in the incoming material. The porosity of the aggregate is also a factor. Moisture in porous material takes longer to be removed from the internal pores. Fine aggregate (sand) is typically heated more quickly and gets hotter than coarse aggregate because of its greater surface area per kilogram (pound).

Once most of the moisture has been removed, the aggregate temperature begins to rise again. After the asphalt cement is injected, mixing flights are used in most drum-mix plants to tumble the mix, partially exposing the material to the exhaust gases. The mix reaches the required discharge temperature as it approaches the end of the drum. In summary, the aggregate increases in temperature until drying begins, the temperature remains relatively constant until the aggregate is dried, and then the temperature increases again as the aggregate proceeds down the drum.

The moisture content of the aggregate decreases gradually in the front portion of the drum and then more rapidly as the aggregate reaches the temperature required to vaporize water. If the dwell time in the central portion of the drum is long enough, the moisture content of the mix at discharge can be reduced to less than 0.1 percent. The moisture content of the mix at discharge should almost always be less than 0.5 percent, and ideally less than 0.2 percent.

ASPHALT CEMENT INJECTION

On a very few old parallel-flow drum-mix plants, the asphalt cement supply line enters from the front of the drum, at the burner end. The diameter of the pipe used depends on the capacity of the plant, with a diameter of 50 to 100 mm (2 to 4 in.) being typical. The asphalt cement is not normally sprayed through a nozzle, but injected into the drum merely by flowing out of the end of the pipe. The actual point of discharge varies but tends to be between the midpoint and about two-thirds of the way down the drum length from the burner.

One advantage of early asphalt cement introduction is quick capture of the dust particles in the aggregate by the binder material. This action reduces the amount of particulate carryout by encapsulating the fines in the asphalt cement. There are, however, three disadvantages: (*a*) the asphalt cement may be hardened more by exposure to the higher-temperature exhaust gases, (*b*) the production of blue smoke (visible stack emissions) from volatilization of the light ends from certain asphalt cements can be increased because of these higher exhaust gas temperatures, and (*c*) an increase in the moisture content of the mix at discharge may occur because the asphalt cement coats the aggregate particles before all the water in the material has been removed. These disadvantages of the system outweigh its advantages. Thus it is not good practice to inject the binder material near the burner end of the mixing drum.

On most parallel-flow drum-mix plants, the asphalt cement is injected through a pipe 100 mm (4 in.) in diameter, entering from the rear of the drum (see Figure 9-7). In many cases, the location of the asphalt cement entry is at a point approximately 40 to 30 percent of the length of the drum from the mix discharge end (60 to 70 percent of the length of the drum from the burner end). At this location, the small amount of moisture remaining in the aggregate causes the volume of the binder to expand by foaming and helps coat the aggregate. 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 of the aggregate is still high at the point where the asphalt cement is injected, the coating of the aggregate particles may be delayed until more moisture is removed.

If the asphalt cement being used contains volatile material, resulting in excessive blue-smoke emissions, it may be necessary to move the asphalt cement supply pipe toward the mix discharge end of the drum. This change will reduce the exposure of the asphalt cement to the higher-temperature exhaust gases and decrease the generation of visible hydrocarbon emissions. If the veil of aggregate at the midpoint of the length of the drum is adequate, however, it should not be necessary to move the asphalt cement line back. Moving the supply line can decrease the uniformity of the coating of the binder on the aggregate if the line is placed too close to the discharge end of the drum.

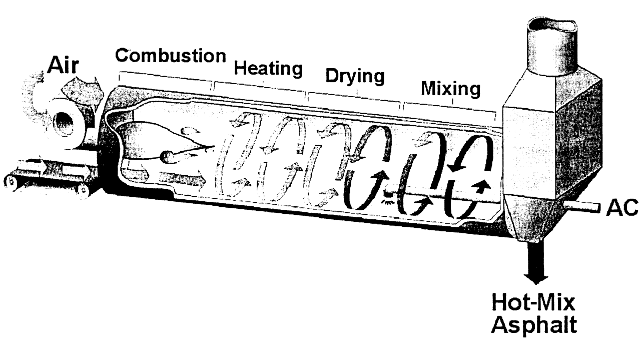


FIGURE 9-7 Parallel-flow drum-mixer zones.

In some drum-mix plants, however, the asphalt cement injection line is completely removed from the drum. The aggregate is heated and dried in the drum but exits uncoated. The aggregate is discharged into a single- or twin-shaft coater unit (screw conveyor), where the asphalt cement is injected (see Figure 5-6 in Section 5). The mixing of the materials occurs as the aggregate and asphalt cement move along the screw conveyor. The blended material is then deposited into a transfer device for transport to the surge silo. The drum-mix coater unit is basically a means to keep the asphalt cement out of the high-temperature exhaust gas stream and thus prevent the generation of visible emissions.

Because of problems in completely coating the coarse and fine aggregates during the very short time they are in the screw conveyor coater unit (not enough mixing time and mixing action), many plants with these units have been modified by the contractor to place the asphalt cement injection pipe back up inside the drum a short distance. This practice results in a longer mixing time for the binder material and the aggregate and thus more complete aggregate coating.

MINERAL FILLER AND BAGHOUSE FINES FEED SYSTEM

Two types of aggregate fines—commercial mineral filler and baghouse fines—can be fed into a drum-mix plant, either individually or in combination. The basic equipment needed to handle each type of material is essentially the same. The primary difference among the various systems relates to the degree of sophistication in the controls used to meter the materials.

Mineral Filler

Mineral filler, such as hydrated lime, portland cement, fly ash, or limestone dust, is stored in a silo or other appropriate container and delivered to the plant through a vane feeder system or small weigh hopper located at the bottom of the silo. The speed of the feeder is related to the amount of new and reclaimed aggregate being delivered to the drum. The silo is normally equipped with an aerating system to keep the mineral filler from packing into a tight mass and bridging the opening to the feeder. If the flow of filler is restricted, the vane feeder will still rotate, but no material will be sent to the plant.

The mineral filler can be delivered to the charging conveyor on the cold-feed system and delivered into the drum as part of the aggregate. This practice is not recommended, however. First, there is a problem of dusting of the filler material when it is deposited on the incoming aggregate. Second, the very fine filler has a tendency to become airborne easily inside the drum (picked up in the exhaust gas stream) and carried either to the discharge chute on the drum or into the emission-control equipment. Thus, some of the filler can be carried out of the drum mixer instead of being incorporated into the mix.

It is also possible to blend the mineral filler with the asphalt cement in the storage tank before the combined materials are fed into the plant. This is rarely done, however, because of problems of separation and settlement of the heavier mineral filler (higher specific gravity) from the lighter asphalt cement whenever plant production is interrupted.

The mineral filler from the vane feeder thus typically enters the delivery pipe and is conveyed pneumatically through the line and into the rear of the drum. The filler is discharged in one of two ways. It can be deposited from the line onto the aggregate at the bottom of the drum or fed into a mixing device, where the mineral filler and asphalt cement are mixed before being dropped into the drum.

If the mineral filler is discharged directly into the drum mixer, this can be done either upstream or downstream of the asphalt cement injection point. If the filler is discharged into the drum upstream of the asphalt cement entry point, it is usually dropped directly on the aggregate in the bottom of the drum because the filler is dry and of very small particle size. If lifted into the exhaust gas stream, a major portion of the material, depending on drum operating conditions, may be carried out of the drum and into the emission-control equipment.

If the mineral filler is discharged from its feed pipe into the drum after the asphalt cement has been injected into the drum mixer, a greater portion of the filler is usually captured by the asphalt cement. The mineral filler has less chance of becoming airborne and being carried out of the drum. If the mineral filler and asphalt cement are blended in some form of mixing device as the asphalt cement is being introduced into the drum, minimal carryout of the filler material normally occurs.

Baghouse Fines

If a baghouse (fabric filter) is used as the emission-control equipment on the plant, either all or a portion of the material captured can be fed back into the drum mixer. The fines captured in the baghouse are carried, usually by a screw conveyor, through an air lock and then fed pneumatically through a pipe into the rear end of the drum, as seen in Figure 9-8.

The baghouse fines typically are not metered, but are returned on a continuous basis and discharged into the drum in a fashion similar to that of mineral filler. Occasionally a surge of fine material may be carried back to the drum mixer. If plant operating characteristics cause such surges of baghouse fines to occur regularly, the fines should be collected in a small surge silo and then metered back into the plant using a vane feeder system. If the baghouse fines are not needed to satisfy mix design requirements, they can be wasted instead of being returned to the mix.

The returned fines must be incorporated into the asphalt mixture and not allowed to recirculate back to the

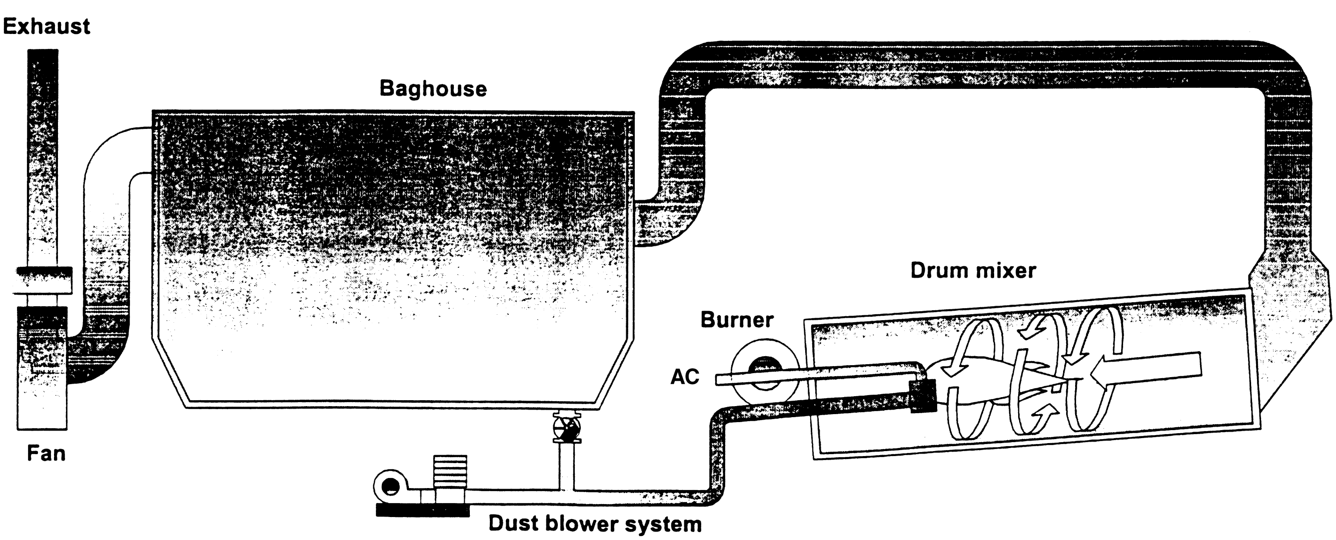


FIGURE 9-8 Pneumatic transfer to mixing area of drum.

baghouse. This is accomplished by ensuring that the fines are kept out of direct contact with the high-velocity exhaust gases and are quickly 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 fines, because new fines are continually being generated inside the plant. The baghouse will become plugged and will not operate properly. It is therefore essential that, as with mineral filler, baghouse fines be coated with asphalt cement before being picked up by the exhaust gases and carried out of the mixer.

The amount and gradation of the baghouse fines returned to the asphalt mix inside the drum can have a significant effect on the properties of the mixture produced.

RECLAIMED ASPHALT PAVEMENT RECYCLING SYSTEMS

Single-Feed Systems

Because of inherent emission-control problems involved in using single-feed systems, split-feed systems, in which the RAP is fed to the drum mixer separately from the new aggregate, are used most commonly to produce recycled asphalt mixes. On the few remaining plants that use a single-feed system to deliver both the new aggregate and the RAP to the burner end of the drum mixer, several methods are used, alone or in combination, to protect the asphalt-coated material from direct contact with the flame and to reduce the generation of visible hydrocarbon emissions.

One method is to spray water on the combined aggregate on the charging conveyor before it enters the drum. The degree of protection offered by the additional water on the surface of the aggregate depends on the amount of moisture already in and on the reclaimed material, the amount of water applied (typically between 1 and 4 percent by weight of reclaimed aggregate), and the position of the reclaimed material on the charging conveyor—underneath or on top of the new aggregate.

Another method involves use of a heat shield to reduce the contact of the combined aggregate with the flame. This device spreads the flame out around the circumference of the drum and decreases the concentration of heat at any one point near the flame. The performance of the heat shield is dependent on its location inside the drum, the amount of RAP in the mix, the moisture content of new and reclaimed aggregate, and the required mix discharge temperature. The efficiency of the heat shield can be determined by the amount of blue smoke that is generated during the recycling operation.

Split-Feed Systems

With a split-feed system, the new aggregate is delivered to the burner end of the drum-mix plant in a conventional manner. The RAP is delivered into a separate entry point near the midpoint of the drum length, as shown earlier in Figure 5-6.

A variety of designs are employed for the intake system used to introduce the RAP into the drum. Typically, the drum has a series of ports or entry chutes cut into the shell to allow the RAP to be introduced from the charging conveyor as the drum turns. At the point at which the RAP enters the shell, a short length of the flighting is often removed or configured so that the asphalt-coated material can easily be added to the new aggregate. The RAP begins heating as soon as it enters the port. The combined aggregate is picked up by the flights, and the heating and drying of the new material and the RAP continue.

