SECTION

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

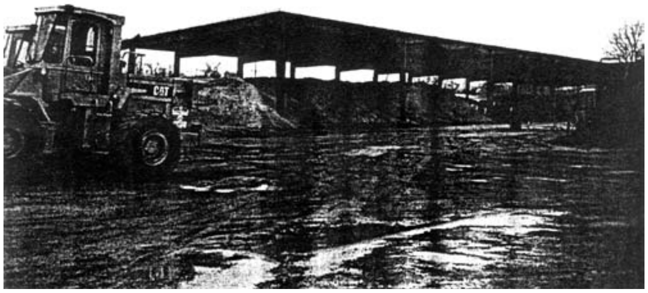

FIGURE 6-1 Covered aggregate stockpiles.

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

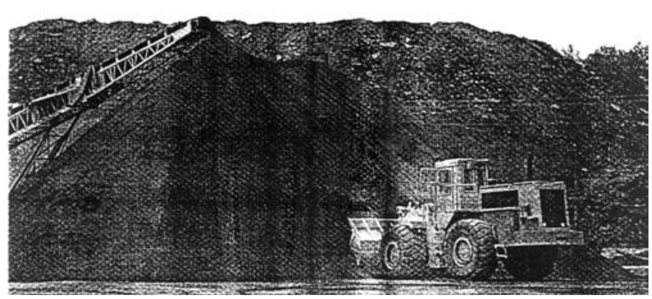

FIGURE 6-3 RAP stockpile using radial stack.

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.

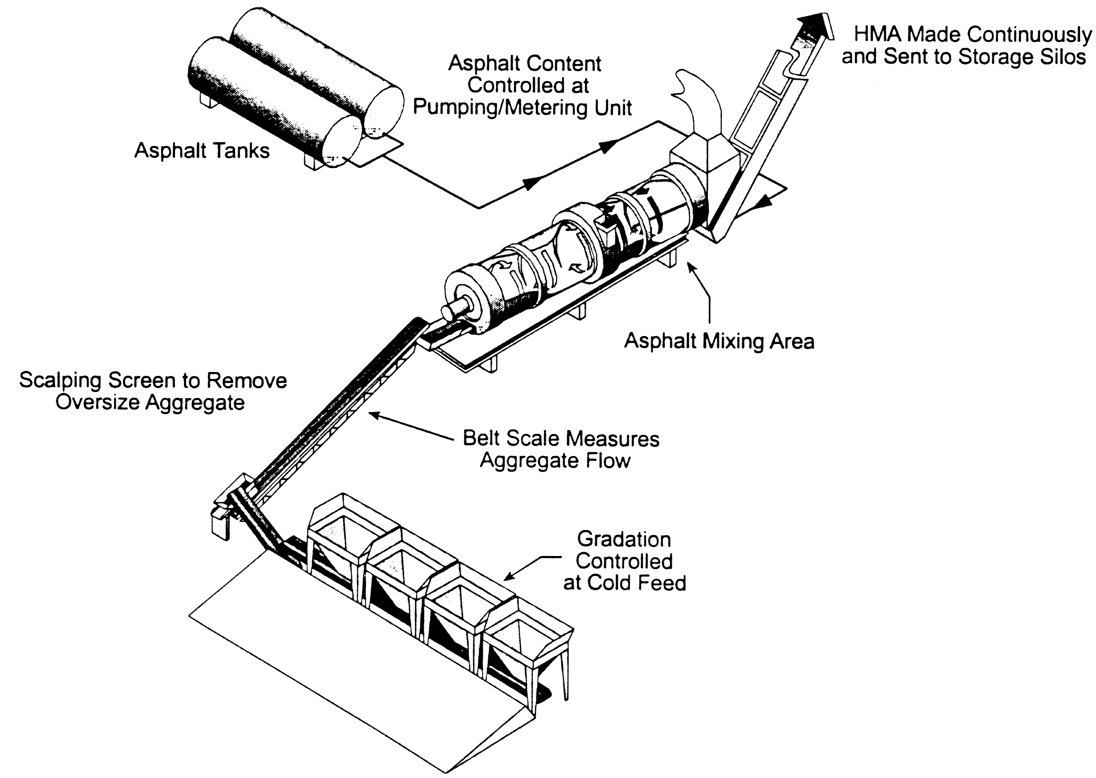

FIGURE 6-4 Flow of material through a drum-mix plant (continuous-flow facility).

