CHAPTER 5
COMPACTION

The compaction process, which must be closely controlled to achieve a quality pavement, is the last chance you will have to make or break a job. The best pavement design, the latest mix design, and the most sophisticated HMA facility don't stand a chance unless you compact the mix (while it is hot) to the specified density. Compaction determines the ultimate performance of the mix and pavement. Although simple in concept, it is often very difficult to achieve in the field because of a number of variables that affect the ability of the rollers to densify the mix. You must understand what these variables are, and how to control them, in order to ensure that you can achieve density under a variety of conditions.

Definitions

Density "A Measurement"

The density of a material is simply the weight of the material that occupies a certain volume of space. For example, an asphalt concrete mixture containing limestone aggregate might have a compacted density of 147 lb/ft^3. This density, or unit weight, is an indication of the degree of compaction of the mixture.

Compaction "A Process"

Compaction is the process through which the asphalt mix is compressed and reduced in volume. This permits the unit weight or density of the mix to be increased by placing more materials in a given volume of space or by taking a given amount of material and compressing it into a smaller space or volume. As a result of the compaction process, the asphalt-coated aggregates in the mix are forced closer together, which increases aggregate interlock and interparticle friction and reduces the air void content in the mix. The maximum theoretical density of a mix can be determined from a laboratory test (the Rice procedure, ASTM Test Method D 2041).

Pass

A pass is defined as the entire roller moving over one point in the mat one time.

Coverage

A coverage is defined as the roller moving over the entire width of the mat one time.

Importance of Compaction

The single most important factor that affects the ultimate performance of a hot-mix asphalt pavement is compaction. Adequate compaction of the mix increases the fatigue life, decreases permanent deformation (rutting), reduces oxidation or aging, decreases moisture damage, increases strength and stability, and decreases low-temperature cracking. An asphalt mixture that has all the desirable mix design characteristics will perform poorly under traffic if that mix is not compacted to the proper density level.

Factors Affecting Compaction

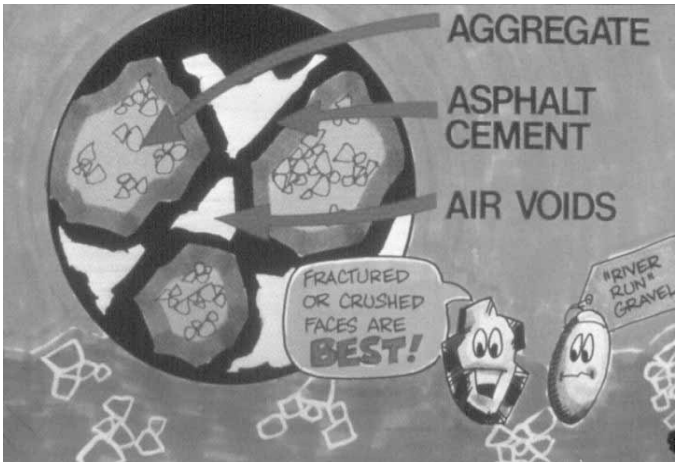
Properties of the Materials

At paving temperatures asphalt cement is a lubricating fluid. As cooling takes place, it becomes a glue-like binder.

Aggregates - "The Rock Carries the Load"

Three properties of the coarse aggregate particles used in an asphalt mixture that can affect the ability to obtain the proper level of density are the particle shape of the aggregate, the number of fractured faces, and the surface texture. As the crushed content of the coarse aggregate increases, as the nominal maximum size of the aggregate increases, and as the hardness of the aggregate (granite compared with limestone, for example) increases, the compactive effort needed to obtain a specific level of density also increases.

Angular particles offer more resistance to manipulation than do rounded aggregate particles. The compactive effort is also affected by the shape of the aggregate, with a cubical or block-shaped aggregate needing a greater degree of manipulation than a rounded particle shape before achieving a given density level.



A continuously graded (dense-graded) aggregate, from coarse to fine, may be easier to compact than a mixture with any other aggregate gradation. A harsh mix typically requires a significant increase in compactive effort to obtain the desired level of density. An over sanded or finely graded mix, on the other hand, tends to be extremely workable. It still might be difficult to achieve density on such a mix, however, because of the inherent tender nature of such an over sanded mix. A mix designed with a high dust content will generally be more difficult to compact than a mix designed with a lower dust content.

Asphalt Cement "Binds the Rock Together"

The grade and amount of asphalt cement used in the mix affects the ability to densify the mix. An asphalt cement that is higher in viscosity or lower in penetration will generally provide for a stiffer mix at a given mix temperature and therefore require a greater compactive effort. The degree of hardening that occurs in the asphalt cement during the manufacture of the mix affects the compactibility of that material. The asphalt cement content of the mix influences its compactibility. In general, a mix with too little asphalt cement may be stiff and require an increase in compactive effort, whereas a mix with too much asphalt cement may shove under the rollers.

