

**PRODUCTION AND LAYING OF
HOT MIX ASPHALTIC
CONARETE**

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CONCRETE

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PREFACE

There are many methods to design and prepare asphalt roads. It seems that we can find many brief statements about every method in most highway construction text-books, but in very few books do we find much detail about the production and laying of asphalt pavements. The purpose of this study is to set forth the production and laying of hot mix asphaltic concrete. Because it can be used not only for light traffic roads, but also for heavy traffic roads, and since it is particularly economical to use for roads carrying heavy loads, its use may be generally recommended.

Indebtedness is acknowledged to Dr. Moreland Herrin for his valuable guidance in preparing this study. We also feel special gratitude toward Barber-Greene Company for the loan of much of the material used.

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(Figure 1, from "Principles of Asphaltic Concrete Pavement Design, Control and Construction" by Moreland Herrin and J. Rogers Martin.)

(Figure 2 to 6 from "Bituminous Construction Handbook" by Barber-Greene Company.)

CHAPTER I

GENERAL DESCRIPTION

Time pushes us forward. The most important factor of modernization is communication. And the most important facility in communication is the automobile. A good example is that every year we increase the number of our automobiles. Acturally, we need good highway besides good cars.

Most roads are built as a comprise - and rightly so. Even in the United States, only a very small amount of the Nation's roads can be approached on the basis of the "ideal type." Usually, it is a question of the best method within limited dollars per mile, and local traffic requirements, materials, and climate. In many instances bituminous road construction fits these needs.

Therefore, it is desirable to start with the objectives. With these in mind, alternative construction methods and machines can be studied and selected on the basis of the degree that they meet these objectives.

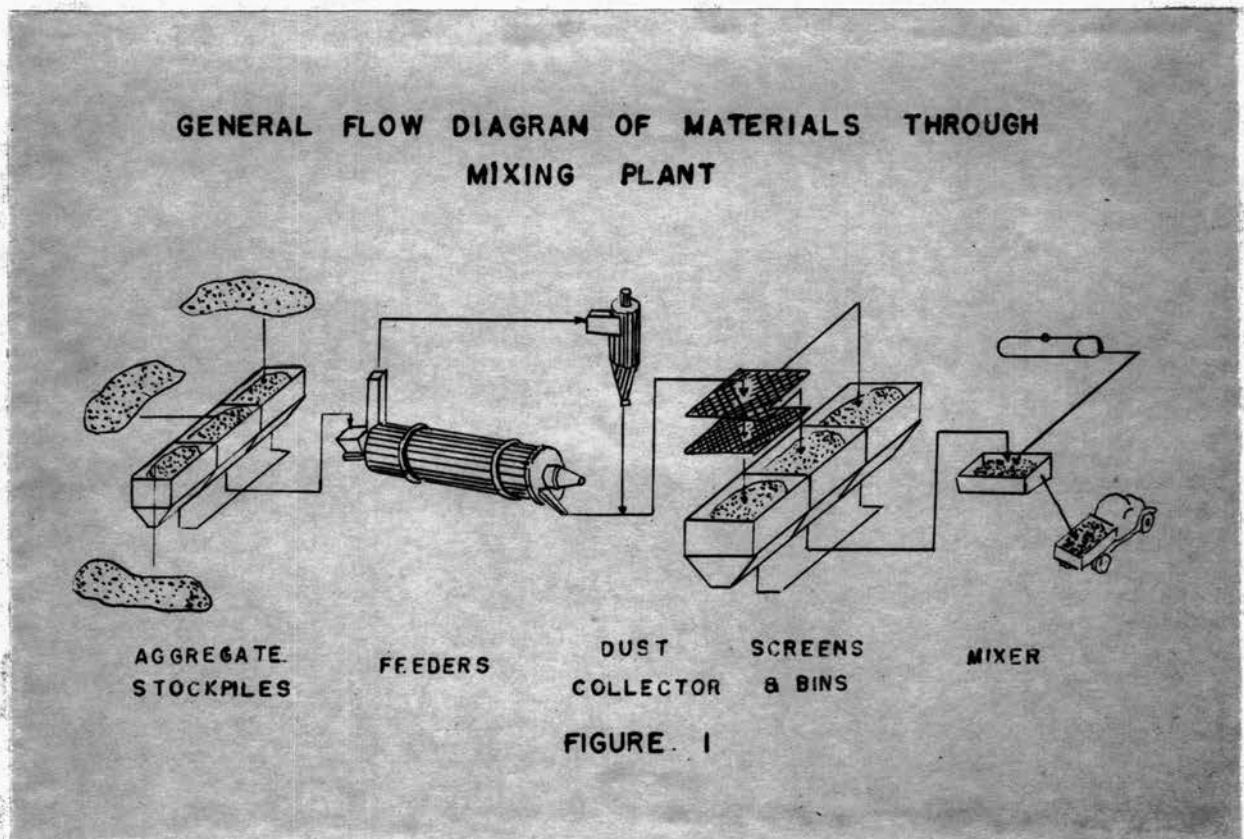
Even in the backward countries, using machines for road construction is necessary if they are to meet the objectives described below.

Many types of asphaltic wearing surfaces are used in highway and airfield paving construction. All of these asphaltic pavements have two basic components -- mineral aggregate and asphaltic binder. These surfaces are asphalt surface treatments, asphalt road, cold-laid asphaltic concrete and hot mix asphaltic concrete. Because the

hot mix asphaltic concrete can be used at either light traffic condition or heavy traffic condition, this report is to only deal with the hot mix asphaltic concrete production and laying.

First, we need to know the procedures in the asphaltic road construction. Then, we know which machines we need to use. And then we know alternative methods and alternative machines we can select.

The following figure shows the movement of the aggregate and bitumen through a hot mix central plant.



From the figure, we know at least we need cold feeding, drying, screening and grading, mixing, dust collecting, finishing, and rolling machines.

Then we shall discuss each machine separately. And at last we can analysis in what condition, we can select which kind of machines.

CHAPTER II

COLD FEEDING

A bituminous plant does not create aggregate or aggregate size. Therefore, proper aggregate must be fed into the plant at what is commonly called the "cold feeding" end.

There are so many methods to feed the required aggregates into the plant, and each method has its advantages and applications. Sometimes only one aggregate is charged into the plant, but usually we need to blend two, three, or four aggregates at the cold feed in order to have a suitable composite gradation.