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.

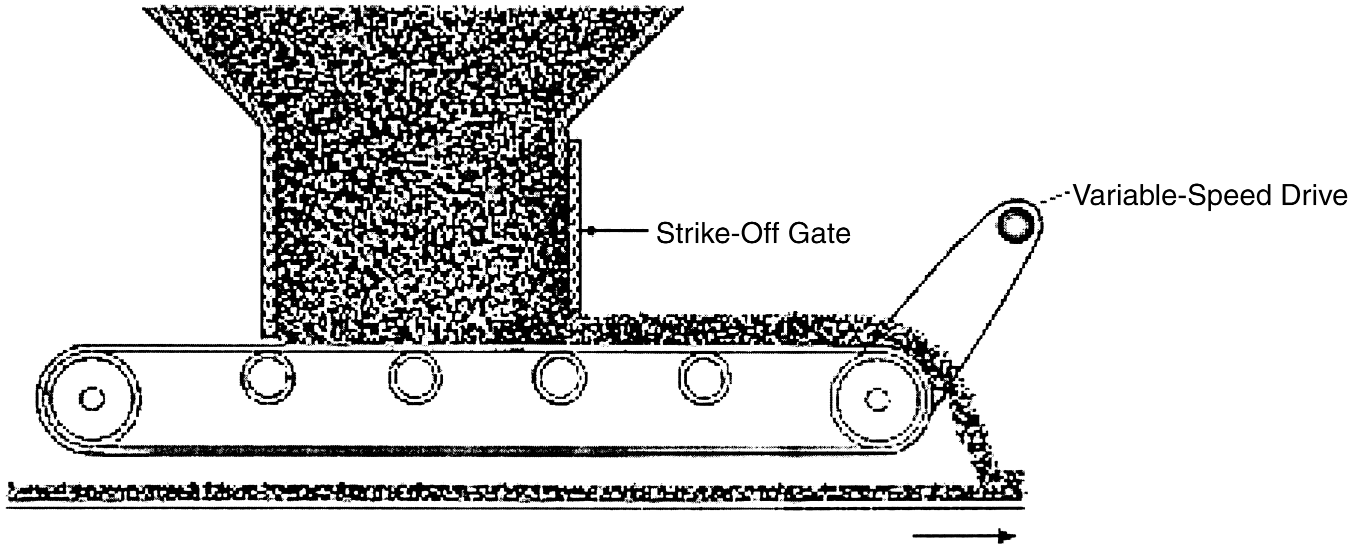

FIGURE 6-5 Continuous feeder belt.

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

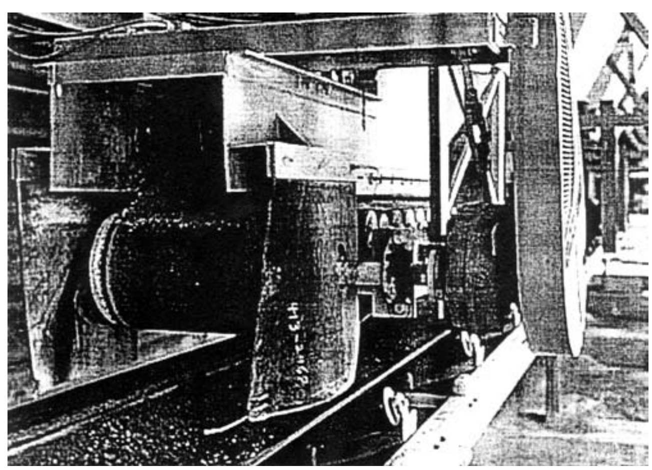

FIGURE 6-6 Collecting conveyor under cold-feed bins.

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.