When RAP is charged into the drum at its midpoint, less new aggregate is placed into the drum at the burner end, reducing the density of the veil of aggregate upstream of the RAP entry and decreasing the amount of heat transferred from the exhaust gases to the new aggregate. Thus the temperature of the gases at the point at which they come in contact with the RAP is higher, and there is a greater chance of burning off the asphalt coating on the RAP. This problem increases in severity as the amount of RAP used in the recycled mix increases and the amount of new aggregate decreases accordingly. Methods for reducing the exhaust gas temperature involve increasing the density of the veil of new aggregate upstream of the RAP entry location, as well as raising the temperature of the RAP before it comes into contact with the heated new aggregate.

Normally, if 20 percent or less RAP is being incorporated into a recycled mix and a split-feed system is used, minimal hydrocarbon emissions are produced, depending on the adequacy of the veil of new aggregate inside the drum and the discharge temperature of the mix. As the percentage of RAP rises and the moisture content of the RAP increases, there is a greater potential for emission problems. When the amount of RAP used exceeds 50 percent by weight of mix, the emission of blue smoke during the recycling process can become significant. A combination of procedures, outlined above, is needed to ensure adequate heat transfer from the exhaust gases to the new aggregate before those gases come in contact with the RAP.

Only under ideal and carefully controlled production conditions may it be possible to incorporate over 50 percent RAP in a recycled mix without a major problem with visible emissions. Because of the reduced production rates and emission-control problems that occur when high percentages of RAP are used in a recycled asphalt mix, it is normally good practice to limit the amount of reclaimed material processed through a split-feed drum-mix plant to approximately 50 percent of the total aggregate weight. In most cases, the amount of RAP actually used is much less than 50 percent of the total mix weight.

PRODUCTION RATES

HMA drum-mix plants are rated by the number of tonnes (tons) of mix that can be produced per hour. The production capacity is usually related to the incoming aggregate temperature, the mix discharge temperature, the specific heat of the aggregate, and an average aggregate moisture content removal of 5 percent for a plant operated at sea level. Plant capacities are also affected by a number of other variables, including drum diameter, fuel type, exhaust gas velocity, capacity of the exhaust fan, amount of excess air at the burner, estimated air leakage into the system, and atmospheric conditions. Aggregate gradation may be a factor with mixes containing a large percentage of coarse aggregate because such mixes are more difficult to heat uniformly than mixes incorporating a balance of coarse and fine aggregate particles.

One of the variables that has the greatest effect on the plant production rate is the average moisture content of the coarse and fine aggregates. The moisture content of the fine aggregate is usually higher than that of the coarse aggregate. The average moisture content is thus a function of the amount of moisture in the coarse aggregate and its percentage in the mix, plus the amount of moisture in the fine aggregate and its percentage in the mix.

If, for example, 60 percent of the mix consists of coarse aggregate with 3.0 percent moisture and 40 percent of the mix is fine aggregate (with 8.0 percent moisture), the moisture content of the combined aggregate is 5.0 percent. If the fine aggregate moisture is reduced to 6.0 percent, the moisture in the cold feed entering the drum is reduced to 4.2 percent. 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 becomes larger. The theoretical relationship among average moisture content, drum diameter and length, and calculated drum-mix plant production rate [at a mix discharge temperature of 132°C (270°F)] is shown in Table 9-1 for different models of one particular make of plant, at a given volume of exhaust gas flow and set of operating conditions for each size of plant. Similar charts are available from manufacturers of other makes of drum mixers.

Table 9-1 indicates that at an average moisture content of 5 percent, a drum-mix plant having a diameter of 1.8 m (6 ft) has a theoretical production capacity of 143 tonnes (158 tons) of mix per hour. If a drum 2.44 m (8 ft) in diameter is used, the manufacturing rate increases to 276 tonnes (305 tons) of mix per hour. For a drum mixer 3.0 m (10 ft) in diameter, the capacity increases to 492 tonnes (541 tons) of mix per hour at 5 percent moisture removal.

As the moisture content in the aggregate decreases from 5 to 3 percent, the production rate for a drum mixer

TABLE 9-1 Nominal Drum-Mix Capacities

Drum Diam. & Length (ft)	Capacity (Tons per Hour) for Surface Moisture Removed (%)								
	2	3	4	5	6	7	8	9	10
5 × 22	178	140	116	100	84	79	74	63	58
6 × 24	278	220	178	158	137	121	116	100	89
7 × 30	420	336	273	236	205	184	163	147	137
8 × 32	541	430	352	305	263	236	210	194	173
9 × 36	719	578	478	410	357	315	284	257	236
10 × 40	956	761	630	541	473	430	378	341	315

NOTE: Figures for each size of dryer are for asphalt concrete mix capacities. Examples of the effects of moisture content on plant production rates are for one manufacturer's drum-mix plants. 1 ft = 0.305 m; 1 ton = 0.907 tonne.
SOURCE: Barber-Greene.

that is 2.4 m (8 ft) in diameter increases from 276 tonnes (305 tons) per hour to 391 tonnes (430 tons) of mix per hour. If the aggregates have a higher moisture content (for example, 8 percent), a drum mixer of the same 2.4-m (8-ft) diameter can produce only 191 tonnes (210 tons) of asphalt mix per hour. Thus the average moisture content of the aggregate directly affects the capacity of a drum-mix plant.

The mix discharge temperature, held constant at 132°C (270°F) in the example above, 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 that can be manufactured in a given period of time increases. Figure 9-9 shows that for a drum-mix plant from one manufacturer that is 2.2 m (7.3 ft) in diameter and 8.5 m (28 ft) in length, with 5 percent moisture removal, the production rate increases from 232 tonnes (255 tons) per hour at a mix discharge temperature of 149°C (300°F) to 273 tonnes (300 tons) per hour at a temperature of 121°C (250°F). When the moisture content of the incoming aggregate is relatively high, the production rate changes are not as great when the mix discharge temperature is decreased. At 8 percent average moisture content, the production capacity of the same plant increases from 159 to 182 tonnes (175 to 200 tons) per hour as the mix discharge temperature decreases from 149°C (300°F) to 121°C (250°F).

The production rate of a drum-mix plant is also affected by the volume and velocity of the exhaust gases being pulled through the system by the exhaust fan. As the volume and velocity of the gases decrease, the production capacity of the drum mixer is reduced.

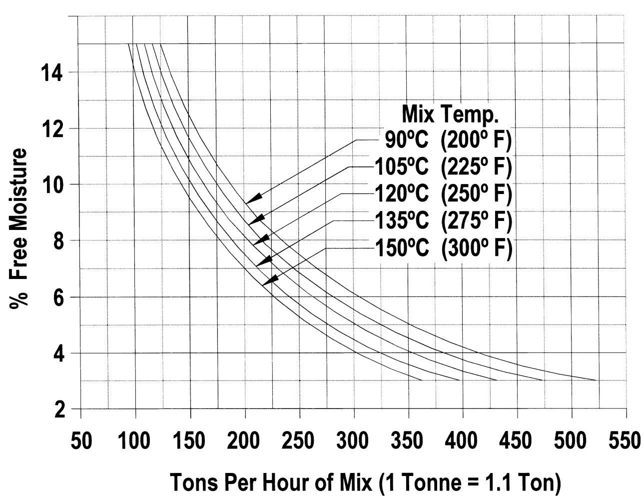


FIGURE 9-9 Effect of moisture content and mix discharge temperature on drum-mix plant production rate.

For those plants that operate with a split-feed system, the production rate of recycled mixtures is also a function of the volume of RAP being fed into the drum mixer. As the amount of RAP delivered to the drum surpasses 50 percent of the total aggregate feed, the capacity of the plant is decreased, as shown in Figure 9-10 for one particular make of drum-mix plant. This decrease is caused by the lack of an adequate amount of new aggregate in the upper end of the drum mixer to provide for proper heat transfer from the burner exhaust gases to the new aggregate. This, in turn, reduces the heat transferred from the new aggregate to the RAP.

Figure 9-10 shows that a recycled mix made up of 60 percent RAP and 40 percent new aggregate, with a weighted moisture content in the combined materials of 5 percent, has an index number of approximately 0.70. The index number means that this plant can produce only 70 percent as much mix per hour, at a 60/40 blend of RAP and new aggregate, as could be produced if the same plant used all new aggregate. Thus, if the plant could manufacture 280 tonnes (308 tons) per hour with 100 percent new material at 5 percent moisture removal, it would theoretically have a capacity of only $280 \times 0.70 = 196$ tonnes ($308 \times 0.70 = 216$ tons) per hour if 60 percent RAP were incorporated into the mix. As the amount of RAP used in the recycled mix increases above 50 percent, the amount of mix that can be produced in a drum-mix plant is reduced proportionately.

The index number provides a means of estimating the effect of the introduction of RAP into the drum mixer on the production rate of the plant. The actual production rate of a drum-mix plant will depend on a variety of factors, including the volume of gases being pulled through the system and the temperature of those gases. In addition, several of the newer types of continuous-mix plants,

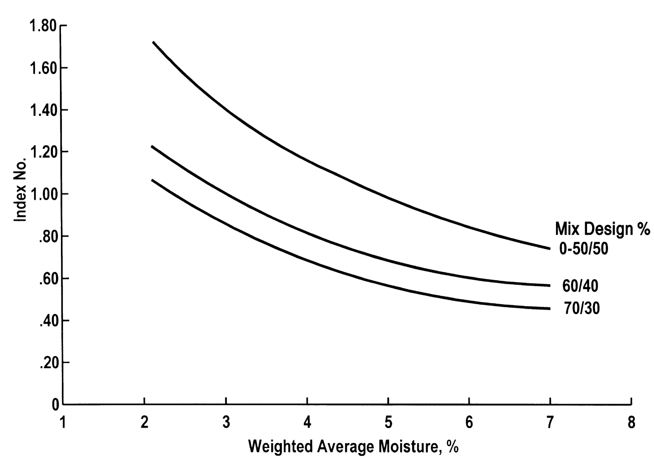


FIGURE 9-10 Effect of amount of RAP on drum-mix plant production.

such as the counter-flow drum mixers (see Section 10), are generally more efficient in heat transfer and thus can process amounts of RAP above 50 percent with less effect on the plant production rate.

PLANT EFFICIENCY

A plant should be operated at the most efficient production rate, irrespective of demand; it should be shut down when the silos are full and restarted when mix is needed once again. There are two methods of judging the efficiency of operation of a parallel-flow drum-mix plant: (*a*) determining the differential between the temperature of the mix upon discharge and that of the exhaust gases at the same point, and (*b*) observing the asphalt mixture as it is discharged.

Mix and Stack Temperatures

If perfect heat transfer could take place inside the drum, the temperature of the mix upon discharge from the parallel-flow drum-mix plant would be equal to the temperature of the exhaust gases at the same point (see also the earlier discussion of the heat transfer process). This equilibrium point would mean that the heat transfer was in balance and the drum mixer was running at maximum possible heat transfer efficiency. Under normal operating conditions, if the veil of aggregate inside the drum is complete, the exhaust gas temperature measured at the drum exit or before the gases enter the emission-control system should be within 10°C (18°F) of the temperature of the mix (assuming that no leakage occurs and no cooling air is added in the ductwork between the end of the drum and the point at which the gas temperatures are measured in the ductwork). Thus, if the mixture discharge temperature is 140°C (285°F), the measured exhaust gas temperature should be less than 150°C (300°F). This small temperature differential implies that the drum mixer is operating efficiently and that minimum fuel per tonne (ton) is being burned.

Exhaust gas temperature higher than about 10°C (18°F) above the mix temperature indicates that the heat transfer process inside the drum is not as efficient as it could be, primarily because of the lack of a uniformly dense veil of aggregate throughout the cross section of the drum. Temperature differentials of up to 55°C (98°F) between the mix and the exhaust gases are sometimes found, indicating that the plant is not being maintained or operated properly and that emission control might be a problem. The degree of operating inefficiency is related to the difference between the two temperatures (mix discharge and exhaust gas) before entry into the emission-control system.

During production of a recycled asphalt mixture in a single-feed drum mixer, the heat transfer between the exhaust gases and the new and reclaimed aggregates should be similar to that for a mixture using all new material. Thus for this process, the exhaust gas temperature should be within the 10°C (18°F) temperature differential if the plant is operating correctly. If a split-feed system is being employed, the difference between the two temperatures may be greater than 10°C (18°F), depending on the proportion of RAP introduced at the center inlet point. As a higher percentage of RAP is incorporated in the recycled mix, the temperature differential increases. When 50 percent of the recycled mix consists of RAP, the temperature of the exhaust gases may be more than 40°C (72°F) above the mix discharge temperature.

The efficiency of the heating and drying operation, therefore, can be judged in part by observing the temperature differential between the mix leaving the drum and the exhaust gases measured in the ductwork. Because both temperatures are usually recorded continuously and displayed on the plant control console, this method of monitoring the plant production process is easy to implement.

High exhaust gas temperatures can also lead to significant, premature corrosion on one side of the ductwork between the discharge end of the drum mixer and the primary collector. This corrosion is another reason why the efficiency of the plant operation needs to be monitored, and the temperature of the exhaust gases at the time they exit the drum mixer must be controlled.

Mix Discharge Monitoring

A second way to judge the efficiency of the drum-mix plant operation is to observe the asphalt mixture as it is discharged from the drum. The appearance of the mix, 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 finer aggregate particles should be evenly distributed throughout the mixture.

If the fuel used by the burner is not being completely combusted, the coarser aggregate particles in the mix may appear to be covered with a dark brown stain instead of with the proper film thickness of asphalt cement. In addition, the adhesion of the asphalt cement binder to the aggregate may be reduced, and the mix will have an increased tendency to strip when tested for potential moisture damage.