Proportioning Aggregates

The simplest method of determining the proportions of each aggregate to use is probably by trial and error. Various percentages of each aggregate are mathematically combined to obtain a composite gradation using the greatest possible amount of the most economical aggregates and meeting the specification requirements. An example of the combination of four aggregates is in figure 2. Ordinarily, two or three trials are needed to find the desired proportions instead of the single trial shown here. The filler, though included in the calculations, is not added at the cold feed, but is added after the other material has been dried.

It is within the specific limits and very closed to the middle of the specific limit 45.

FIGURE 2

TRIAL BLEND OF FOUR AGGREGATE

Sieve	Crushed Stone		River Sand		Fine Sand		Filler		Composite	Specification
Size	Grad.	55%	Grad.	26%	Grad.	16%	Grad.	3%	Gradation	Limits
1"	100	55	100	26	100	16	100	3	100	100
3/4"	74	40½	100	26	100	16	100	3	85½	70-100
3/8"	35	19½	100	26	100	16	100	3	64½	50-80
#4	10	5½	100	26	100	16	100	3	50½	35-55
#10	5	3	58	15	100	16	100	3	37	23-42
#40	3	1½	9	2½	69	11	100	3	18	12-27
#80	2	1	4	1	37	6	94	3	11	8-18
#200	1	½	2	½	3	½	87	2½	4	3-7

Note: All figures in the table are percent passing #4 sieves:

Crushed Stone	10 X 0.55 = 5.5
River Sand	100 X 0.26 = 26.0
Fine Sand	100 X 0.16 = 16.0
Filler	100 X 0.03 = 3.0
Composite grading	<u>50.5</u>

Methods of Cold Feeding

A very common method of handling the aggregate at the cold feed is by means of aggregate surge bins and a crane to charge them from the stockpiles of aggregate located close by. The number of bins or hoppers used depends upon into the plant. Beneath each bin is located a feeder to control the rate of flow.

Another common method of handling the aggregate is with a bulk-head setup. The aggregate is stored on the ground against the bulk-

head, and a dozer is used to keep the material pushed over the feeder. Two different aggregates may be handled.

Another method of aggregate control makes use of a conveyor is located in a tunnel beneath the stockpiles of aggregate, and the conveyor belt is charged with aggregate from each of the stockpiles by means of a feeding mechanism. The number of different aggregates that may be handled is limited only by the length of the conveyor and the size of the individual stockpiles.

Bin Controlled

Each bin should have an accurately controlled individual gate to form an orifice for volumetrically measuring the aggregate drawn from each bin compartment. The orifice should be rectangular of dimension about 8 to 9 inches with one dimension adjustable. Arrangements should be made so that aggregates can be by-passed to a test box, as required, to determine the accuracy of the volumetric control.

The proper opening of each cold bin is usually determined by intelligent trial and error. In cases where a contractor has previous experience with his bins, he will know about what the opening on each bin should be to give a specified flow. Some equipment manufacturers furnish tables for their bins which will guide the operator in making the initial openings.

If all the cold bins are of the same type and have the same forward speed, the initial settings may be made by fixing the area of each opening in direct proportion to the weight percent to be added from that bin, except that the fine bin opening should be increased about 10 percent more than its calculated value.

If the materials are carried to the drier on a belt conveyor, it is a simple matter to check the feed from each bin. Close all the bins except one which is set at the opening that is believe to be about right. Start the plant, and allow the belt to become loaded with aggregate, then stop the plant. Remove and weigh the material from a measured distance on the belt, and calculate the pounds of material per foot of belt. This, when multiplied by the speed of the speed of the belt in feet per minute, gives the pounds per minute of feed. Two determinations will usually yield the information needed to make the correct initial setting on the bin gate.

CHAPTER III

AGGREGATE DRYING

The dryer drives off most of the moisture present in aggregate and, at the same time, heats the material to the desired mixing temperature.

The actual drying process is simply a transfer of heat from a blast of hot gases to the veil of aggregate within the dryer drum causing the moisture to be vaporized and conducted out the exhaust stack.

Generally speaking, aggregate dryers used in bituminous central plants look very similar. They are essentially a long rotating drum with inside lifting flights which continuously drop a veil of aggregate through the hot gases. The drum is inclined, the amount determining the time required for the aggregate particles to pass through the drum.

A feeding hopper for the aggregate is located at the high end, and the oil or gas burner is located at the low or discharge end. This arrangement gives a counter flow of the gases to the aggregate so that the highest temperature is located at the point of aggregate discharge.

Principles of dryer design

The following principles were quite universally followed by manufactures of aggregate dryer for a number of years:

1. Drying and heating were best accomplished by passing the hot gases of a burned fuel around the individual particles of a veil of aggregate.

2. The dryer drums were relatively long to provide sufficient time for heat transfer.

3. Channel type lifting flights, which spilled the aggregate over hardly more than 50 percent of the drum cross sectional area, were used. This permitted a free passage for the hot gasses along one side of the drum but contributed to the necessity of a long drum.

4. Heat stresses, warpage, and abrasive wear caused by sliding aggregate created a need for thick and heavy drum shells.

5. Gear drives were used, requiring heavy structural supports, trunnions, etc. to prevent misalignment.

After much testing and development work, however the following principles have been evolved for the present day type of aggregate dryer:

1. Heat transfer could be more quickly accomplished through radiation than through convection. In other words, the drying process would be speeded up in a smaller space if more of the aggregate could be suspended near the flame instead of depending upon the hot gases to transfer the heat by convection (The speed of heat transfer by radiation is demonstrated by the rapidity with which snow melts in the direct sun versus the speed with which it melts in shade at the same air temperature.)

2. Special lifting cups were designed that would give a veil of aggregate across the entire cross section of the dryer drum. The spacing of the cup flights was controlled to give the correct veil density in order to have the optimum particle surface area for heat

transfer. Too great an area cooled the flame too rapidly and prevented complete combustion; too small an area reduced drying capacity.

3. The first two principles permitted utilization of a shorter drum where quicker heat transfer could be achieved through the effects of radiation and through a more rapid contact between the gases and more of the suspended aggregate particles.

4. With the establishment of a reasonable minimum length of dryer drum, experience showed that dryer capacity increased in proportion to the drum cross sectional area.

5. It is proved that a thinner drum shell could be used than was previously thought advisable. Properly designed lifting flights protected the drum against sliding abrasion and impact. The special high temperature steel used in the drum was more flexible to adapt itself to heat stresses. The decreased weight substantially helped portability.