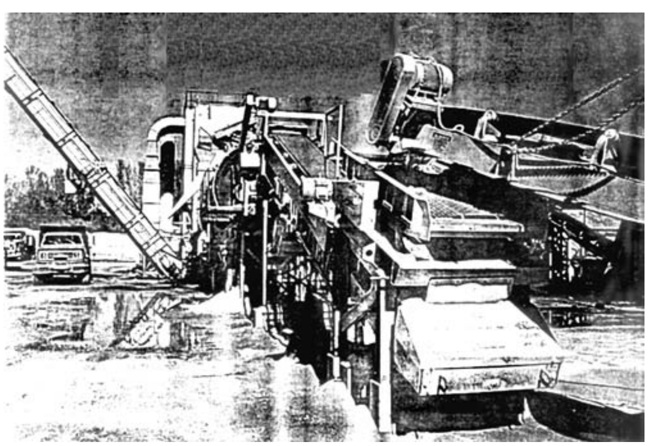

FIGURE 6-7 Single-deck scalping screen on drum-mix plant.

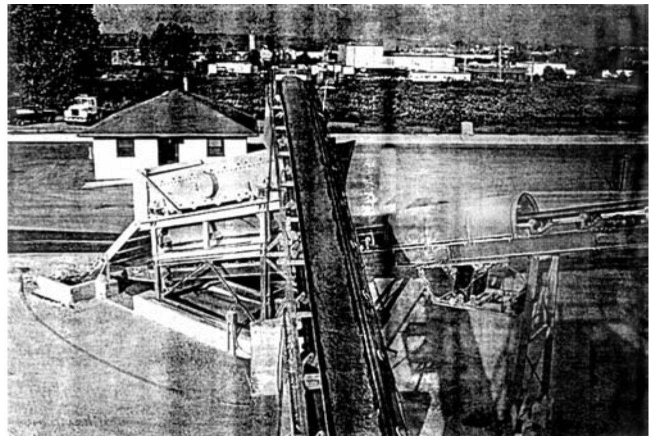

FIGURE 6-8 Double-deck scalping screen on drum mixer with air-operated deck selector.

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.

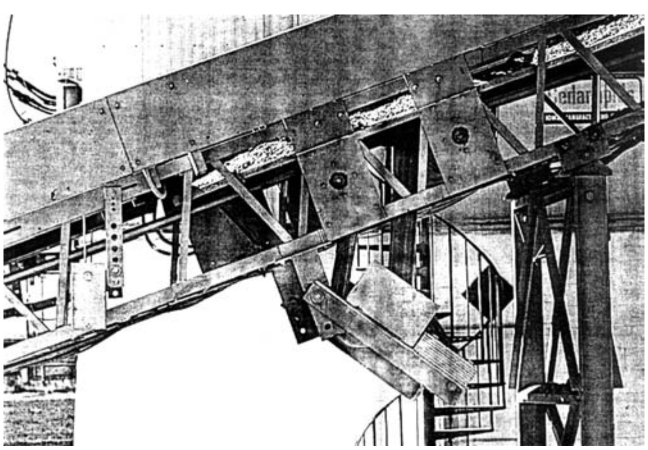

FIGURE 6-9 Weigh bridge.