If the veil of aggregate inside the drum is not complete, the exhaust gases will travel down one side of the drum, depending on which direction the drum is turning, at a higher velocity than on the other side of the drum. Fine dust-sized particles will be picked up in the exhaust gas stream and carried to the rear of the drum. As the exhaust gases change direction to enter the ductwork, the larger dust particles will drop out of the gas stream. These uncoated particles will be 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 HMA discharge chute thus indicates 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 mixer, it is possible for very fine material to be picked up in the exhaust gases shortly after it is charged into the plant. When the aggregate veil is proper, the fine material will be trapped in the tumbling mass of aggregate and incorporated into the mix. If the aggregate veil is incomplete, however, the powdered material may be carried down one side of the drum and then dropped into the bottom of the drum at the mix discharge point, depending on the size of the particles relative to the exhaust gas velocity. The powdered lime will then be visible on one side of the asphalt mixture as it is discharged from the drum. Thus this method of adding mineral filler should not be used unless that filler is well blended with the incoming aggregate before the two materials are charged into the drum mixer.

Typically, a high stack temperature relative 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 efficiently. The plant operator should alter the production process to achieve a denser veil of aggregate in the drum.

SUMMARY

The following key factors should be considered when monitoring the operation of a parallel-flow drum-mix plant:

- The sound of the burner should be monitored. A uniform, constant roar is desirable. A coughing, sputtering, or spitting sound may mean that the burner is not able to properly and completely combust the fuel it is trying to burn. Brown stains or a reduced asphalt cement film thickness on the coarser aggregate particles at the discharge end of the drum mixer also indicates problems with unburnt fuel.
- The density of the veil of aggregate inside the drum near the midpoint of its length is the key to efficient operation of the drum mixer and economical fuel usage. The completeness of the veil can be determined from a comparison of the discharge temperature of the mix with that of the exhaust gases at the stack. The stack temperature should be no more than 10°C (18°F) higher than the mix discharge temperature if the veil of aggregate inside the drum is complete across the cross-sectional area of the drum (assuming that no cooling air is added in the emission-control system). Greater temperature differentials indicate that the plant is not being operated efficiently.
- The presence of light-brown, uncoated fine aggregate on one side of the mix in the discharge chute is also an indication that the veil of aggregate is incomplete across the drum circumference.
- The generation of visible hydrocarbon emissions from the stack further indicates that the temperature of the exhaust gases inside the drum is too high at the point where the asphalt cement is injected into the drum.
- The density of the veil of aggregate inside the drum can be increased through the use of kicker flights, dams, donuts, or retention rings near the midpoint of the drum length. The density can also be increased by lowering the slope of the drum to increase the dwell or residence time of the aggregate in the drum.
- Mineral filler or baghouse fines should be added through the mix discharge end of the drum. These materials should be coated with asphalt cement or captured in the mix before they are exposed to the exhaust gases moving down the drum.
- If RAP is added to the drum through a split-feed system, the difference between the mix discharge temperature and the exhaust gas temperature measured at the stack will typically be greater than 10°C (18°F) and will usually increase roughly in proportion to the amount of RAP added to the mix.
- The plant production rate is determined at a given mix discharge temperature and an average moisture content in the aggregate, usually 5 percent, at a given elevation (sea level). An increase in the moisture content or an increase in the mix discharge temperature will decrease the capacity of the drum mixer in terms of tonnes (tons) of mix produced per hour.
- Production rates for recycled HMA, up to a RAP content of 50 percent, will normally be similar to the production rates for mixes containing all new aggregate. Above that amount of reclaimed material per ton of mix, the production rate of the parallel-flow drum mixer will decrease as the amount of reclaimed material increases.

10 Counter-Flow Drum-Mix Plants

In this section the processing of aggregate and asphalt cement inside a counter-flow drum-mix plant is addressed. This type of plant, developed in the early 1930s, has replaced the parallel-flow drum-mix plant in recent years as the primary type of plant purchased by contractors to manufacture HMA. The counter-flow drum-mix plant is essentially a counter-flow aggregate dryer similar to that used to heat and dry aggregate for a batch plant operation, with a mixing unit attached in one of two primary ways to the end of the dryer. The methods used to introduce the aggregate into the drum, the operation of the burner, and the heating and drying of the aggregate as it moves through the drum against the direction of the exhaust gases from the burner are reviewed first. The operation of the mixing unit is then described, including the introduction of the hot aggregate, the RAP, and the asphalt cement binder. The blending of the mix components is also reviewed. The section ends with a summary of the key factors that should be considered in monitoring the operation of a counter-flow drum-mix plant.

Two different types of counter-flow drum-mix plants are commonly marketed. The first, more conventional plant, shown earlier in Figure 5-7, has the mixing unit extended on the end of the aggregate dryer portion of the drum. The second type, a double-barrel plant shown in Figure 5-8, has the mixing unit folded back around the aggregate dryer portion of the drum. Both styles of plant accomplish the same processes—heating and drying the aggregate; adding mineral filler, baghouse fines, and RAP, as needed; adding the asphalt cement binder material; and mixing all of the components together to produce a high-quality HMA product.

AGGREGATE ENTRY, HEATING, AND DRYING

The aggregate enters the counter-flow drum-mix plant from the upper end of the drum, similar to the entry used for a batch plant dryer as discussed in Section 8. The aggregate normally is delivered into a sloped chute by the charging conveyor and slides by gravity into the drum. A Slinger conveyor system may be used to feed the aggregate into the drum. On some plants, a rotating chute is employed to ensure that the aggregate does not hang up during introduction into the drum.

On the conventional counter-flow drum-mix plant with the mixing unit extended behind the aggregate dryer portion of the drum (Figure 5-7), the burner head is embedded into the rotating drum. Although the burner itself is located outside the drum, the burner fuel does not ignite and burn until it reaches the burner head. All the air needed to combust the fuel is delivered through the burner. Additional air is drawn into the drum by the exhaust fan through a tube that surrounds the burner assembly and protects the burner from damage by the aggregate. Figure 5-7 shows the burner head as the aggregate moves downstream toward the burner, with the exhaust gases moving in the opposite direction.

On the double-barrel type of counter-flow drum mixer, the burner location is similar to that on a normal counter-flow aggregate dryer. The burner is a total-air burner, as discussed in Section 9 and shown in Figure 9-4. The position of the burner on this type of plant is seen in Figure 5-8.

The heating and drying of the aggregate are accomplished as the combined coarse and fine aggregate material moves through the dryer by the action of the rotating flights and gravity. The burner is located at the lower or discharge end of the drying unit, and the aggregate moves toward the burner as it travels through the drum. The exhaust gases from the burner move upstream, in the opposite direction to the flow of the aggregate. As the aggregate moves toward the burner and continues to heat, the moisture is removed from the surface of the aggregate particles. The internal moisture in the aggregate pieces is driven out, and the heating of the aggregate continues until the required aggregate discharge temperature is obtained.

If RAP is to be added to the new aggregate, the temperature of the new aggregate is increased to the level necessary to permit adequate heat transfer between the superheated new aggregate and the ambient-temperature reclaimed material. This practice is similar to the additional heating of the new aggregate when RAP is to be used in a batch plant mixing process (see Section 8).

In contrast with a parallel-flow drum-mix plant, no asphalt cement binder material is added inside the drying portion of the counter-flow drum mixer. The initial section of the drum is a dryer only. No material—mineral filler, baghouse fines, or RAP—is added upstream of the burner.

MIXING UNIT

Conventional Counter-Flow Drum

For the counter-flow unit in which the burner is embedded into the drum and the mixing occurs as an extension of the operation of the drying drum, the heated and dried aggregate passes over a dam or retention ring located just behind (downstream of) the burner head. A series of openings or ports is typically used to permit the aggregate to pass into the mixing unit.

Once the heated aggregate has entered the mixing chamber of the drum, the RAP, if used, is added to the new aggregate. Because the RAP is introduced into the drum behind the burner, it is not exposed to the burner flame. For this reason, hydrocarbon emissions are not a problem, as they can be with a parallel-flow drum mixer. Heat transfer from the new aggregate begins as soon as the two materials come together at the upper end of the mixing unit. Moisture contained in the RAP is pulled out of the mixing unit and around the burner by the exhaust fan. Any hydrocarbon emissions released from the RAP are also pulled out of the mixing unit by the exhaust fan, but these fumes are incinerated as they pass through the burner area. Thus with a counter-flow drum mixer, the generation of blue smoke is minimized.

Shortly after the RAP has been introduced into the mixing portion of the drum, any other additives needed in the HMA, including baghouse dust and mineral filler, are also introduced. Because the air flow in the mixing unit is minimal, there is no chance for any relatively heavy powdered additive, such as the returned fines or filler, to become airborne and be drawn into the drying portion of the drum by the exhaust fan. Mixing of the RAP, filler and baghouse fines, and new aggregate begins as soon as the materials are introduced into the mixing chamber.

Very soon after all of the aggregate materials have been initially blended together, the binder is added to produce the HMA. The coating of the aggregate takes place as the combined materials are tumbled together and move toward the discharge end of the unit. Depending on the angle of the drum, as well as the number and type of flights in the mixing chamber, the mixing time in this type of counter-flow drum is typically in the range of 45 to 60 seconds. On completion of the mixing process, the HMA material is delivered into a discharge chute and transported to a silo.

Double-Barrel Counter-Flow Drum

With a double-barrel system, the mixing chamber is folded back around the aggregate drying drum. This mixing unit is unusual because it does not rotate. As seen in Figure 5-8, the heated and dried aggregate is discharged from underneath the burner downward into the nonrotating outer shell or drum. This occurs at the lower end of the mixing unit.

Shortly after the new aggregate enters the mixing chamber, RAP, if used, is added to the external drum. This material falls into the shell and quickly blends with the superheated new aggregate. Heat transfer from the hot new aggregate to the ambient-temperature RAP begins immediately. As with the conventional counter-flow drum mixer, any moisture in the RAP and any hydrocarbon emissions that develop during the heating process are drawn back into the dryer unit by the exhaust fan. The moisture is carried into the emission-control equipment, similar to what happens with the moisture released by the new aggregate during the heating and drying process. The hydrocarbon emissions from the RAP, if any, are incinerated by the burner.

Once the RAP has entered the outer shell, any additives, such as mineral filler, needed in the mix are deposited into the mixing area. The baghouse fines are also introduced into the outer shell at the same location. Because the flow of air in the area between the inner drum and the outer shell is minimal, there is no tendency for the added materials to be pulled out of the mixing chamber and into the aggregate dryer section of the drum-mix plant.

When all of the aggregate materials are in the outer shell, the asphalt cement is added to the mix. On most double-barrel plants, the binder materials can be added in one of two different locations. If RAP is not added to the mix, the asphalt cement is most often introduced as quickly as possible—shortly after the new aggregate, baghouse fines, and mineral filler, if any, have been charged into the exterior drum. If RAP is used in the mix, the addition of the binder material is delayed so some heat transfer can take place between the superheated new aggregate and the reclaimed material. The new binder material enters the outer shell slightly farther downstream (but uphill).

Mixing takes place by a series of paddles attached to the outside of the inner drum—the aggregate dryer (see

Figure 5-8). The paddles are set at the proper angle to push the combination of new aggregate, baghouse fines and mineral filler, RAP, and asphalt cement uphill, blending these materials together as they travel in the narrow space between the outside of the rotating inner drum and the inside of the nonrotating outer drum. Mixing occurs only in a lower quarter-portion of the circumference of the outer shell; the mix is not carried over the top of the inner drum. In addition to the heat transfer that takes place by direct contact between the new aggregate and the other mix components, further heating occurs as all the materials come in contact with the inner drum and by radiation of heat from the inner drum into the outer shell.

To achieve efficient mixing, the appropriate distance between the ends of the paddles and the inside of the outer shell must be maintained. The paddle tips and liner plate of the outer shell must be checked for wear periodically to ensure that material is not building up on the outer shell and that adequate mixing is occurring. Depending on the size and production capacity of the double-barrel plant, blending of all of the mix components typically occurs in less than 60 seconds. Upon completion of the mixing process, the HMA material is delivered into a discharge chute for transport to a silo.

SUMMARY

The following key factors should be considered when monitoring the operation of a counter-flow drum-mix plant:

- The new aggregate should be introduced into the upper end of the counter-flow dryer without obstruction. An inclined or rotating chute can be used for this purpose.
- The RAP is introduced into the mixing unit behind the burner for a conventional counter-flow drum-mix plant and under the burner into the outer shell for a double-barrel plant.
- In general, the RAP should enter the mixing unit before the mineral filler and baghouse fines are introduced into the mixing chamber.
- The asphalt cement should be charged into the mixing unit after some heat transfer has taken place between the superheated new aggregate and the RAP. If mineral filler or baghouse fines are also being added to the mix, the binder material should be injected into the mixing area after the additives have entered.
- The HMA mix being discharged from the mixing unit should be sampled to ensure that the mix components are completely mixed and adequately coated with asphalt cement.

SECTION

11 Surge and Storage Silos and Truck-Loading Techniques

The primary purpose of a silo on a batch plant is to allow the plant to continue to produce material when trucks are not available to accept mix directly from the pugmill. For a drum-mix plant (either parallel-flow or counter-flow) operation, the main purpose of the silo is to convert a continuous mixing operation into a discontinuous or batch-type truck-loading process and to hold the mix temporarily until the next transport vehicle is available. In this section the types of silos and silo designs, as well as mix loading and unloading operations, are described. The emphasis throughout is on measures taken to prevent segregation, defined as the separation of the coarsest aggregate particles in the mix from the rest of the mix. The section ends with a summary of key factors that should be considered in monitoring silo and truck-loading operations.