6. A chain drive was designed for the drum to give greater flexibility so that a more reasonable amount of structural misalignment could take place than would be permissible with a gear drive.

The most efficient dryer is the one that can remove moisture and raise the temperature of the aggregate to the specified point with the minimum amount of air going out the stack and at minimum stack temperature

Methods of Combustion

Dryer efficiency and burner combustion efficiency are often confused. Dryer efficiency was discussed immediately above. Many times, it is more economical on construction jobs to operate a dryer

beyond its optimum heat efficiency point in order to produce higher capacity with the same physical equipment.

A burner operating at maximum combustion efficiency burns the fuel completely and releases all of the heat available in a unit of fuel. The efficiency can generally be measured, in lieu of testing instruments, by observing the amount of black smoke coming out of the stack. An absence of black smoke indicates maximum burner efficiency, provided the air volume is reduced to a minimum — regardless of the make, type, or principle of the burner.

The burner selected must be in balance with the potential drying capacity of the dryer to provide the necessary amount of heat and still maintain efficient combustion performance.

Burners of the same combustion efficiency have different burning characteristics. Some burners produce a long controlled flame, which reaches far into the dryer drum. Other burners tend to produce a fine dispersal of fuel at the nozzle end, and, therefore, quick combustion. The flame is of the blossom type, with the heat concentrated close to the burner. The combustion chamber must absorb this heat, and it is more difficult to utilize the advantage of direct heat radiation than with the longer flame.

Two basic types of burners are now in general use. One type uses steam to atomize the fuel. The low pressure method uses air pressure produced by blowers or fans. It was formerly considered impossible to produce a long controlled flame with a low-pressure burner in higher-capacity dryers. Recently, however, low-pressure burners have been developed that will produce a flame equal to that of high-pressure steam burners.

An important point to consider in the selection of a burner is combustion chamber and dryer drum maintenance. A short blossom type flame will greatly increase dryer maintenance costs because of the intense heat produced near the burner. It should also be borne in mind that high pressure steam permits the choice of steam jets of a fan to assist the stack draft, while with low-pressure air an exhaust fan must be used. Dust collectors are always recommended for low-pressure air systems, and they usually increase dryer performance with high-pressure steam systems through increasing the draft.

CHAPTER IV

DUST COLLECTING

Dust collectors are installed in asphalt plants to reduce the dust nuisance and to recover a portion of the usable fines that would otherwise be lost to the atmosphere and surrounding territory. Occasionally, some type of wet process is added to the dust collection system to further assist in the control of the dust nuisance around the plant.

Cyclone Dust Collectors

The normal dust collector is of the cyclone type in which the fines are separated from the dryer exhaust gases by centrifugal force. It uses a bank of cyclones for more efficient fines collection through reduced cyclone diameters. The air enters tangentially at the side near the top and is exhausted through the outlet pipe which extends part way into the cyclone. The collected fines are withdrawn from the bottom by means of a screw conveyor and returned to the aggregate flow in the plant.

When considering cyclone efficiency on the basis of clearing up the dust nuisance, it can be frankly stated that a cyclone type of dust collector will not eliminate the nuisance under normal types of operations. Figure 3 shows a general curve of cyclone efficiency for various particle sizes. It will be noted that if an aggregate includes dust particles in the smaller micron sizes (one micron

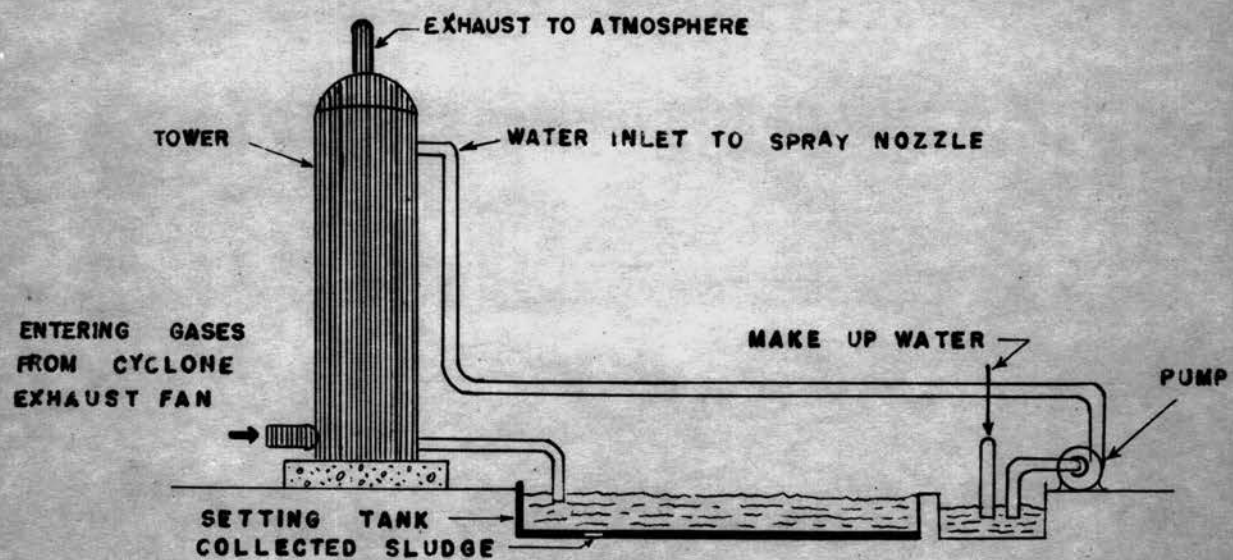
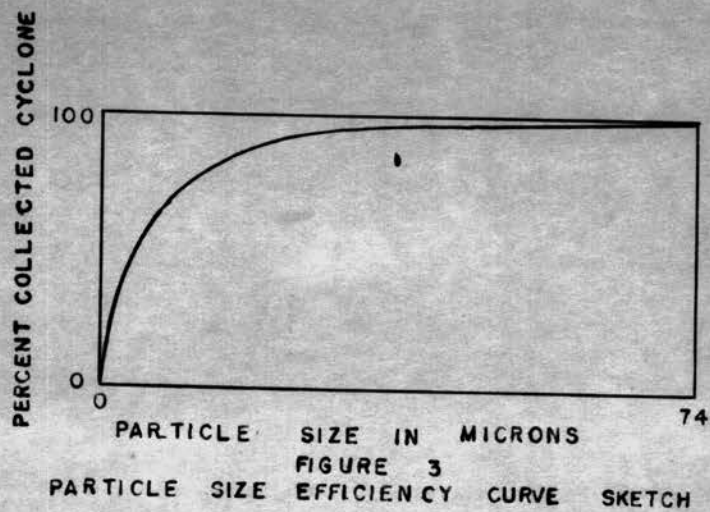


FIGURE 4
WATER SPRAY TOWER

equals one-millionth of a meter or $1/25,400$ of an inch. A particle of #200 mesh size is approximately 74 microns.) — as most dense-graded aggregate do — there will be a considerable amount of dust leaving the dust collector through the exhaust stack. The only practical means in use today for disposing of these fine particles exhausted from the dust collector is with a washing system.