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

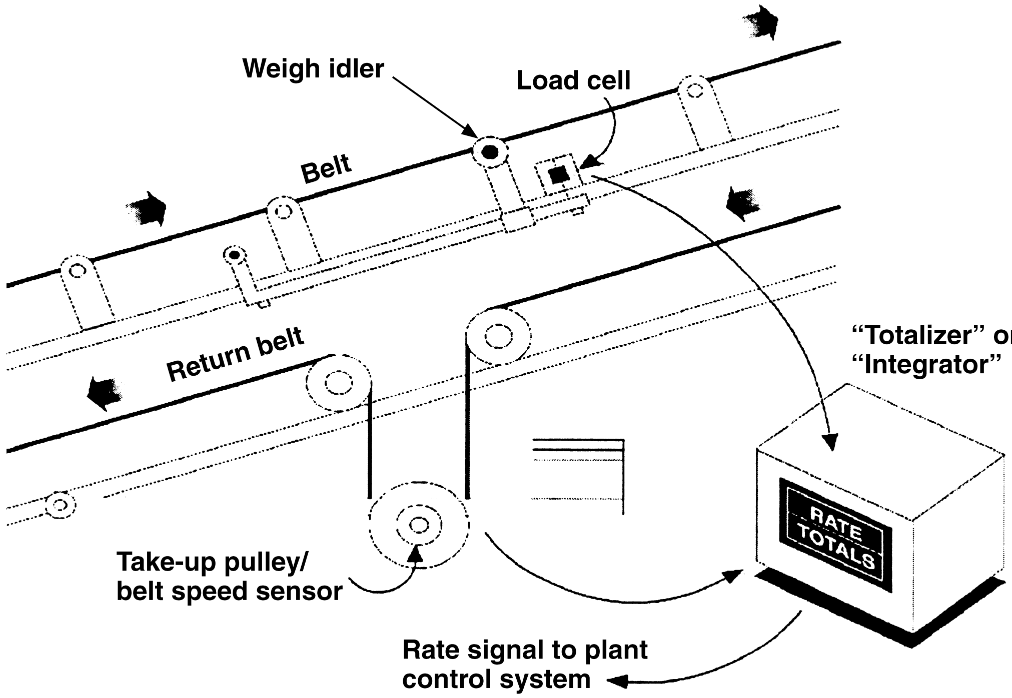

FIGURE 6-10 How a weigh bridge works.

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

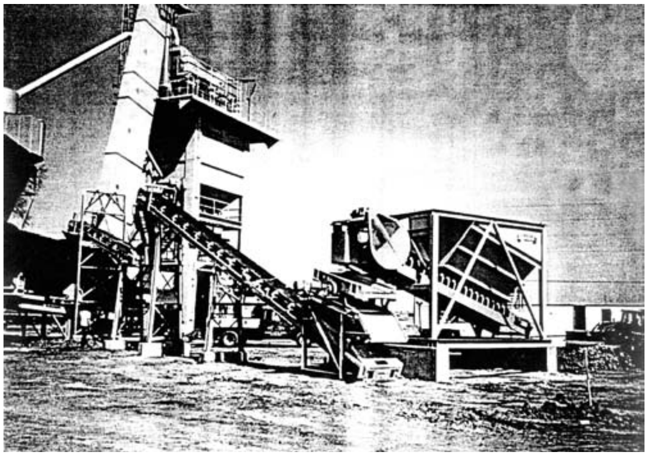

FIGURE 6-11 Inclined RAP feeder.

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

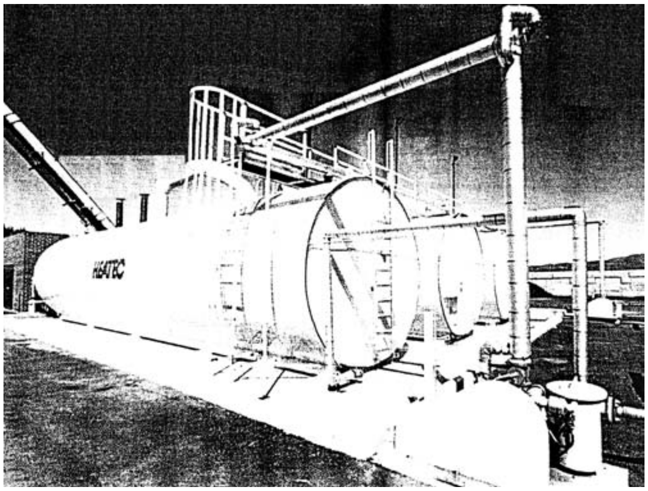

FIGURE 7-1 Typical horizontal asphalt cement storage tanks.

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

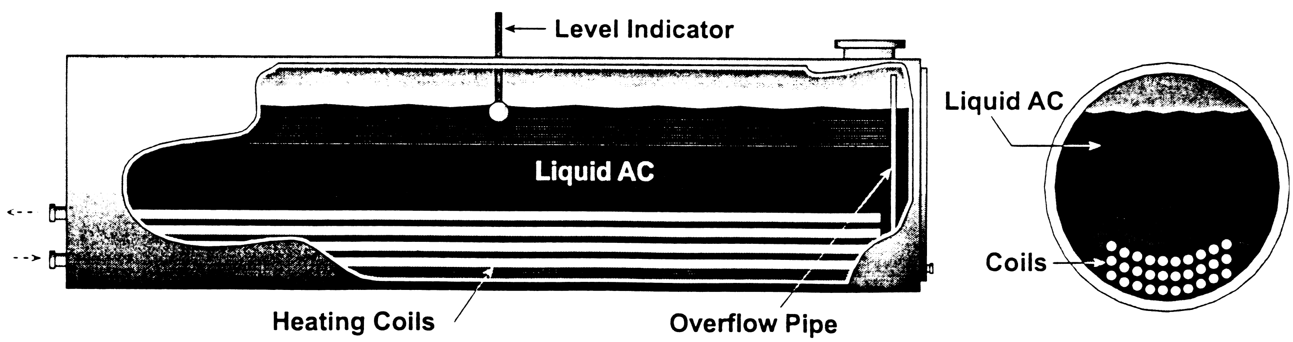

FIGURE 7-2 Heating of horizontal storage tank.