TYPES OF SILOS AND SILO DESIGNS

Surge Versus Storage Silos

During the normal daily operation of an HMA plant, a silo can be used to store asphalt mix between the arrivals of trucks at the plant. In this case, the silo is typically termed a surge silo. If the silo is to be used to hold the mix for longer periods of time (several hours or more), it may be termed a storage silo. A storage silo can easily be used as a surge silo, but a surge silo may not be suitable for use as a storage silo.

There are several differences between the two types of silos. First, the capacity of a storage silo is typically greater than that of a surge silo. Second, a surge silo is usually insulated but not heated, whereas a silo used for mix storage is always well insulated and usually heated, either completely or partially. Third, the gates at the bottom of a storage silo are heated and sealed when mix is to be held for a long period of time; this is done to reduce the amount of air that can pass up into the mix through the gates. The bottom of a surge silo, on the other hand, is not normally heated or sealed.

The primary operation of both types of silos, however, is similar. Only the ability to store quantities of mix for longer time periods without significant changes in the mix properties differentiates the two types. Regardless of the type of silo used, the mix that is held in the silo and then delivered to the haul truck should meet the same specifications and requirements as that discharged directly from the pugmill on a batch plant or from the discharge end of the drum mixer before passage into and out of the silo.

Insulation and Heat

As noted, most surge silos are insulated; this is done to reduce the loss of heat from the mix as it resides temporarily in the silo. The type of insulating material used and its thickness vary among silo manufacturers.

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

Storage

If an asphalt mixture must be retained in the silo overnight or over a weekend, this can usually be accomplished quite successfully without undue hardening or temperature loss in the mix. A well-insulated silo is required, but heating of the vertical silo walls is generally unnecessary. Mixes stored for several days in silos equipped with heated cones have shown only minimal oxidation and temperature loss. The amount of hardening that 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. The amount of temperature loss in the stored mix will depend on a number of other factors as well, including the initial mix temperature, the gradation of the material, and environmental conditions.

Asphalt mix (except mixtures with high coarse aggregate content, including friction course, stone-matrix asphalt, and coarse-graded Superpave mixes) may be stored for as long as a week when kept in a heated, air-tight silo. An inert gas system can be used to purge the silo of oxygen, but this is rarely done. The gates at the bottom of the silo, as well as any openings at the top of the silo, must be well sealed, however, to prevent the movement of air into and through the mix. The silo must also be completely heated and very well insulated. Mixes with high coarse aggregate content may tend to experience draindown if stored for an extended period of time.

If mix is to be stored in a silo for more than 2 or 3 days, such as over a long weekend or because of inclement weather conditions, it is advisable to remove a small amount of mix [at least 2 to 3 tonnes (2 to 3 tons) of material] from the silo every day or every other day during the storage period to ensure that the mix at the bottom of the cone does not set up and become impossible to discharge. If the mix is left undisturbed for a number of days, a plug of cold mix may form. When the discharge gates are finally opened, nothing happens—the mix has set up and will not flow out of the silo. The small amount of mix that is removed from the silo can be placed on the RAP pile for later recycling.

Although mix can be stored for relatively long periods of time, it is rarely necessary to do so with a continuously operating plant. Most silos, therefore, are used either as surge silos or periodically for overnight storage of the asphalt material. Mix held for more than 2 or 3 days in a silo should be tested to ensure that it meets all the same specifications and requirements as mix delivered directly to the paving site. This testing should include measurement of the mix temperature upon discharge from the silo and the properties of the asphalt cement recovered from the mix. As long as the mixture meets specifications, the length of time for which material is held in the silo should not be restricted. Such restriction increases the cost of the mix and reduces the efficiency of the mix production.

If an open-graded mixture is being stored temporarily, however, care must be taken to keep the mix storage temperature low enough so that the asphalt cement does not flow off of the aggregate (drain down) and collect at the bottom of the silo at the discharge gates. In general, it is not advisable to store an open-graded HMA mix overnight.

Conveying Devices

A variety of conveying devices are used to carry the HMA from the discharge chute on the drum mixer or the hopper under the pugmill of a batch plant to the silo. The equipment most commonly used is the drag slat conveyor, shown in Figures 11-1 and 11-2. In this system, a continuous set of flights connected by a drag chain pulls the mix up an inclined metal chute. The amount of mix that can be carried by the drag slats depends on the spacing between the slats, the depth of the individual flights, the width of the flights, and the slope of the conveyor, as well as the size and speed of the drag chain and the power of the drive motor. On some drag slat conveyors, the speed of the conveyor can be altered to change the capacity of the device to better match the output of the plant.

A belt conveyor can also be used to deliver the mix to the silo. This belt is essentially the same as those that carry the incoming aggregate into the drum mixer or dryer, except that it is able to withstand the increased temperature of the hot-mix material. A conveyor belt cannot operate at an angle as steep as a slat conveyor. As shown in Figure 11-3, a bucket elevator is also used on some plants. This device is similar to the equipment used

FIGURE 11-1 Slat conveyor feeding silos at an HMA plant.

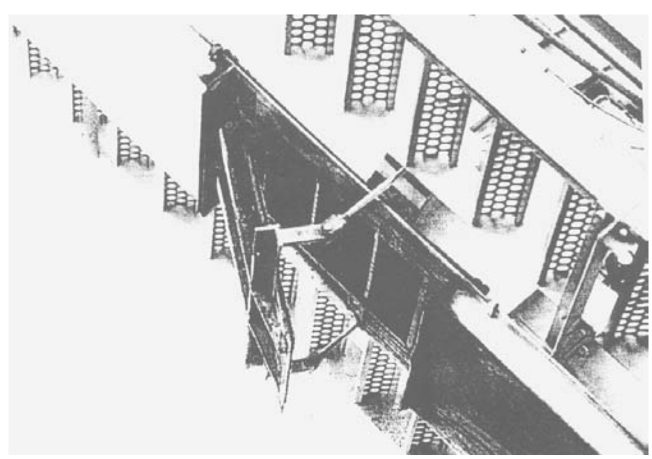


FIGURE 11-2 Drop-out chute in slat conveyor.

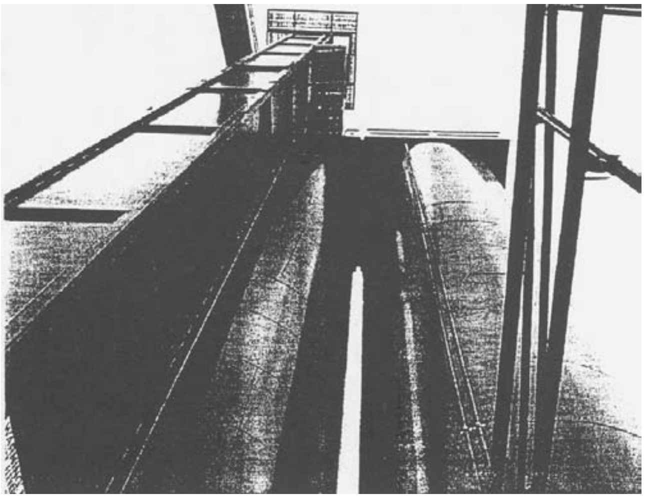


FIGURE 11-3 Bucket elevator feeding silos.

on batch 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 seldom a major factor in the uniformity of the mix delivered to the silo. The important factor is the manner in which the mix exits from the conveying device and is delivered into the top of the silo, as discussed later in this section.

Bin Geometry

Silos come in a variety of shapes. The vast majority of silos currently in use are circular, but silos can also be oval, elliptical, rectangular, or square. The shape of the silo can affect the amount of segregation that occurs upon both loading and unloading of the silo. Less segregation of a given mix is generally found with circular silos than with those of other shapes. For circular silos, the probability of segregation problems with mixes containing larger-sized coarse aggregate increases as the diameter of the silo increases. In general, however, the silo geometry is not a major factor in segregation; the manner in which the silo is operated (loaded and unloaded) has a greater effect on the uniformity of the mix and the amount of segregation.

Silo Cone

The bottom of the surge silo is shaped like a funnel or cone. Sometimes the cone is visible, and sometimes it is covered with sheet metal, as a downward extension of the side walls of the silo. The angle of the cone varies among manufacturers, but is usually between 55^0 and 70^0. This slope ensures that the mix is deposited as a mass into the truck. The angle needs to be steep enough and the gate opening(s) large enough to ensure that the larger aggregate particles do not roll into the center of the cone (rathole) as the mix is drawn down, causing segregation.

The vast majority of surge silos have low bin indicator systems that warn the plant operator when the level of mix in the silo has decreased to a point near the top of the cone. Keeping the volume of mix in the silo above this minimum level will reduce random segregation. As very coarse 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. These larger aggregate particles may then appear in the mix behind the paver as random pockets of segregation.

MIX DELIVERY

Segregation most typically occurs in mixes that contain a significant proportion of large aggregate or are gap-graded. The actual separation of the large and small particles occurs when the asphalt mix is placed in a conical pile inside the silo and the bigger particles run down the side of the pile, collecting around the bottom edge. Segregation can also occur when all the mix being discharged from the conveying device is thrown to one side of the silo, allowing the coarser pieces to run back across the silo to the opposite wall.

Recently, differential cooling of the mix as a result of materials segregation has been identified as a problem. The issue is addressed in the discussion of segregation in Section 13.

Top-of-Silo Segregation

Segregation on the roadway is often the result of operation at the top of the silo. Mix delivered to the top of the silo by a slat conveyor, belt conveyor, or bucket elevator will be discharged to the sides of the silo, as illustrated in Figure 11-4, unless some means is employed to redirect the flow into the center of the silo. On some silos, a series of baffles is used to contain and change the direction of the material. Other silos are equipped with a splitter system to divide the mix as it is delivered, causing a portion of the mix to be placed in each part of the silo. In general, use of a baffle or splitter system can reduce the tendency for segregation on the roadway but does not always eliminate it. Use of a batcher system generally provides a better means of solving the segregation problem (see Figure 11-5).

With such a system, a temporary holding hopper is used at the top of the silo to momentarily store the mix being transported by the conveying device. This hopper collects the continuous flow of mix. When the hopper

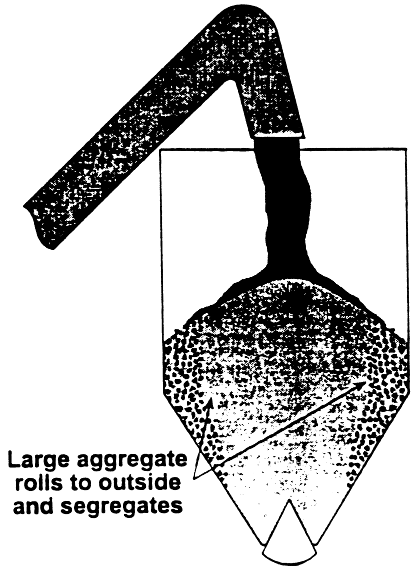


FIGURE 11-4 Segregation at top of silo without batcher.

is nearly full and the hopper gates are opened, the mix is deposited into the silo in a mass. The mass of mix hits the bottom of the empty silo or the top of mix already in the silo. Upon contact, the mix disperses in all directions uniformly, minimizing segregation. Moving HMA in a mass will always minimize segregation.

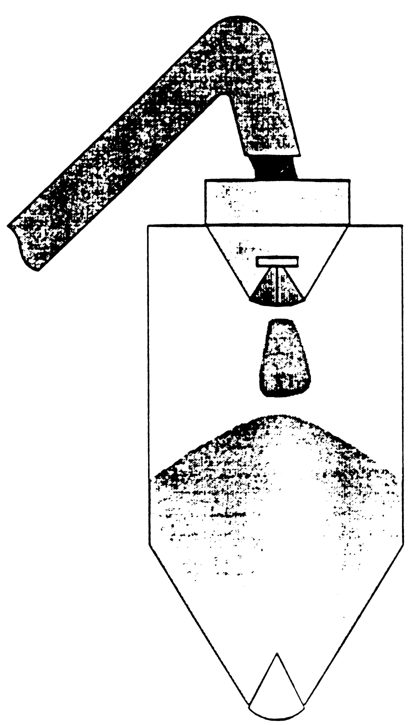


FIGURE 11-5 Use of batcher to prevent top-of-silo segregation.

The batcher system functions well unless the silo is almost full. In the latter case, the mix does not fall very far when released from the hopper. When the falling mix hits the mix already in the silo beneath the hopper, it lacks the momentum to spread out over the area of the silo and forms a conical-shaped pile instead. This pile can be the beginning of a segregation problem as more mix is deposited on top of it. Most silos are therefore equipped with high silo indicator warning systems that alert the plant operator to cut off the flow of incoming mix when the silo becomes too full.

The batcher may not prevent a segregation problem if the mix is delivered improperly. In some cases, the transporting device places the mix all on one side of the hopper, as shown in Figure 11-6. This practice causes rolling of the coarse aggregate in the batcher itself. It also causes the mix to be dropped into the silo off center. Thus to prevent segregation of mixes containing a large portion of coarser aggregate, the mix must be deposited uniformly into the center of the hopper and delivered from the batcher into the center of the silo.

The batcher is typically equipped with a timing device that opens the discharge gates at the bottom of the silo on a regular basis. The amount of time between drops can be altered to match the production rate of the plant. If properly set, the timer will open the gates before the batcher is too full and will close the gates before the batcher is completely empty. This allows the conveying device to operate continuously while preventing discharge from the conveyor directly into the silo through the open batcher gates.