It is true that different cyclones vary in efficiency. This is because they are designed and balanced out to operate with specific dryers under certain prescribed operating conditions. The efficiency of a well designed cyclone may of necessity be partially reduced to achieve a practical cost, portability, economical operation, etc. If an operator does not reduce the stack draft to the minimum possible for the specific drying conditions and capacities, there will be an increased loss of fines as well as an excessive heat loss.

Water Spray System

Central plant operations in or near towns may require additional control of nuisance dust. Numerous types of wet dust collectors have been used, but they tend to be expensive, bulky, and difficult to move. Operators are hesitant to invest in this additional equipment, feeling that the cost is out of proportion to the basic plant.

However, one wet system that is used frequently is a water spray tower such as that illustrated in figure 4. This may be constructed of wood or from a used railroad tank car. wood is corrosion resistant and longer lasting but easily ignited by the hot gases. The opposite is true of tank cars.

The exhaust gases from the cyclone enter the tower tangentially

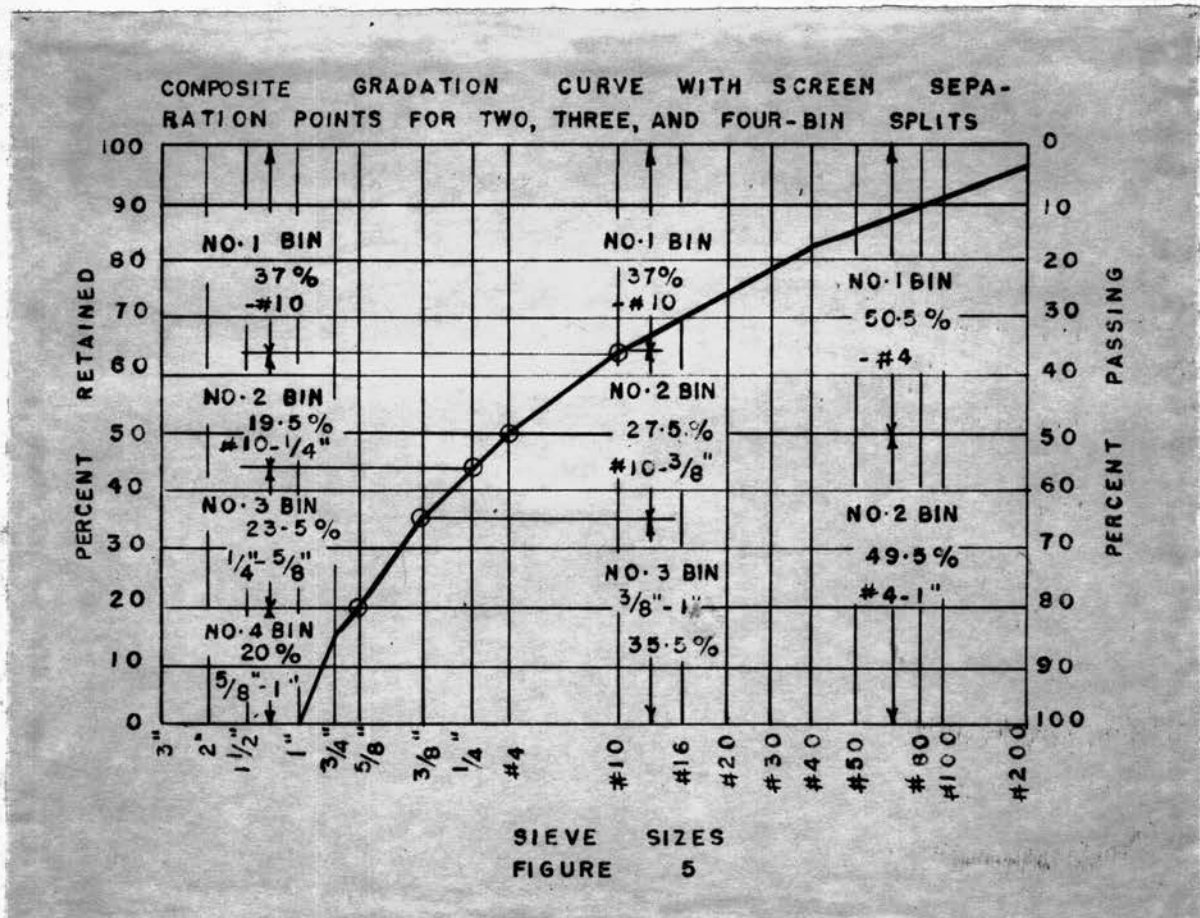
at the bottom and leave from the top. Water spary nozzles are located at several levels and are so placed as to completely blanket the entire cross sectional area of the tower with a fine spray. The spray cools the gases and collects much of the entrained dust.

A settling tank permits the dust to settle to the bottom and the water to be recirculated. Make-up water is continuously required, the exact amount depending upon the particular conditions.

CHAPTER V

SCREENING

After the aggregate has been dried, it is transferred to a hopper, from which it may be measured out to the mixer. Usually though the aggregate, before entering the hopper, is screened into two or more size ranges. The screens are selected so that the gradation is split according to the specifications. Examples of screening follow, using aggregate having the composite gradation shown in figure 2 and plotted in figure 5.



Screening and Grading

One screen is used to split the aggregate into two fractions, and a second screen may be used to scalp off any oversize material that is present. For the particular example shown in figure 5, the — #4 fraction falls into the No.1 bin and the $\frac{1}{2}$ #4 fraction falls into the No.2 bin. We call it two-bin split.

Three-bin split: Reference is again made to figure 5, which shows the same aggregate gradation divided at the #10 and $\frac{3}{8}$ " sizes for a three-bin split.