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-

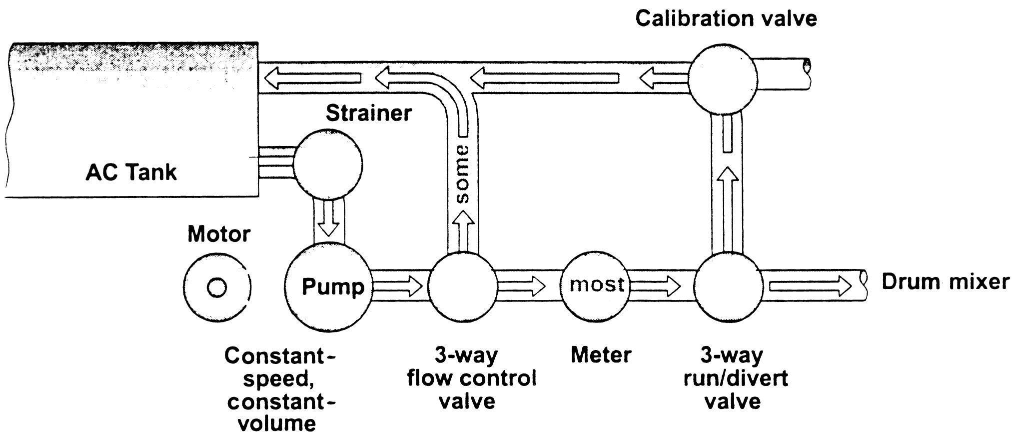

FIGURE 7-3 Asphalt metering system for drum-mix plants with constant-volume, constant-speed pump and flow control valve.

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

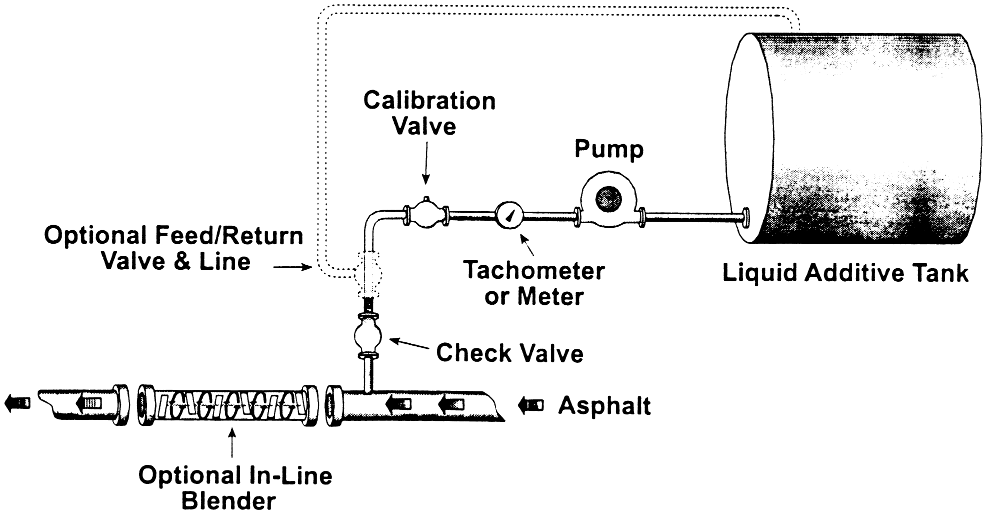

FIGURE 7-4 Typical asphalt additive tank system.

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.