If the timer operates improperly, too much mix will be delivered into the batcher before the discharge gates are opened. If this occurs, the HMA material may overflow the batcher and back up into the conveying device. The conveyor will quickly become overloaded and then stop functioning. The plant will, in turn, have to cease

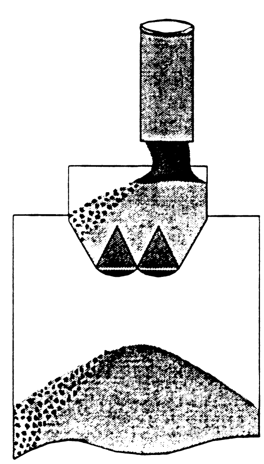


FIGURE 11-6 Segregation caused by feeding batcher off center.

production to prevent this problem, particularly if the timing device is not functioning properly. The plant operator may improperly leave the gates on the bottom of the batcher wide open. Doing so defeats the purpose of the batcher and allows the mix to dribble into the silo in a continuous stream, just as if the batcher were not there.

In other cases, the batcher may be emptied more often than is necessary—when only partially full. Such continual dumping of the hopper reduces the mass of material dropped into the silo at one time and increases the opportunity for formation of a conical pile of mix. The timer device should be set so that the gates of the batcher are closed before the batcher is empty. This practice will ensure that all the mix falls in a mass and will minimize segregation.

The capacity of the batcher at the top of the silo is related to the production capacity of the plant and is usually in the range of 2 to 5 tonnes (2 to 5 tons). A typical haul truck can hold from 14 to 20 tonnes (15 to 22 tons). Thus, depending on the capacity of both the batcher and each haul truck, it will take 3 to 11 batcher drops of mix to make up a full load in the haul truck.

Longitudinal (Side-to-Side) Segregation

Longitudinal (side-to-side) segregation will occur on one side of the lane being paved if the coarser aggregate particles are allowed to roll to one side of the silo. Depending on how the mix is delivered into the silo from the conveying device, the coarsest aggregate particles in the mix may collect on the opposite or the same side of the silo as the conveyor. In either case, those coarse aggregate particles will travel down one side of the silo and end up on one side of the haul truck and thus on one side of the laydown machine.

Longitudinal segregation will normally be found on only one side of the paver. In most cases, it will be relatively continuous on that side of the laydown machine if the plant is operated in a consistent manner. An easy way to determine the cause of this type of segregation is to reverse the direction in which the haul truck is being loaded underneath the silo and see whether the longitudinal segregation changes sides at the paver. If, for example, the longitudinal segregation is seen on the left-hand side of the paver lane and the haul truck is being loaded under the silo in its normal direction, the loading direction for the truck should be reversed. When the mix is subsequently delivered into the paver hopper—either directly from the haul truck or by means of a windrow and pickup machine—the longitudinal segregation should occur on the opposite side (the right side in this example) of the paver lane. If the position of the longitudinal segregation changes sides at the paver when the direction of the truck loading is reversed, the cause of the side-to-side segregation is in the loading of the mix into the silo from the conveying device. The direction of the mix entering the silo at the top of the silo must then be changed so that the mix is deposited directly into the center of the silo and not permitted to roll to one side or the other.

LOADING OF TRUCKS FROM SILOS

Just as it is important to deliver mix in a mass into the center of the silo in order to avoid causing longitudinal segregation, it is important to deposit the asphalt mix in a mass into multiple locations in the bed of the haul truck in order to avoid truckload-to-truckload (or end-of-load) segregation.

Most silos have only one discharge opening, equipped with a single or double gates. The gates on the bottom of the cone should be opened quickly and completely so that the flow of mix begins immediately and is unrestricted. Once the proper weight has been discharged into the truck bed, the gates should be closed quickly. For silos equipped with double (clamshell-type) gates, closing of the gates generally does not create any problems. For silos equipped with a single gate, however, it is possible for the mix to be thrown to one side of the truck bed as the gate is closed. To minimize this problem, it is important to close the single gate as quickly as possible.

Some silos are equipped with two separate discharge openings. These silos distribute the mix over a greater length of the truck bed and thereby reduce the amount of segregation that may occur. The silo gates may be parallel or perpendicular to the direction of the truck. Both systems can deliver mix into the haul vehicle without segregation as long as the correct amount of mix is placed into the right position in the truck bed.

Segregation can be eliminated by moving the HMA in a mass and by reducing the distance that the coarse aggregate can roll. Multiple discharges of mix into the haul vehicle are very beneficial in keeping the mix uniform and in reducing the amount of segregation. Some plants are equipped with automatic silo discharge systems. The number of each truck is entered into the computer system, and that truck is loaded at predetermined intervals with preselected amounts of mix for each drop. With a manual system, the silo discharge operator should be able to determine the time it takes to deliver the proper amount of mix, per drop, into each haul vehicle. This can be done by timing the discharge of the mix and comparing that time with the weight of mix delivered. Because trucks come in a variety of sizes, the time per drop and the number of drops per truck may differ from truck to truck. With practice, however, the operator should be able to judge accurately the time needed to place the proper amount of material in each truck bed. This amount can be confirmed visually by watching the height of the growing pile of mix in the truck as the loading continues. Specific loading practices for the different types of haul trucks—end-dump, belly- or bottom-dump, and live-bottom—are described later in this section.

The operator should not be allowed to "top off" or dribble mix into the haul vehicle. The gates on the silo should not be opened and closed continually to deliver only small amounts of mix to the truck. This practice occurs most frequently in plants where the surge silos are placed directly over the truck scales. Because the operator can quickly determine the amount of mix actually in the truck bed by observing the scale readout on the control console, the tendency is to load the vehicle up to the legal limit by using multiple drops of small quantities of mix at the end of the main delivery. This topping-off process causes the coarsest aggregate particles in the mix to roll down the slope of the mix in the truck bed toward both the front and back of the truck, significantly contributing to segregation of the mix. If the discharge of mix from the silo is timed, however, this procedure is unnecessary, and the potential for mix segregation is reduced accordingly.

Some silos have a loading hopper or batcher under the cone. In many cases, this hopper is supported on load cells to measure the amount of mix being delivered from the silo into the haul vehicle. The mix from such a hopper or batcher must still be deposited into different sections of the truck bed in order to minimize segregation by reducing the distance that the coarsest aggregate particles can roll. It is important to determine the size of the batch being loaded into the truck from the hopper versus the amount of mix needed in each portion of the truck bed. Depending on the capacity of the hopper and the size of each truck, multiple batches may be needed at each loading location. The hopper should not be used to top off drops of mix already in the truck bed.

End-Dump Trucks

If the mix is deposited into the center of an end-dump truck bed, the material will build up into a conical pile. Because the growth of the pile will be restricted by the sides of the truck, the larger aggregate particles will roll toward both the front and the back of the truck bed. In most cases, because of truckload weight laws and the amount of HMA that can be carried legally on the back axles, the mix is actually deposited into the truck bed to the front of the center of the length of the bed. This practice reduces the distance that the coarse aggregate particles can roll to the front of the bed but increases the distance that they can roll toward the tailgate.

The coarse aggregate pieces that accumulate at the tailgate area of the truck bed of an end-dump truck are deposited first into the paver hopper when the material is delivered to the laydown machine, while the pieces that accumulate at the front of the truck bed are deposited into the paver hopper last. Truckload-to-truckload segregation with this type of truck, then, is really a combination of what comes out of one truckload last (coarse aggregate at the front of the truck bed) and what comes out of the next truckload first (coarse aggregate at the tailgate of the truck bed). Because of the way trucks are often loaded—one drop of mix into the bed, generally forward to the length of the truck bed—most of the total amount of truckload-to-truckload segregation is caused not by what comes out of the truck bed last (end of load), but by what comes out of the next truck bed first (beginning of load).

As noted earlier, this segregation problem can be significantly minimized by dividing the delivery of the asphalt mix 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 to be hauled should be loaded into the center of the front half of the truck. 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, near the tailgate. The vehicle should then be moved backward so that the remaining 20 percent of the mix can be dropped into the center of the bed, between the first two piles.

A complaint commonly expressed about this type of loading procedure is that the truck driver must back the truck up under the silo in order to load the back of the bed. Yet the same driver will have to back the truck up once he or she reaches the paving site in order to deliver the HMA into the hopper of the paver. Another complaint is that it takes longer to load the truck when multiple drops are used as compared with a single drop of mix. While this is certainly true, the total number of tons of mix produced each day will almost always be limited by the capacity of the plant and not by the time it takes to load individual trucks. If segregation is to be eliminated, the truck driver will have to learn to move the haul vehicle back and forth under the silo and allow the mix to be deposited into the proper locations in the truck bed in order to reduce the distance that the coarse aggregate pieces can roll.

If a large end-dump truck is used to deliver the mix, the number of drops of material from the silo should be increased to distribute the mix along the length of the truck bed. The first drop of mix should be into the front portion of the bed and the second near the tailgate. The remaining mix should be delivered in evenly divided drops into the rest of the length of the truck bed. In no case should the truck be loaded continuously by the truck driver's moving forward under the silo as the mix is being discharged. This practice will cause the coarse aggregate particles to roll toward and then collect at the tailgate of the truck and increase the amount of segregation. Thus for a semi-truck trailer type of truck, five drops of mix should be made into the truck bed: the first at the front of the truck, the second at the tailgate, the third in the middle of the length of the bed, the fourth between the first and third drops, and the fifth between the second and third drops. This loading sequence requires that the truck driver reposition the truck after each drop of mix and increases somewhat the time needed to load the truck, but it also minimizes the segregation problem, which is the most important thing.

Because of weight laws in some states, it may not be possible to deposit a batch of mix directly in front of the tailgate of an end-dump truck and still legally scale the truck axles. In this case, the second batch of mix delivered into the truck should be placed as close to the tailgate as feasible while allowing the axle weight restrictions to be met.

Since different trucks have beds of different lengths, it is important to provide the truck driver with some sort of positive guidance on where to place the truck so that the mix will be discharged into the correct location along the length of the bed. One way to accomplish this is to paint a series of numbers, one foot apart, on the edge of the truck scale and have the driver stop at different numbers to load different parts of the bed. For example, the driver might position his or her door (or rearview mirror) above number 6 to be in the proper position to load the front of the bed—Drop 1. The driver would then move the truck forward until the door or mirror was above number 22 (or whatever the correct number was for the particular truck being loaded). The second drop of mix would then be placed near the tailgate of the truck. The driver would next back the truck up until the door or mirror was above Number 14, for example, in order to have Drop 3 placed in the center of the length of the bed. Different sets of numbers are used for trucks of different sizes and bed lengths.

A second method is similar to the first, but uses a horizontal piece of wood or board that extends between the legs of the silo and out in front of the silo legs for some distance at a height equal to the driver's position in the cab of the truck. For a tandem-axle truck, for example, red tape is used to indicate the proper loading position. A piece of red tape is placed on the rearview mirror of the truck, and the driver is asked to pull under the silo until the mirror is even with a piece of red tape under which is the number 1. The front of the truck bed is then loaded. Next the driver pulls the truck forward until the mirror is even with the piece of red tape numbered 2, and the rear of the truck (tailgate area) is then loaded. Finally, the driver is asked to back the truck up until the red tape on the mirror is even with the piece of red tape numbered 3, and mix is delivered into the middle of the truck bed.

For triaxle trucks, which have a longer bed length, blue tape (or any other color) can be used to indicate the proper loading positions. For semi-trucks, yellow tape can be used, for instance, to show the driver the correct locations at which to stop the truck in order to properly load the truck bed with five different drops of HMA. In any case, the truck driver must be given positive guidance on the correct place to stop the haul vehicle so that the proper amount of mix will be placed in the right position to eliminate the segregation problem.

Belly- or Bottom-Dump Trucks

If a belly- or bottom-dump truck with a single discharge gate is used to haul the HMA, it, too, is frequently loaded in a single drop of mix from the silo. The mix is deposited into the center of the length of the bed, directly over the discharge gates. This practice results in a mound of mix inside the bed, and the coarse aggregate pieces in the mix have a tendency to segregate. Those particles roll toward both the front and back of the truck bed at the top of the load since this type of truck has sloping front and back walls. Loading this type of truck in one drop of mix into the bed is therefore an improper procedure. Segregation of the mix occurs not at the beginning of the load when the mix is first deposited from the gates of the truck into the windrow, but at the end of the load when the coarse aggregate particles that have rolled to the front and back of the top of the load are discharged from the gates into the end of the windrow. Coarse aggregate pieces are often found in the windrow at the end of the load, resulting in segregation on the roadway at this point.

The proper loading sequence for this type of truck is to deposit about 70 percent of the total weight of the load into the center of the truck bed, directly over the discharge gate. This practice results in a slight mound of mix in the center of the length of the bed. The truck should then be moved backward and about 15 percent of the total weight discharged into the front portion of the truck, between the initial portion of mix and the sloping front wall of the truck bed. Once this has been done, the truck should be backed up and the final 15 percent of the total weight delivered into the back portion of the truck, between the initial portion of the mix and the sloping back wall of the truck bed. This loading procedure greatly reduces the rolling of coarse aggregate particles to the front top and back top of the truck bed and eliminates the segregation that occurs when the mix in the two corners (front and back tops) is finally deposited into the windrow.

A slightly different loading sequence is used if the belly- or bottom-dump truck is equipped with double discharge gates. In this case, the first drop of mix should be about 40 percent of the total load and should be placed directly over the front discharge gate. The truck should then be moved forward and a second 40 percent of the total load deposited directly over the second (rear) discharge gate. Once this has been accomplished, the truck should be moved forward once again and approximately 10 percent of the weight placed on the back top portion of the bed—between the second drop of mix and the sloping back wall of the truck bed. The truck should then be backed up and the fourth and final drop of mix, about 10 percent of the total load, placed on the top forward portion of the bed—between the first drop of mix and the sloping front wall of the truck bed. Thus with double-gated bottom-dump trucks, four different loading positions should be used to reduce the distance that the coarse aggregate particles can roll.