Four-bin split: When a four-bin split is made of this aggregate gradation, it is divided at #10, $\frac{1}{4}$ ", and $\frac{5}{8}$ ". Nothing smaller than a #10 mesh screen is used because the plant capacity would become too restricted by the small openings in the screen cloth.

The purpose of any control of the aggregate gradation is to more accurately regulate variations in gradation of the stockpiled aggregate and variations in the cold feed of two or more aggregates. The use of multiple aggregate cold feed is a form of gradation control, but the degree of accuracy necessary for the high-type mixes cannot be assured when using that method. The screening and grading takes place after the aggregate has been dried so that when the aggregate is split and recombined according to the specifications, any segregation that has taken place is corrected immediately prior to mixing the aggregate and binder.

Vibrating

Vibrating screens represent the most recent innovation in screen-

ing and have now become standard equipment for screening. In the various screens of this classification several types of mechanism are used to impart a rapid and positive vibration of low amplitude to the screen surface. In many cases the flow of material along the screen is provided by inclining the screen. Rapid low-amplitude vibration, in comparison with other types of screen motion, gives higher capacity and efficiency. Blinding, one of the most troublesome difficulties in fine screening, is reduced to a minimum. The rapidity of movement of all particles in the bed affords each under-size particle a greater number of direct contacts with the screen surface per unit time, and thus screening rate is increased and there is less chance of fine particles passing into the oversize product. Capacity and efficiency are further favored by the stratification induced by vibration. The agitated bed tends to stratify with the finest material on the bottom next to the screen and the coarsest on top.

Vibrating screens are divided into three principal types according to the mechanism used to provide the vibration: (1) off-center weights, (2) "positive throw", and (3) electro-magnetic.

The off-center weight vibrator is the simplest. Attached rigidly to a screen frame holding one or more decks of screen cloth is a shaft, mounted on ball or roller bearings, and rapidly revolved by a belt from a motor mounted outside of the screen frame. The shaft is supplied with two or more off-center weights, or the shaft itself may have eccentric bearings, so that as it revolves, it will "shiver" or vibrate the screen frame to which it is attached. The amplitude of vibration may be changed by changing the eccentricity

of the weights and the frequency of vibration by changing the speed of the supporting structure, the screens are mounted on various kinds of springs. The vibrating mechanism may be on a single shaft, or there may be two or more mechanisms designed to operate in tandem, in which case by varying the synchronism different kinds of vibration impulses may be transmitted to the frame and the screening surfaces.

In the positive-throw type of vibrating screen, the screen body itself is mounted on an eccentric shaft, which is rapidly revolved by a direct-connected motor or which is belt-driven from it. The screen body thus completes a circular gyration with every revolution of the eccentric shaft, the amplitude or throw of the screen body being fixed by the eccentricity of its bearing on the shaft. Counterweights on the ends of the drive shaft are designed to counterbalance the screen body and to prevent vibration of the supporting structure. This type is usually selected for screening large sizes, because, theoretically at least, the off-center weight type of screen, would have smaller amplitudes the heavier the loading, while the positive-throw type has same amplitude regardless of loading. The general rule is the coarser the screen the greater the amplitude and the lower the frequency of vibration, but some manufacturers use a more or less standard frequency for all mesh sizes.

The electro-magnetic vibrating screen derives its vibrating impulses from electric magnets and moving armatures. In one type the magnet is mounted over the center of the screen surface and the armature is attached rigidly to the screen surface. A special alternating current through the magnet alternately raises and pushes the armature away. On the upward stroke the armature contacts

an "anvil," designed to shake the meshes free from blinding particles, In other designs, synchronized electro-magnetic vibrators are placed at the four corners of the screen frame, and the screen is vibrated as a whole.

A second kind of electro-magnetic screen has the armature attached to the screen body by means of a bundle of spring bars. As the magnet pulls back the armature, the spring bars are flexed, and when the magnet releases the armature the springs snap it back. The magnetic impulses are turned to the vibrations of the spring bars and thus the screen body is made to vibrate as whole. A third type of electro-magnetic screen has two opposite magnetic coils with the armature between. The armature is rigidly attached to the screen body, and its back-and-forth movement between the coils is imported to the screen body.

All types of electro-magnetic vibrating screens require special electrical devices for supplying the kind of current needed, when and where it is needed. They have the advantage that by manipulation of these controls the amplitude and frequency of vibration can be readily changed, and they are capable of greater frequencies than any mechanically vibrated screen. This makes them preferable in many cases for fine screening, particularly with wet materials.

There is no generally accepted formula for estimating screen capacity because there are a number of variables of uncertain value which can be determined only by experiment and experience with the particular materials to be screened, and these may be vary from time to time in the same operation. One manufacturer has developed a formula and assigns values to the various factors. The formula is:

$$CP = \text{Area} (A \cdot B \cdot C \cdot D \cdot E \cdot F) \text{ ----- (1)}$$

$$TC = CP \div \text{Oversize} \text{ ----- (2)}$$

$$\text{Area} = \frac{TC - \text{Oversize}}{A \cdot B \cdot C \cdot D \cdot E \cdot F} \text{ ----- (3)}$$

In this formula CP is capacity in tons per hour passing the screen cloth, and TC is the total capacity including the oversize — the limit of feed to the screen. Factor A depends upon the size of the square-mesh screen opening and the character of the material to be screened. Factor B depends on the percentage of oversize in the feed. Factor C is a correction for the efficiency, which is practically an ideal condition. Factor D is the percentage of feed material less in diameter than one-half the size of the screen opening. Factor E is an attempt to evaluate the factor of wetness of the material. Factor F applies only to multiple-deck screens. The foregoing six variables refer to the material. There are at least five other variables in regard to the screen itself which affect both capacity and efficiency. These are (1) slope of angle of screen surface, (2) degree and method of loading, (3) amplitude of vibration of gyration, (4) speed of vibration, (5) direction of throw or vibration (with-flow or counterflow of the material on the screen). All of the factor A. B. C. etc., necessarily had to be based on some standards for the five variables mentioned here.