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-

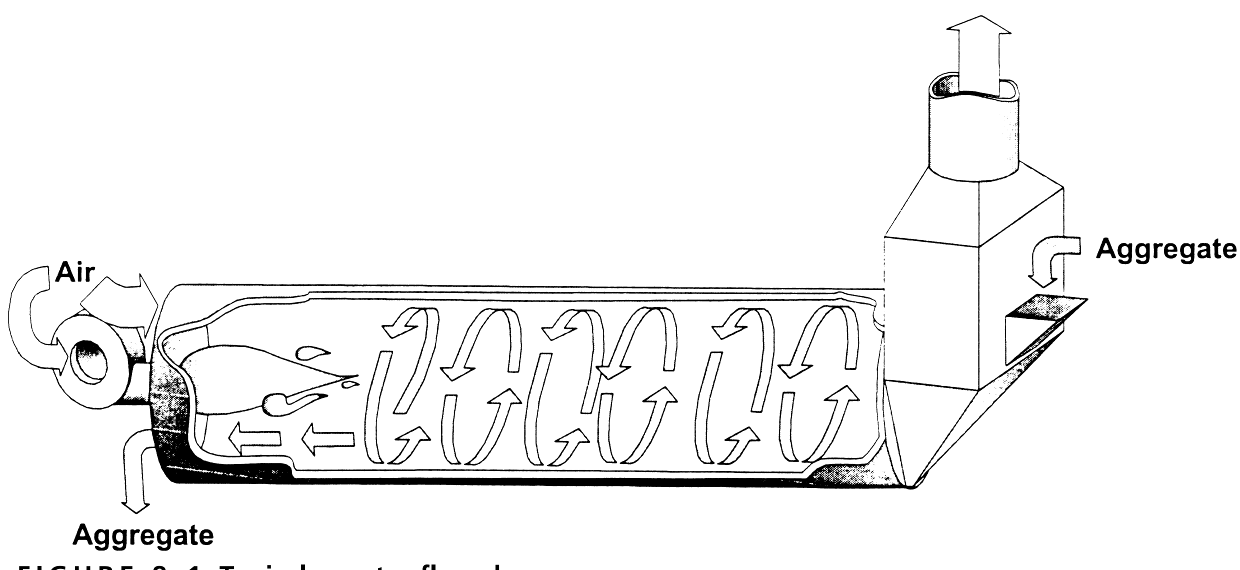

FIGURE 8-1 Typical counter-flow dryer.

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 (5⁄16 to 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.

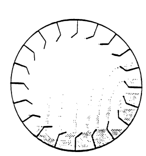

FIGURE 8-2 Proper veiling.

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 ($1\frac{1}{4}$ in.) for the top deck, 14 mm ($\frac{9}{16}$ in.) for the second deck, 8 mm ($\frac{5}{16}$ in.) for the third deck, and 4 mm ($\frac{5}{32}$ in.) for the bottom deck. The sand-sized aggregate, smaller than 4 mm ($\frac{5}{32}$ 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 ($\frac{5}{32}$ in.) but no larger than 8 mm ($\frac{5}{16}$ 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.

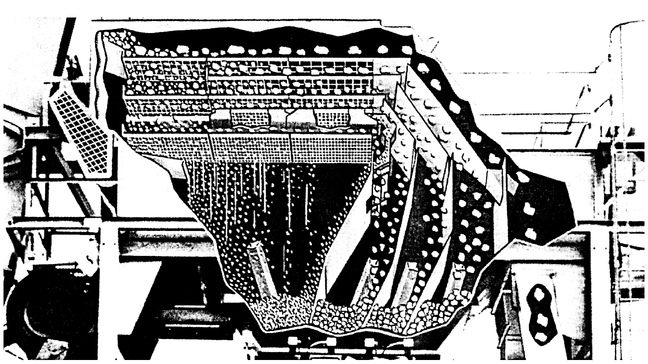

FIGURE 8-3 Cutaway illustration of screening process.

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 ($\frac{5}{16}$ in.) for the half of the deck nearest to the hot elevator and a screen with an opening of 32 mm ($1\frac{1}{4}$ 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 semi-automatic 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

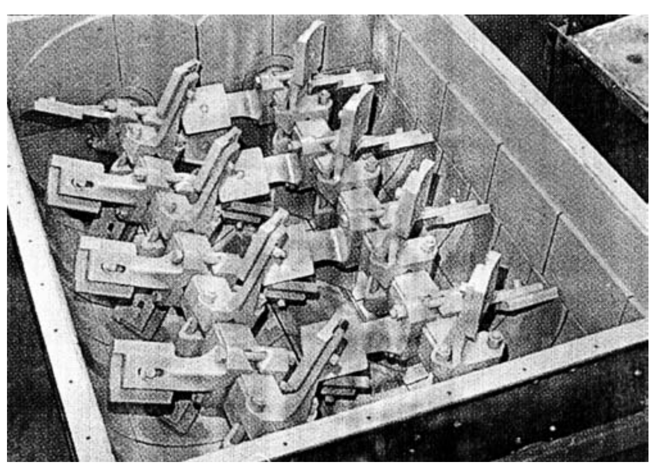

FIGURE 8-4 Interior of pugmill.