As with end-dump truck-loading procedures, positive guidance should be provided to the belly- or bottom-dump truck driver so that he or she knows where to stop the truck under the silo in order to load the vehicle in three or four drops of mix, depending on the number of discharge gates on the truck. Again, although this loading sequence takes longer than loading the truck in only one drop, such a procedure is absolutely necessary if segregation is to be prevented.

Live-Bottom Trucks

For live-bottom (also known as flow-boy or horizontal discharge) trucks, segregation can be a problem if coarse aggregate particles are allowed to roll to the back of the truck bed—to the discharge gate. If this type of truck is loaded with the truck moving slowly forward, the coarsest aggregate particles will move backward toward the tailgate as the mix is deposited into the bed. Upon completion of loading, those coarse particles will have accumulated at the discharge gate and will be delivered first into the paver hopper. Thus for this type of truck, segregation on the pavement surface is typically related to what comes out of the truck bed first, or beginning-of-load segregation.

The proper loading procedure for a live-bottom truck is to place the first drop of mix at the back of the bed, as close to the discharge gate as possible. Doing so will minimize the distance that the coarse aggregate particles can roll to the tailgate. The truck should then be backed up under the silo and the next drop of mix placed as close to the front of the bed as possible. Then because of the conveyor belt or slat conveyors in the bottom of the truck bed, the rest of the total weight of mix can be deposited into the truck bed with the truck moving slowly forward. When the mix reaches the end of the bed, the first drop will already be there, and the rolling of the coarse aggregate pieces will be halted.

As for the other truck types, positive guidance needs to be provided to the truck driver so that he or she knows the proper location at which to stop in order to allow the first drop of mix from the silo to be placed as close to the discharge gate as possible. Different types and lengths of live-bottom trucks will require different loading positions under the silo.

SUMMARY

Segregation usually begins at the surge or storage silo in the loading and unloading process. The key operating factors that should be monitored to prevent segregation include the following:

- Top-of-silo segregation is typically caused by the way the HMA mix is placed into the top of the silo as the mix is discharged from the conveying device.
- Longitudinal (side-to-side) segregation is caused by loading the silo to one side, so that the coarser aggregate particles roll to the opposite side inside the silo.

- The conveying device from the discharge chute of a drum-mix plant or the hopper under the pugmill of a batch plant must deposit the mix into the center of the batcher at the top of the silo.
- If longitudinal segregation is present behind the paver, several haul trucks should be loaded under the silo facing in the opposite direction from their normal loading pattern. When these truckloads of mix are unloaded at the paver, the location of the segregation should change sides in the lane being paved. If this happens, the cause of the longitudinal segregation probably lies in the procedure used to place the mix into the silo from the conveying device.
- A batcher should be used at the top of the silo. The batcher should not be operated with its gates wide open, allowing the mix to pass right through it. The batcher should be filled up with mix and should then drop the mix in a mass into the center of the silo. Further, the gate on the bottom of the batcher should be closed before all of the mix is discharged from the batcher.
- If the silo is to be used for overnight storage of asphalt mix, the cone should be heated and the silo walls insulated. If mix is stored for more than 2 days, a small quantity of mix should be withdrawn from the silo at least every other day to prevent plugging of the cone.
- If the mix is stored for more than 2 or 3 days, it should be checked upon discharge for temperature and for properties of the asphalt cement recovered from the mix. The mix should meet the same specifications and requirements as a mix placed immediately after manufacture.
- The plant operator should not top off the load of mix in the truck or dribble mix into the truck bed in small drops to fill the truck to legal capacity.
- Truckload-to-truckload segregation is typically caused by the way the HMA mix is discharged from the silo and where it is delivered into the length of the truck bed.
- An end-dump truck should never be loaded in only one drop of mix into the center of the truck bed. Multiple drops of mix are necessary, the first located near the front of the bed and the second near the tailgate. A third drop of mix should be made in the middle of the first two drops.
- If a long end-dump truck (semi-truck) is used, at least five drops of HMA mix should be made into the truck bed: the first at the front of the bed; the second at the back of the bed at the tailgate; the third in the middle of the length of the bed; and the fourth and fifth drops between the second and third and the first and third drops, respectively.
- An end-dump truck should never be loaded by slowly driving the truck forward as mix is being delivered from the silo. This will cause the coarser aggregate particles to collect at the tailgate of the truck and significantly increase the amount of segregation that occurs.
- If a belly- or bottom-dump truck is used, three or four drops of mix should be used to load the haul truck, depending on the number of discharge gates at the bottom of the bed.
- If a live-bottom truck is used, the first drop of mix should be delivered into the back end of the truck.

SECTION

12 Emission Control

The primary source of emissions from a batch or drum-mix plant is the carryout of fines during the aggregate heating and drying process. In this section the three types of emission-control equipment that may be found on batch and drum-mix plants are described: dry collectors, wet collectors, and baghouses or fabric filters. If used, the dry collector is usually placed in front of one of the other two types and is termed the primary collector; the wet collector or baghouse is the secondary collector through which the exhaust gases flow after passing through the primary collector. The primary collector is used to remove the larger fine particles from the exhaust gases and reduce the loading on the secondary collector, which is used to capture the very fine particles.

All batch and drum-mix plants have a small amount of fines aggregate carryout from the dryer or the drum mixer. To meet federal and state air quality codes, emission-control equipment is necessary to capture particulate emissions that might otherwise be released to the atmosphere. In addition, some emission-control devices permit the plant operator to control the amount of fines returned to the asphalt mixture.

The velocity of the exhaust gases inside a dryer or drum mixer is a function primarily of the diameter of the drum, the capacity of the exhaust fan, and the speed of the exhaust fan. A minimum volume of air is needed for proper operation of the burner. This air, combined with the products of combustion from the burner and the moisture vapor from the aggregate, moves through the dryer or drum mixer at a velocity that varies with the operating conditions of the plant. The amount of fines carryout increases as the exhaust gas velocity rises.

In a parallel-flow drum mixer, the amount of fines carryout can be reduced significantly by encapsulating or coating the aggregate with the asphalt cement early in the drying process. The farther up the drum (toward the burner) the asphalt cement is injected, the greater is the amount of fines that will be captured in the asphalt cement before the fines can become airborne. Typically, the amount of fines carryout increases as the asphalt cement pipe is positioned farther down the drum toward the discharge end of the parallel-flow drum.

The amount of fines carryout is a function of the amount of very fine material in the new aggregate; the size, weight, and moisture content of the fines; and the amount of very fine particles in the RAP (if used in a parallel-flow drum-mix plant). The amount of fines is also related to the operation of the drum—the production rate (density of the aggregate veil), the location of the asphalt cement injection pipe (for a parallel-flow drum mixer), and the velocity of the exhaust gases. The amount of carryout can vary widely with a change in the properties of the incoming aggregate and the production rate of the plant.

The efficiency of the emission-control equipment is related to the amount of particulates that is captured by the equipment versus the amount that enters the emission-control equipment. If 1,000 particles per minute enter a baghouse, for example, and 990 of those particles are caught in the baghouse, the collection system is 99 percent efficient. The efficiency can be determined, in part, by observing the amount of particulates being emitted from the stack. This is done by checking the opacity of the exhaust gas beyond the end of the steam plume (if one is present). If a dust trail is seen, the operation of the emission-control equipment must be checked.

DRY COLLECTOR

Dry collectors are not used or needed on all asphalt plants. If used, they may be of several types, used singly or in combination. The original dry collector was a cyclone device that forced the exhaust gases to swirl inside the collector (see Figure 12-1). The dust in the gases was removed by centrifugal force, being thrown to the side of the cyclone as the gases moved in a circular motion. The operation of a cyclone dry collector is shown in Figure 12-2.

Most dry collector systems in use today have an expansion chamber combined with a baghouse. The expansion chamber or knockout box (see Figure 12-3) has a greater cross-sectional area than the ductwork through which the exhaust gases pass between the dryer (batch plant aggregate dryer or counter-flow drum mixer) or parallel-flow drum mixer and the secondary collector.

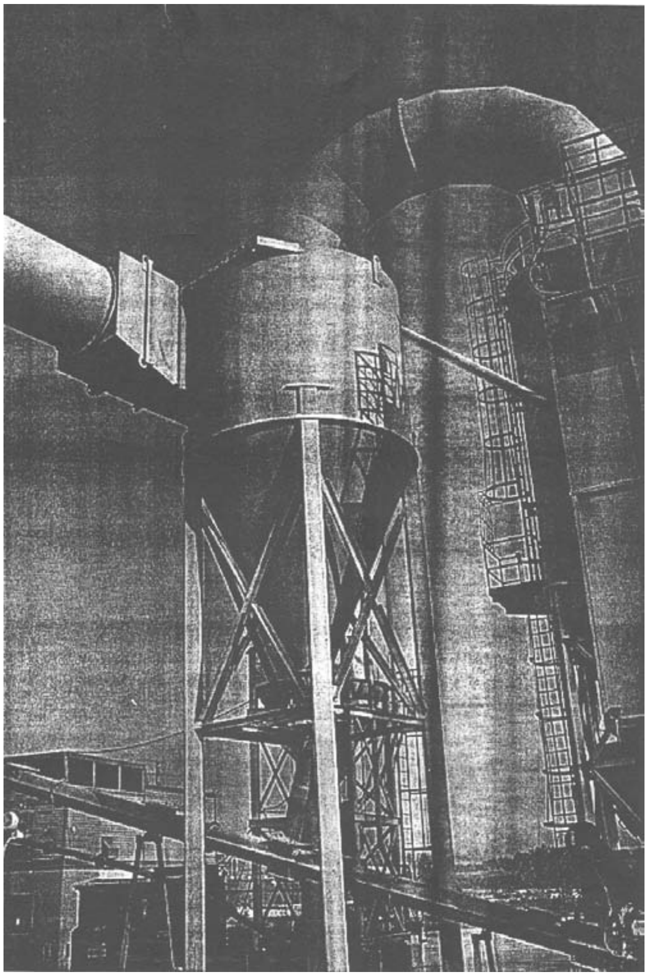


FIGURE 12-1 Vertical cyclone dry collector.

A typical knockout box used in combination with a baghouse is shown in Figure 12-4.

The exhaust gases from the dryer or drum mixer travel through the ductwork into the front end of the knockout box. At that point, the velocity of the exhaust gases is significantly decreased as the gases enter the expanded area. The amount of dust that falls out of the gas stream is directly related to the size of the expansion chamber and the decrease in the velocity of the gases. The velocity of the larger particles decreases such that the slow-moving particles drop to the bottom of the expansion chamber. The collected particles can then be returned uniformly to the batch plant or the drum mixer, either alone or in combination with the fines collected by the baghouse, or they can be wasted.

The efficiency of the dry collector depends in part on the size of the fine particles in the exhaust gases and on the type of collector used. Primary collectors can have an efficiency (percentage of amount of fines removed from the exhaust gases as compared with the total amount of fines in the gases) as low as 50 percent for a knockout box to as high as 70 to 90 percent when a dry cyclone is used. Thus only a portion of the fines in the exhaust gases is removed by this equipment. The main purpose of the dry collector is to improve the operation of the secondary collector by reducing the fines loading on the wet collector or baghouse.

WET COLLECTOR

After moving through a primary dry collector (if used), the exhaust gases on most newer plants equipped with a wet collector (wet scrubber) system are forced through a narrowed opening, or venturi, as shown in Figure 12-5. When the gas flow is concentrated in a small area, it is sprayed with water from multiple nozzles, and the fines are wetted. The exhaust gases and wet fines then travel into the separator section of the collector.

The exhaust gases are sent around the circumference of the unit in a circular motion, as seen in Figure 12-5. The wetted fines, which have increased in weight because of the added water, are removed from the gas stream by centrifugal force and fall to the bottom of the collector. The clean gas continues to swirl around the collector until it reaches the end, when it travels into the stack and then out to the atmosphere.

Depending on the size of the fine particles in the exhaust gases, a wet collector system is usually 90 to 99 percent efficient in removing particulates from those gases. In addition to being related to the size and amount of fines present, efficiency is a function of both the cleanliness and the volume of water used to spray the exhaust gases. If the water sprayed is clean and free from sediment and if all of the nozzles in the scrubber are open and working, the amount of fines removed by the wet collector system, and thus the efficiency, will increase.

The cleanliness of the water and the condition of the nozzles are related in turn to the size of the settling pond used to collect the water discharged from the scrubber. The water and fines, in the form of a sludge, are sent from the bottom of the collector through a pipe to the first section of the pond, where the heaviest fines settle out of the water. The cleaner water at the top of the pond in this first section is drawn off through an outlet on the opposite side of the pond. Additional settling of the fines occurs in each succeeding section of the pond.