There is a wide variety of choice in the selection of the screening surface both in wire-mesh fabric and perforated metal. The selection of the proper mesh size to make a specified product is only indirectly indicated by the mesh designated in the specification. Thus the openings in the standard No. 8 test sieve are 0.093 in. sq. while an mesh of 8 commercial screen cloth has an opening 0.084 to 0.071 in. sq. depending on the diameter of the wire used; According this specification

aggregate producer does not order his screens by the specified mesh but by the size of opening best suited to make the desired product. Since in this case, the maximum size of the particle desired is 0.093 in. and for particle screening under ordinary conditions the mesh size might be about a half larger than the particle size, the producer would use a commercial screen cloth having approximately a 0.140-in. opening, which corresponds to about a 6-mesh commercial screen.

A great deal of experimenting is necessary in order to accomplish a desired result. There are various types of wire weaves, some designed to retard the flow of the material over the screen, others to hasten it; there are hexagonal openings, slotted openings, diamond shaped, etc. Ordinary rectangular mesh would be used with the long side of the opening in the direction of flow, but for dewatering or final rinsing or elimination of an excess of fine material, it may be desirable to put the long side of the mesh crosswise of the flow.

CHAPTER VI

MIXING

From the hoppers the aggregate is measured out to the mixer. The asphalt is measured and also added into the mixer. Within the mixer, the two are mixed together and discharged to a truck.

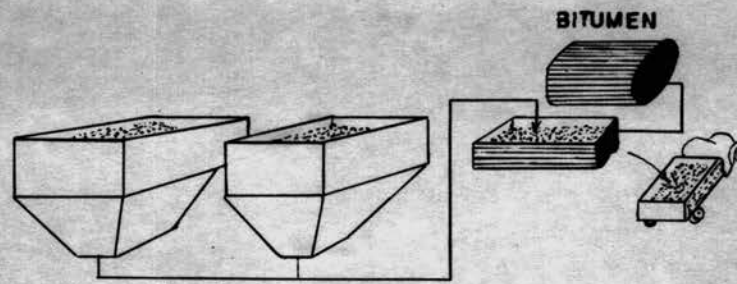


FIGURE 6
MIXING

Up to this point the discussion has considered neither batch plants nor continuous plants separately. Both the batch and continuous processes are identical through the screening and grading stage. However, proportioning and mixing are not performed in the same manner.

The pugmill type of mixtures are used instead of other mixtures because they are the result of years of experience and research into the basic characteristics of the mixing operation.

Common Batch Plant

The common batch plant includes a means for accurately weighing each bin size of aggregate in a weigh box or hopper, suspended on scales, ample in size to hold a full batch without hand raking or running over.

If an asphalt bucket is used for weighing the asphalt cement it shall have sufficient capacity to hold not less than twenty per cent of the weight of aggregate required for one batch. It is steam jacked or equipped with properly insulated electric heating units and is suspended on dial scales or beam scales so that the tare weight of the bucket is shown for each weighing. The bucket is so arranged that it will deliver the molten asphalt cement in a thin uniform sheet or in multiple streams the full width of the mixer, excepting in the case of a rotary mixer where the asphalt cement is sprayed.

The plant includes a batch mixer of an approved twin pugmill type, and is capable of producing a uniform mixture within the job mix tolerances. If not enclosed, the mixer box is equipped with a dust hood to prevent loss of dust by dispersion. The mixer is so constructed as to prevent leakage of contents until the batch is to be discharged.

The mixer has an accurate time lock to control the operation of a complete mixing cycle by locking the weigh box gate after the charging of the mixer, until the closing of the mixer gate at the completion of the cycle; it locks the asphalt bucket throughout the dry mixing period and locks the mixer gate throughout the dry

and wet mixing periods. The dry mixing period is defined as the interval of time between the opening of the weigh box gate and the application of asphalt; the wet mixing period is the interval of time between the application of asphalt and the opening of the mixer gate.

Barber-Greene Automatic Batch Plant

Lately a new type of batch plant has been developed by Barber-Greene Company, instead of batching the aggregate on a weight basis, it is batched on a volumetric basis. Plant operations are also automatic.

Dried aggregate is elevated to the tower, screened, and the individual sizes stored in separate storage bins in the conventional manner. Measuring of aggregate and bitumen, and the mixing, are all accomplished by new principles which are inherently automatic in themselves.

Instead of the conventional single weigh-hopper, in which the aggregates are weighed by adding one after another. The weigh-hopper has five individual compartments, one for each size of aggregate, including the mineral filler. Each compartment has an adjustable side-wall which varies its capacity. For automatic operation, the weigh-hopper compartments are pre-set to measure the correct weight of each aggregate. All sizes of aggregate are measured at the same time. All gates over the weigh-hopper compartments open simultaneously. All compartments fill, forming a solid column of aggregate extending past the gate and up into the storage bin. All gates close simultaneously, striking off the aggregate in each compartment. All the

weigh-hopper compartments discharge into the pugmill simultaneously. Actually, there is one weigh-hopper divided into five compartments, all with one common clam-type discharge gate.

A special scale-mounted weigh-bucket is filled to a fixed level by an automatic overflow principle. For automatic operation, the adjustable suction-pipe is lowered into the weigh-bucket to the proper depth to pump out the correct amount of asphalt required for the batch. Once the pipe has set, it will continue to deliver the same amount of asphalt for every succeeding batch.

The operator can instantly switch from manual to automatic operation and vice versa. He can instantly cancel the preset proportions and weigh out special loads in the conventional manner.

Continuous Plant

The gradation unit separates and stores up to four sizes of dried aggregate and automatically measures and feeds the required percentage of each size. Individual aggregate samples are easily taken without interrupting plant production. The mixture automatically meters the correct amount of bitumen, precoats the aggregate, and thoroughly mixes the material in the twin-shaft pugmill. Aggregate and bitumen feeds are positively interlocked.

Actually, each bin has an apron feeder and adjustable graduated gate. For simplicity we assumed a single shaft, equipped with a revolution counter turning all feeders. The same shaft drives the bitumen metering pump. The correct weight of each size of aggregate is continuously fed out and the combined aggregate is continuously sprayed with the correct weight of bitumen. All materials are continually mixed as

they moved from one end to the other of the pugmill. Each revolution of the feeder shaft may be regarded as a batch.

The continuous plants have been used successfully in bigger jobs. If it is prepared from carefully graded aggregates, is scientifically proportioned and is properly mixed, it can be safely hauled through a distance of several miles and delivered on the job in satisfactory condition for good construction. On many jobs, the employment of continuous plant may greatly expedite the progress of the work.