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

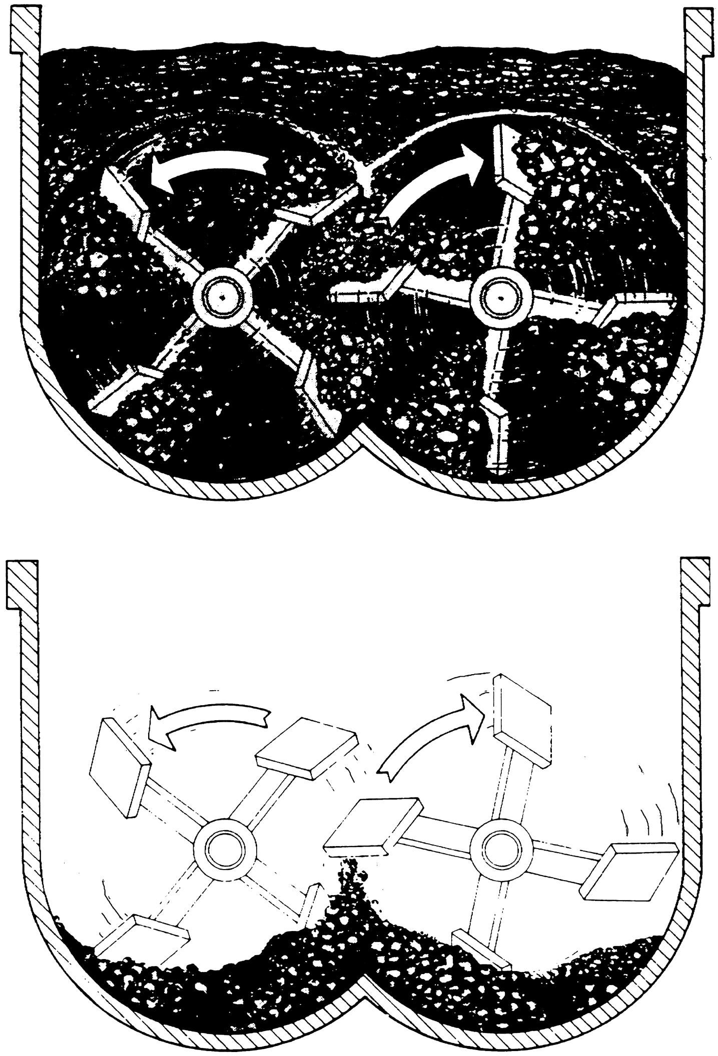

FIGURE 8-5 Overfilled and underfilled pugmills.

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-

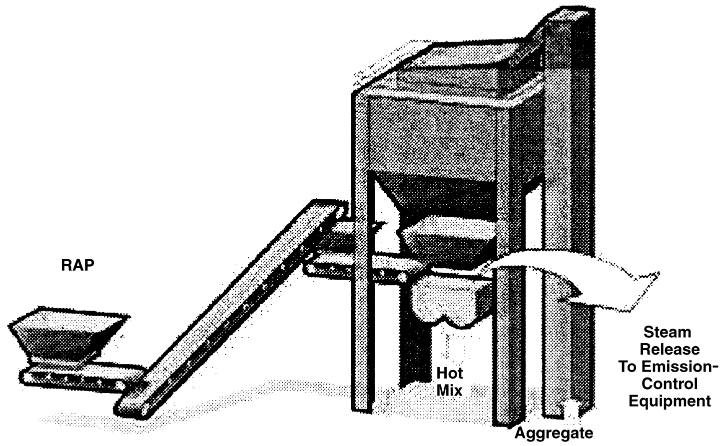

FIGURE 8-6 Weigh-box method of batch plant recycling.

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.