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 is available, and the more time there is for the fines to separate and settle before the water

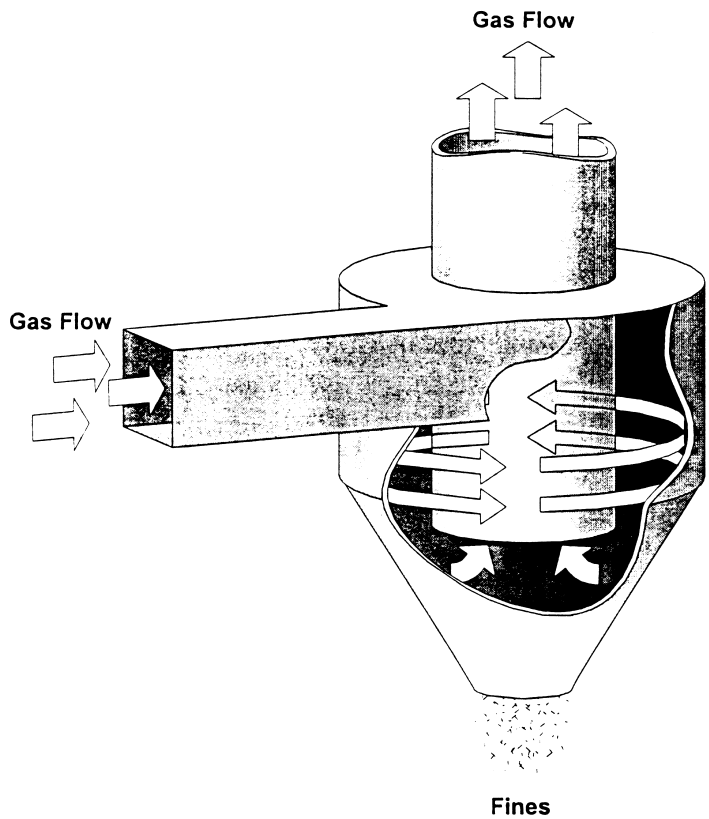


FIGURE 12-2 Flow through a typical cyclone dry collector.

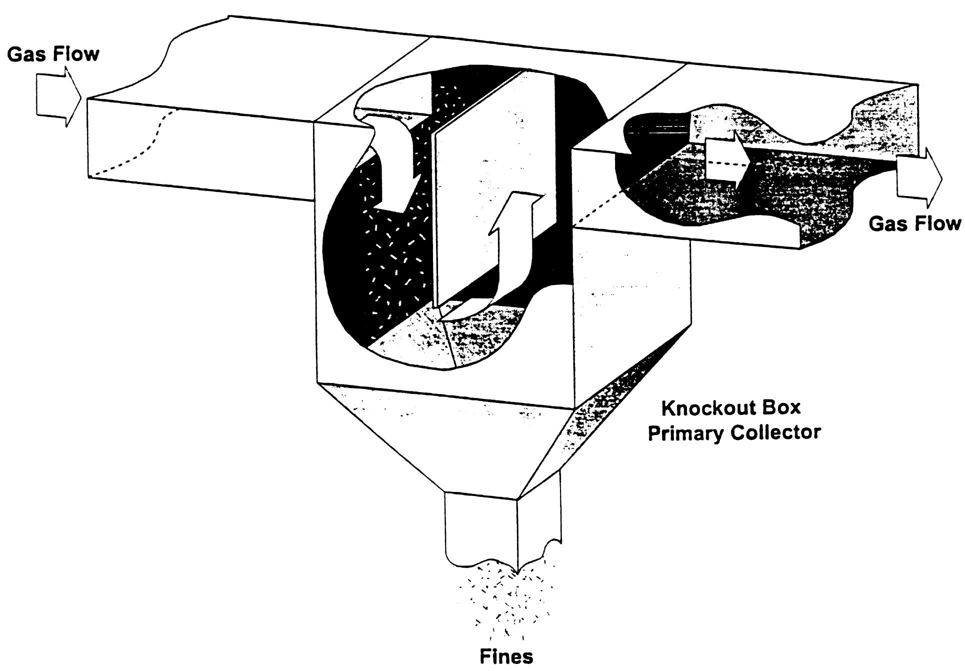


FIGURE 12-3 Flow through a typical knockout box.

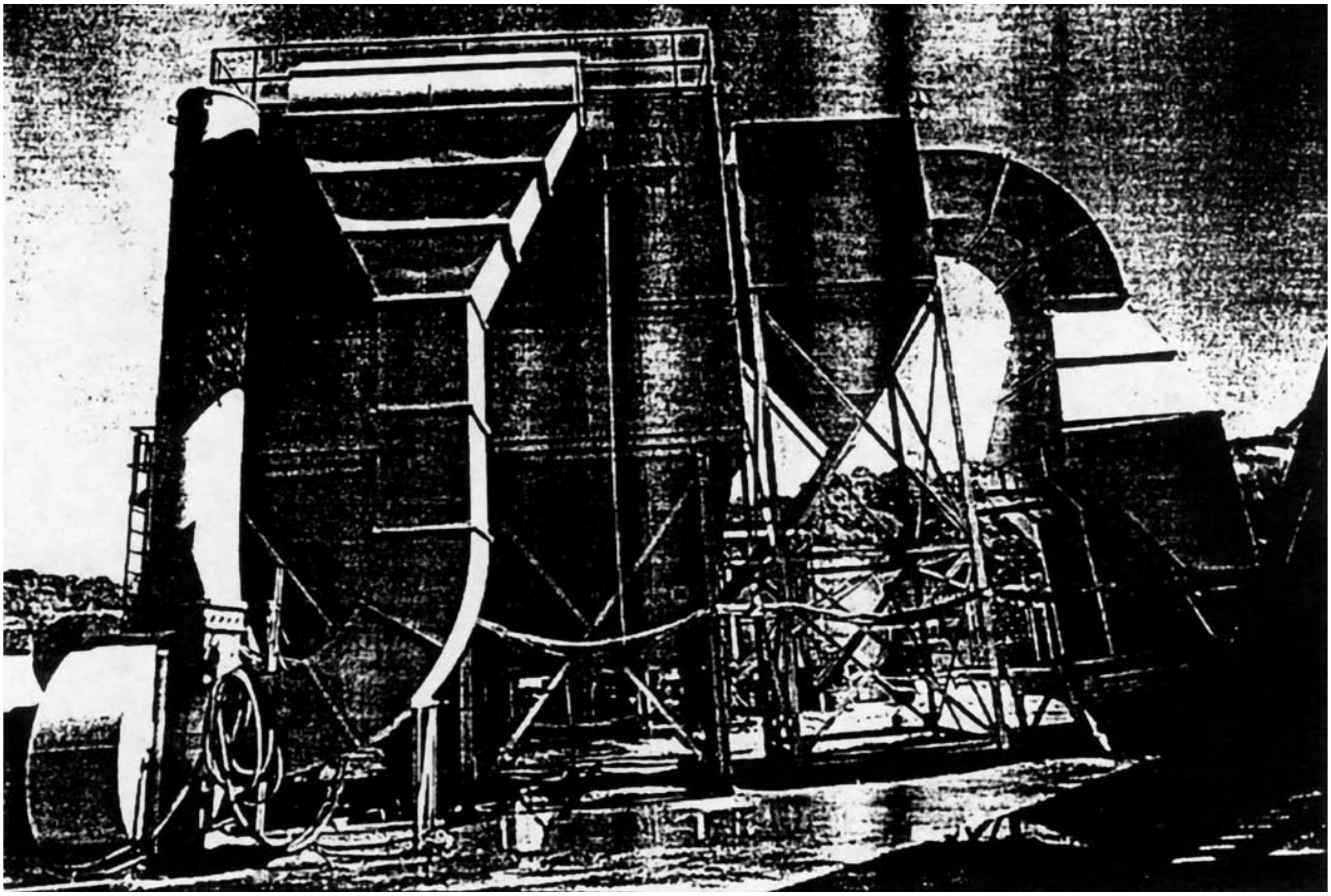


FIGURE 12-4 Knockout box installed prior to baghouse.

is pumped from the pond back to the wet collector unit. A settling pond is illustrated in Figure 12-6. As the settling pond fills up with fines, the time the water remains in the pond and the amount of settlement that can occur decrease. When a pond becomes too shallow, dirty water will be sent back to the scrubber. To maintain a supply of clean water for use in the fines collection equipment, the sediment on the bottom of the pond must be removed periodically. In addition, water lost from the pond through evaporation and leaks in the piping system should be replaced as often as necessary.

Any fines removed from the exhaust gases by the wet scrubber are no longer available for use in the mix. The gradation of the mix produced in the batch or drum-mix plant is thus not the same as the gradation of the incoming new and/or reclaimed aggregate. In most cases in which the amount of fines carryout is not great, the change in gradation will be small; if a large volume of fines is captured in the exhaust gases, however, a significant change can occur in the aggregate gradation, particularly in the very fine particle sizes.

BAGHOUSE

The exhaust gases that pass through the primary collector (if used) can be pulled by the exhaust fan on the plant through another type of secondary collector called a baghouse or fabric filter, as shown in Figures 12-7 and 12-8. It should be noted that although baghouses can be operated without the gases being passed through a primary collector first, doing so generally reduces the efficiency of the system and is not usual practice. The material used as the filter cloth is generally a special type of synthetic fiber that is resistant to high fines loadings, high humidity, and high temperature while undergoing multiple cycles of bending and flexing. The fabric is dense enough to catch the particulates while still permitting the air to pass through.

The fabric is made into a cylindrically shaped bag and placed on a circular metal framework or cage that is closed on the bottom and open on the top. The filter bags on the cages are arranged in rows inside the baghouse, as illustrated in Figure 12-9. The number of bags needed depends on the size of the dryer or drum mixer,

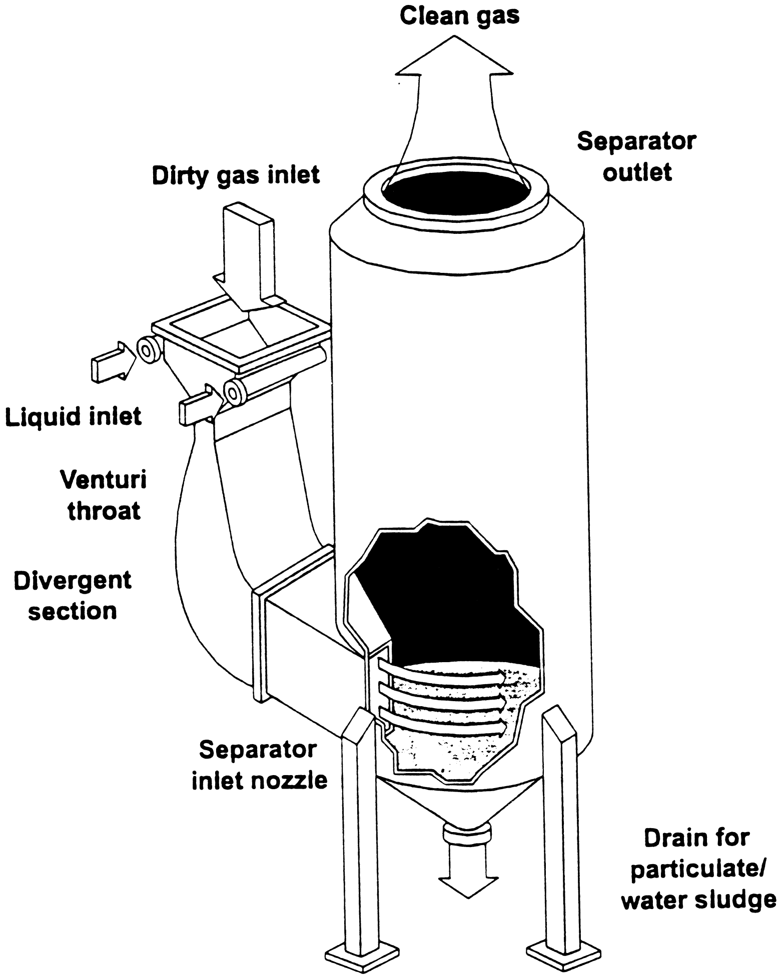


FIGURE 12-5 Flow through typical venturi scrubber.

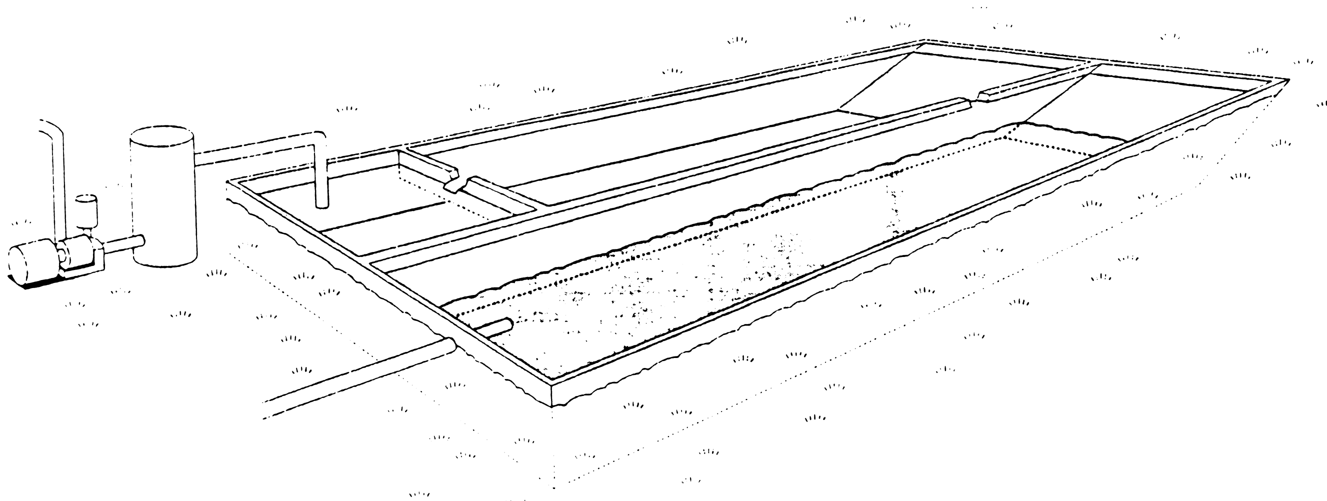


FIGURE 12-6 Typical settling pond.