Portability of Plant

Central plants for the production of asphalt paving mixtures are frequently described as being portable, semiportable or stationary in nature. The term portable is applied to small units which are self-contained and wheel-mounted, and it is also applied to large mixing plants in which the separate units are themselves easily moved from one place to another. The term "semiportable" is reserved for those plants in which the separate units must be taken down, transported on trailers, trucks, or railroad cars to a new location, and then reassembled, which process may require only a few hours or several days, depending on the plant involved. "Stationary plants" are those which are permanently constructed in one location and are not designed to be moved from place to place. Portable and semiportable plants are much more numerous than stationary plants and are widely used in the construction of rural highways. The capacities of these two types of plants may vary all the way from 5 to 125 tons of mixture per hour. Both continuous and batch plants may be portable or stationary.

CHAPTER VII

SPREADING AND FINISHING

The material that arrives at the road from the central plant must be spread over the road width being paved and struck off to the desired shape and thickness.

Methods of Spreading

Hand spreading is the oldest method used, the mix is dumped from the trucks onto the road, raked smooth to grade and contour, and rolled.

Because of the expense of labor and the inability to obtain a smooth and even-textured surface, hand spreading is not used to any great extent nowadays except to supplement the other spreading methods. For example, in city street work, hand spreading is used effectively adjacent to curbings, around manholes and at the curved corner sections at intersections.

Similar to road-mix spreading — Motor graders are used on occasion to spread plant-mix just as they are used to spread road-mix, so that what is said here also applies to road-mix work. Of course, for road-mix in most instances, the mixed aggregate and binder are already on the road, while plant-mix is dumped onto the road from trucks,

Although some specifications still permit the use of motor graders with plant-mix, they are not used to any great extent today on surface

work. Counties probably use graders for spreading more than any one else as they generally have several available. Motor graders are occasionally used to spread material for a leveling course, with the combination of a long wheel base, position of blade midway between the front and the rear, and multiple passes, it is possible for skilled operator to obtain a reasonably good surface smoothness. Each successive pass of the blade reduces the reflection of the base irregularities in the surface through what might be called "multiple correction." If, for same reason, a volatile cut-back must be used at the central plant, then a blade will be needed to work the mix so that the volatile are permitted to evaporate before rolling.

Multiple passes indicate the need for mix workability during the time that the blade work is in process. Accordingly, a more fluid bituminous material than is needed with mechanical spreaders must be used to maintain this mix workability long enough for the mix to be manipulated without any tearing of the mat behind the blade. More solvent is used with the bitumen to provide the added workability, and the cost of the mix is increased with no corresponding increase in road quality. Poor edges usually accompany blade spreading operations, and for this reason joints become a problem. In fact, joints are seldom attempted, and instead, the mix is spread across the full width of the road at one time by an echelon of the same grader. During this time, traffic must either be detoured permitted to drive over the freshly spread mix, or held back until the mix can be rolled. In hilly terrain, blading tends to drift the mix downhill permitting an excess to accumulate at the bottom. Segregation of the mix may be caused by blade spreading methods. As the blade spreads out the

windrow, the larger particles of coated aggregate fall toward the outside edge of the road.

The mechanical spreaders include only the self-propelled, specialized machines which have been developed to lay bituminous surfaces. Some have crawlers or wheels which run on the base. Others have rollers which run on the surface. The mix is dumped by the trucks into a hopper at the front end of the spreader or finisher for subsequent placement on the road. The past years, some bituminous spreaders required side forms similar to concrete pavers for support of the spreader and to insure a so-called level surface. The present-day mechanical self-propelled machines are able to lay better surfaces at a reduced cost without the side forms.

There are numerous advantages of these machines over blades. Probably the most important are the time element or high capacity, the smoother riding surface, and the ability to handle the stiffer hot-mixes. Blades, as pointed out, require easily worked mixes to prevent premature setting up. The mechanical spreaders and finishers, on the other hand, need little or no volatile matter in the mix, as the mix can be laid into position as rapidly as it arrives from the central plant. No additional work is required, other than rolling after the surface has been laid.

Adjustable crown control is built into some machines so that it is a simple matter to pave the complete road width to the desired cross section or contour.

Finishers and spreaders give a uniform thickness of pavement across the entire width of the machine, and the pavement edges are straight and smooth. Consequently, the road can be paved with any

number of lanes, and the joints are quite easily and accurately matched — either hot or cold. Subsequent rolling smooths and consolidates the joint.

Types of Strike-off

There are two basically different methods of striking off the bituminous mix to the correct grade by the spreader or finisher. The first of these might be called "loose strike-off" in which the mix is struck off in a loose condition, and the second "compacted strike-off" in which the mix is struck off in a compacted condition.

The loose strike-off principle is used by some of the mechanical, self-propelled spreaders. These machines receive the mix in the hopper, spread it on the base over the width of the strip being paved, and strike it off to a predetermined thickness as the machine moves forward. One way that the spreaders strike off the mix is with a screed oscillating in the horizontal plane. This screed or cutter bar is adjustable for the desired pavement thickness.

There is a distinct disadvantage to loose strike-off methods. Striking off the mix over an irregular base results in a variable thickness of the surface course. Since all compaction takes place after strike-off, and since the compaction will not be the same when a variable thickness is countered, base irregularities become apparent in the surface after it has been rolled. This is irrespective of any leveling principle connected with the spreader. Transverse joints are difficult to make as an allowance must be made for compaction of the mix when determining the proper height of the strike-off. After the new strip has been laid and rolled, the joint will be rough

if there is either an excess or deficiency of material in the newly laid portion adjacent to the joint. Incorporated with loose strike-off spreaders are various methods used to maintain as level a surface as possible. Generally, the methods are based upon some type of proportioning device located between the strike-off and the wheels or crawlers. This device reduces, at the strike-off, the effect of rises and falls in the subgrade.

The compacted strike-off principle gave rise to the use of the term finisher in the bituminous paving industry because so little need be done to the surface after it has been laid. Striking off the mix in a compacted condition is accomplished by means of a tamper which compacts the mix and then strikes it off to the desired thickness.

When the mix is struck off after the compaction, there is relatively little additional compaction left for the roller. Consequently, less rolling is required, and base irregularity is not appreciably reflected in the surface. Transverse joints can be made more easily since the amount of roller compaction can be more closely estimated. The use of compacted strike-off also permits a superior leveling principle to be utilized. The leveling action is controlled by means of a screed riding on the compacted surface immediately behind the strike-off. This screed is guided by long arms that feel out changes in grade ahead of the strike-off without reflecting the small base irregularities in the compacted surface. The changes in grade are reflected over many feet of travel, and abrupt changes in the surface level are mechanically impossible.

CHAPTER VIII

ROLLING

Specifications for practically all type of bituminous construction include requirements for the compaction of the mat or mixture and surface rolling to obtain the requisite density and smooth-riding qualities.

Specifications should state the type of rolling equipment to be used as well as the amount of rolling. This may be expressed either in general terms or more specifically as a required percentage of the theoretical maximum density of the mixture that shall be discussed latter.

Type of Rollers

Self-propelled rollers have been used for years in bituminous construction. They are of two general types, commonly referred to as the 2-wheel or tandem and the 3-wheel or macadam rollers. The two rolls of the tandem type are of the same width but may or may not be of the same diameters. The 3-wheel type may have a wide but relatively small diameter front wheel and 2 narrower rear wheels whose diameter is usually much greater than that of the front wheel. In principle, rollers of these types are the same as those in use for years but improvements have been made which have increased their practicability and efficiency. One rather recent development has been the addition of an auxiliary roller on which practically the

entire weight of the machine can be concentrated if necessary to reduce high spots. In the 3-wheel type of roller, this auxiliary roll is mounted between the front and rear rolls in some types and behind the rear wheels in others. In the tandem types the third roll is usually the same size as the front one and is attached to the front of the frame.

Another development is the variable-weight tandem roller. In this type the rolls are hollow, closed cylinders that can be partially or completely filled with water for added weight if desired. They are listed according to their variations in weight, as 4 to 8 tons, or 10 to 15 tons, etc. Rollers of this type are more adaptable to various uses than are those of a fixed weight.

In addition to the self-propelled rollers just described, various types of pulled rollers are used for compacting. One of these, the pneumatic-tired, multiple-wheel roller, is an outgrowth of compacting by traffic and construction equipment. This roller consists of a heavy, box-like frame supported by two sets of truck wheels having pneumatic tires. The front set carries four wheels and the rear set carries five wheels, the wheels being spaced about 13 inches apart on the axles. The front wheels are in line with the spaces between the rear wheels so that in operation, the full distance from outside to outside wheel is compressed either by a front or a rear wheel.

The flexing action of pneumatic tires exerts a pronounced densifying effect in the upper portion of a hot-mix pavement, provided it occurs while the surface is warm (about 140 F. or above). The usual traffic arteries such as highways and city streets get this action from normal traffic if the job is built in warm weather.

However, when the pneumatic kneading cannot be expected from traffic, it should be performed artificially with rubber-tired rollers. This is commonly carried out by operating the pneumatic roller between the breakdown and finish rollers. Such a technique is employed by the U. S. Corps of Engineers to produce a surface which is resistant to fuel spillage from jet planes. It is also a highly effective means of sealing the surface of parking lots and parking lanes. So that they will be resistant to injury from dripping oil. In addition, pneumatic rolling seems to create a higher density in the pavement than can be achieved by steel wheel rolling alone.

The particular type and weight of roller required will depend upon local conditions and upon the type of construction. The amount and method of compaction should be stated definitely in the specifications.

Method of Rolling

The compaction secured on the first trip of the roller determines the final compaction to a marked extent, and heavy rollers, weighing from 8 to 15 tons are desirable for the initial rolling.

The speed of rolling is an important factor in obtaining a dense and smooth surface. Rolling of binder courses should, in general, be restricted to 300 sq. yds. per hour or less, and of surface courses to 200 sq. yds. per hour or less.

Joints between cold and freshly laid sections of pavement are usually formed by cutting back the end of the previous work so as to expose a granular surface to which the new material may be bonded.

In order to prevent the entrance of water, it is desirable to

paint upper edges of all contact surface, such as curbs, gutters, and manholes, with hot asphalt cement or asphalt cement dissolved in naphtha.

Method of Controlling Compaction

The thorough compaction of the mix materially affects the stability of the pavement. The thoroughness of the rolling operation may be determined by comparing the density (or specific gravity, in C.G.S. units) of a portion of the compacted pavement with that of a sample of the mix compressed under laboratory conditions. A sample of the mix is removed from the compacted mix and the specific gravity of it determined. Another portion of the sample is then broken up, heated to approximately the temperature used in placing the mix (usually about 350 F) and compacted according to the prescribed laboratory method. The specific gravity of this specimen is then obtained and compared with the specific gravity of the sample as compressed in the pavement. The specific gravity of a pavement sample should be at least 95 per cent of the specific gravity of the laboratory compressed sample; 97 per cent or high, is generally obtained with proper rolling. The theoretical maximum density of a compacted asphaltic mixture is obtained when the asphalt in the mix is just sufficient to fill the voids in the mineral aggregate in the compacted mix.

The maximum practical density corresponds closely in many cases, but is always less than the theoretical maximum density. In some cases there may be a wide difference between the two densities. The reason for this variation is not completely understood; the grading of the mineral aggregate, the shape of the particles and the amount of air entrapped in the mixture during compaction, are perhaps the most important factors.

CHAPTER IX

CONCLUSION

The term "central plant-mix" surface refers to a type of surface in which the mineral aggregates and bituminous material are proportioned and mixed at a central plant. The mixture is then hauled to the job site and the surface is prepared by spreading, compacting, and finishing the prepared mixture. The paving plant may be small and very simple in nature or it may be large and complex, depending largely on the type and quantity of bituminous mixture which it is desired to produce.

The range in size and complexity of paving plants may be indicated by mention of two extreme installations of this type. The smallest type of machine or plant applicable to this work might consist of a simple concrete mixture of the drum type in which the aggregate and a cold bituminous material, such as asphalt emulsion, are proportioned by shovels and buckets. This type of machine might be used in the production of bituminous mixture to be used in patching operations conducted on a small scale, with the capacity of plant perhaps being in the neighborhood of five cubic feet of mixture per minute. On the other end of the scale are the tremendously large and complex stationary plants, such as might be installed by a city or county agency, which are capable of producing up to 2000 tons per day of "hot mix" bituminous concrete. In between these two extremes may be placed a large number of plants of different manufacture design and capacity.

The finished hot-mix asphaltic concrete surface is smooth, true, relatively impervious to water, and, unlike some types of surfacings, can carry vehicular traffic very shortly after rolling is completed.

Because it has so many advantages mentioned above, therefore we like to recommend its methods of production and laying. Further study is suggested for the design and theory of it.

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