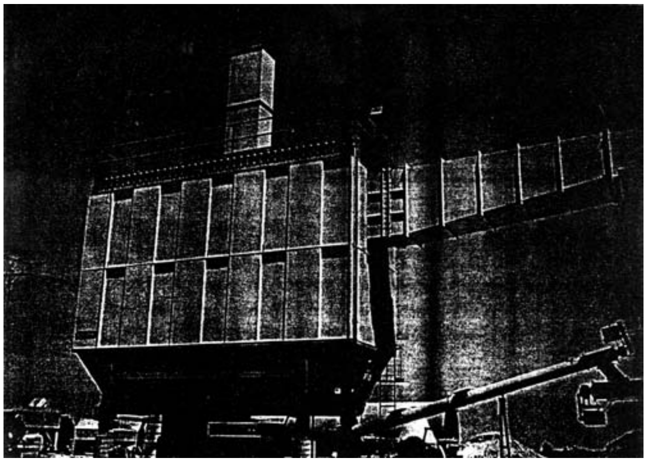


FIGURE 12-7 Pulse-jet baghouse.

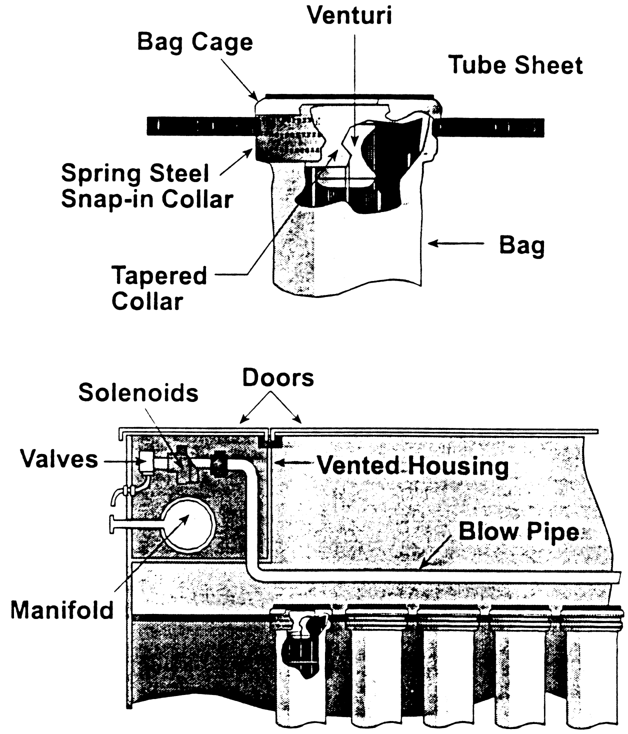


FIGURE 12-9 How bags are mounted to cage, sealed to tube sheet, and installed in baghouse.

the diameter and length of the individual bags, and the emission-control specifications. Each baghouse has a clean-air and a dirty-air side. The exhaust fan pulls the dirty air from outside the filter fabric through the material to the inside. The fines are caught on the outside surface of the bag, and the cleaned exhaust gases, relieved of the dust, are carried out the top of the bag and to the stack. The fines build up on the outside of the bag with time and form a dust cake or coating on the bag. The extent of the dust coating determines the efficiency of the filter: if the bags are too clean, only the coarser fines will be caught, and the finer particles will pass through the fabric; if the bags are too dirty or blinded, the exhaust gases will be unable to pass through the dust cake, and the baghouse will eventually stop operating. The thickness of the dust cake is generally determined by the frequency of the filter bag cleaning cycle.

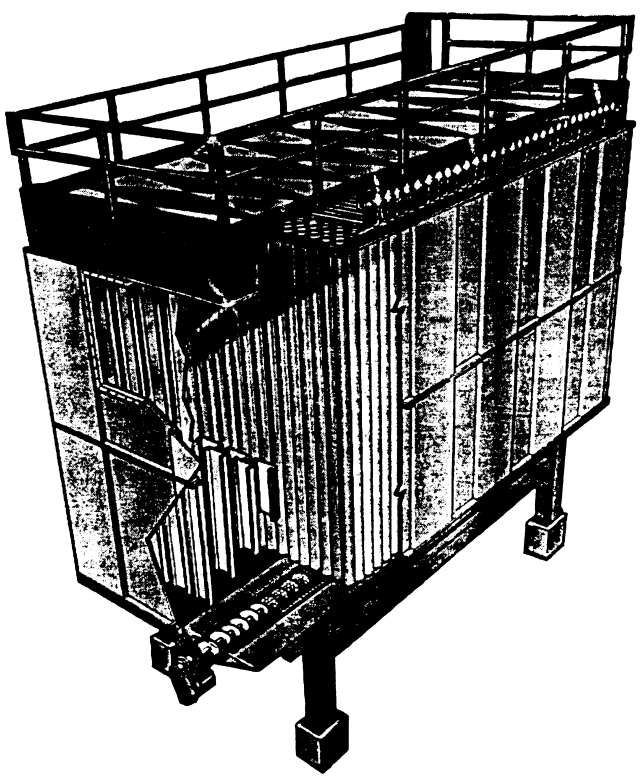


FIGURE 12-8 Cutaway view of typical baghouse.

To remove a portion of the built-up dust on the filter bags, the bags must be cleaned periodically (see Figure 12-10). Bags are cleaned in rows or in groups so that most of the baghouse is in the collecting mode while some of the bags are being cleaned. One of two primary processes is used for the cleaning—reverse air or pulse jet. Reverse-air cleaning is done by passing a large volume of low-pressure air backward through each bag (from the clean side to the dirty side) to release the pressure on the dust cake adhering to the outside of the bag and cause the dust to fall off. Pulse-jet cleaning is done by injecting a small volume of high-pressure air into the bag, causing the fabric on the cage to expand. The expansion of the bag fabric knocks the dust cake loose from the outside of the bag, and the dust then falls to the bottom of the baghouse. Pulse-jet cleaning is the

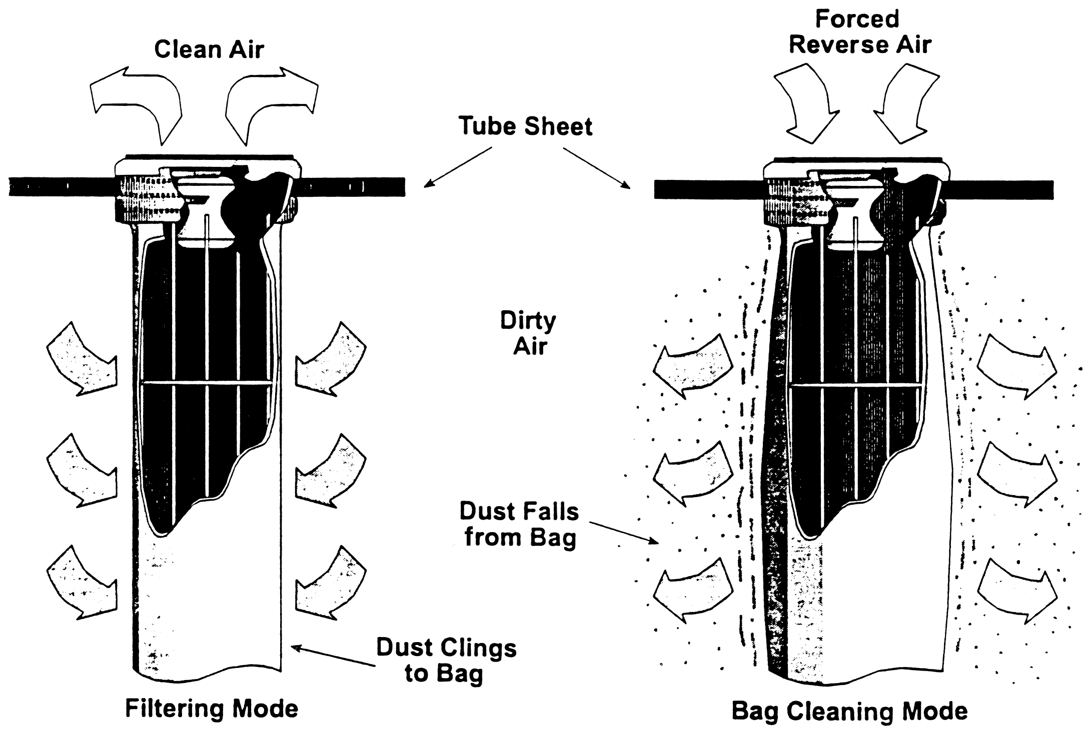


FIGURE 12-10 Bags filtering air and being cleaned.

method used most commonly on most of the newer fabric filters. The particulates removed from the bags are collected for return to the plant or are wasted.

A baghouse can remove up to 99.9 percent of the fines in the exhaust gas stream. This efficiency is measured in part by the amount of pressure drop—generally in the range of 50 to 150 mm (2 to 6 in.) of water column—between the dirty and clean sides of the bags. If the pressure drop is too low [25 to 50 mm (1 to 2 in.)], the bags are too clean, so that some of the very fine dust particles will pass through the filter and travel up the stack and out to the atmosphere. If the pressure drop is too high [greater than 150 mm (6 in.)], the fines buildup on the bags is excessive, the exhaust gases will be restricted from passing through the fabric, and the capacity of the dryer or drum mixer will be reduced.

The efficiency of the baghouse will be affected if the temperature of the exhaust gases entering the baghouse is below the dew point—the temperature of the exhaust gas at which moisture begins to condense. The moisture, combined with the fines in the exhaust gases, forms a mudlike coating on the outside of the bags that cannot easily be removed during the bag-cleaning cycle. Should this happen, the pressure drop across the bags will increase significantly, reducing the efficiency of the baghouse and even choking off the burner flame in extreme cases. To prevent this from occurring, the baghouse must be preheated by running the burner on "low fire" without aggregate in the drum before mix production begins each day.

If subjected to temperatures above 225°C (440°F) for extended periods of time, the synthetic fiber bags can char, disintegrate, and then burn. To prevent this, a temperature sensor and automatic shutdown devices are installed in the ductwork upstream of the baghouse. The sensor is typically set at a temperature of 205°C (400°F). If the temperature of the exhaust gases exceeds this value, the sensor sends a visual and/or audible signal to the plant operator or may automatically shut off the fuel flow to the burner. Some baghouses are fitted with automatic fire extinguisher devices to control a fire should one occur in the emission-control equipment.

The gradation of the asphalt mix produced in a batch or drum-mix plant may change depending on whether any or all of the baghouse fines are returned to the plant. If the collected dust is returned, the mix gradation will be approximately the same as the gradation of the incoming new and reclaimed aggregate (assuming minimal degradation of the aggregate during processing through the dryer or drum mixer). If the baghouse fines are wasted, there may be a considerable change in the mix gradation. Note that if the fines are returned, it is important that they be introduced into the batch or drum-mix plant continuously and uniformly.

FUGITIVE DUST

Although the primary source of emissions from a batch or drum-mix plant is fines carryout, additional emissions are possible in the form of fugitive dust. This dust consists of material that leaks from the plant through holes in the equipment or ductwork while the plant is operating.

For a batch plant, the three most likely sources of fugitive dust are the hot elevator, the plant screens, and the pugmill. As the aggregate is delivered from the hot elevator to the screen deck, it passes over the vibrating screens. This movement creates dust, as does the mixing of aggregate in the plant pugmill during the dry-mix cycle. Fugitive dust can be eliminated by enclosing the screen deck area completely and tightly and by keeping the dry-mix time in the pugmill to a minimum. In addition, a scavenger air system (fugitive dust evacuation system) creates a negative air pressure inside the plant housing and greatly reduces the amount of dust carryout during plant operations. This system usually consists of ductwork with adjustable dampers extending from the screen deck, hot bins, weigh hopper, and pugmill to the inlet of a fugitive dust fan, which then blows the dust to the dust collection system. On some plants, a fugitive dust fan is not used; in this instance, the ductwork extends directly to the inlet of the secondary collector.

For both batch and drum-mix plants, holes in the emission-control equipment, primarily in the ductwork between the end of the dryer or drum mixer and the dry or wet collector, may allow the escape of fine aggregate particles or dust. These holes should be patched so that all of the dust in the exhaust gases will be drawn into the emission-control collectors. Further, the holes should be eliminated in order to prevent the exhaust fan from drawing in excess (leakage) air and reducing the amount of air available for proper combustion of the fuel at the burner.

SUMMARY

The following key factors should be considered when monitoring the operation of the emission-control equipment:

- The discharge of the exhaust gases from the stack should be observed for a dust trail at the end of the steam plume. If one exists, the operation of the emission-control equipment should be checked.
- If a wet scrubber is used, the spray nozzles in the venturi should be checked to ensure that all are open and spraying water properly.
- The cleanliness of the water being returned to the spray nozzles from the pond should be checked at the point at which the water is drawn from the pond to be returned to the plant by the water pump.
- If a baghouse is used, the pressure drop across the bags should be in the range of 50 to 150 mm (2 to 6 in.) of water column.
- The temperature of the exhaust gases entering the baghouse should be less than 205°C (400°F). An automatic shutoff device should be used to stop the operation of the plant if the exhaust gas temperature exceeds this value. The temperature of the gases entering the baghouse should be considerably less than this if the veil of aggregate inside the dryer or drum mixer is correct.
- The gradation of the mix produced in the batch or drum-mix plant should be compared with the gradation used in the mix design process. The amount of change in gradation will depend on whether a wet scrubber system is used and whether the baghouse fines are returned to the plant or wasted.