Mix Properties

A mix that is placed at a higher temperature will be easier to compact than a mix that is lower in temperature. The workability of the mix is affected by the temperature susceptibility of the asphalt cement. The fluids content of the mix, not just the asphalt content, affects the compactive effort needed. Fluids content is the sum of the asphalt cement content and the moisture content of the mix. The moisture content of the mix should be less than 0.5 percent, by weight of mix, when the mix is discharged from the plant.

Environmental Variables

Research work in the early 1970's determined the time available for compaction of various asphalt concrete mixes. The time available for compaction was defined as the time, in minutes, it took for a mix to cool from laydown temperature to a minimum compaction temperature. Laydown temperature is the mix temperature when the paver screed passes over the mix. Minimum compaction temperature for this study was set at 175°F. Below this temperature, it was found that the internal friction and cohesion of the mix increases to the point that little density gain is achieved with the application of additional compactive effort.

Six variables were found to have an effect on the rate of cooling (and, therefore, on the possibility of obtaining a required level of density) of a layer of asphalt placed on top of another existing layer of the same type of material. Those variables are: layer thickness, air temperature, base temperature, mix temperature, wind velocity and solar flux.

Layer Thickness

Layer thickness is probably the single most important variable in the rate of cooling of asphalt mixtures, especially for thin lifts. It is very difficult to obtain the desired density on thin lifts of mix in cool weather because of the rapid loss in temperature in the mix. For example, for a mix laydown temperature of 250°F and a base of 40°F, a 1 inch thick mat will cool from that 250°F temperature to the 175°F compaction cutoff point in less than 4 minutes. For a 2 inch thick layer, under the same mix and base temperature conditions, it will take about 10 minutes for the material to cool to 175°F.

Air and Base Temperature

A portion of the heat in the asphalt layer is lost to the air. All other factors being equal, an increase in the ambient air temperature decreases the rate of cooling of the mix. Heat in the mix is also lost to the layer on which the new material is placed. There usually is more rapid cooling of the mix downward into the base than upward into the air. Base temperature is actually more important than air temperature in determining the time available for compaction. It is often assumed that air and base temperature are the same. This is not necessarily true, particularly in cool weather. A moist base layer significantly increases the cooling rate of the new overlaying asphalt layer. Heat is lost from the mix to the moisture, turning water into steam and increasing the rate of heat transfer.

Mix Laydown Temperature

Asphalt mixes are usually produced at temperatures between 250°F and 350°F. Depending on environmental conditions and the length of haul, the mixture can lose between 5°F and 25°F from the plant to the paver. As the temperature of the hot-mix asphalt being placed is increased, the time available for compaction is greater. The effect of mat laydown is more significant at lesser mat thickness and lower base temperatures.

Wind Speed

A thin layer of mix will cool more quickly in a strong wind than when there is little or no wind. Wind has a greater effect at the surface of the mix than within the mix, and can cause the surface to cool so rapidly that a crust will form.

Solar Flux

The amount of radiant energy available from the sun (solar flux) is a function of many variables, including the position of the sun above the horizon, the distance above sea level of the paving project, the amount of turbidity in the air, and the degree of cloud cover. A mix will cool more slowly on a sunny day compared with a cloudy one. The amount of solar flux is more important in its effect on base temperature than its effect on mix temperature.

Laydown Site Conditions

A number of factors at the laydown site directly affect the ability of the compaction equipment to gain the required level of pavement density. The relationship between lift thickness and nominal aggregate size in the mix is another variable that affects the amount of density that can be obtained. The uniformity of the lift thickness is another factor to be considered. It is easier to obtain a required level of density in an asphalt layer that has a constant thickness compared with a course that varies in depth. Asphalt leveling courses that, by their very nature and purpose are non-uniform in thickness, are often difficult to densify to a given air void content uniformly, especially when placed over a rutted or wavy road.

Types of Rollers

The type of equipment used to compact the asphalt mix obviously has a significant effect on the degree of density that can be obtained in a given number of passes of a particular roller. Three types of self-propelled compaction equipment are currently being used: steel wheel rollers, pneumatic tire rollers, and vibratory rollers.

How do Rollers Compact?

Rollers compact by applying their weight over the area of the drum/tires that touch the mat (contact pressure). The process packs the aggregate particles together and removes most of the air voids that exist. For example: If you walk across a new mat (not recommended) you will sink in because you exert a higher contact pressure (your weight divided by the area of the sole of your boots) than bearing capacity of the mix. As the roller passes over the mix repeatedly, the aggregate particles are packed closer together, the excess air is removed, the asphalt cement cools and acts more like a glue than a lubricant, and the bearing capacity of the mix increases.

When the bearing capacity of the mix equals the contact pressure exerted by the roller, the roller has "walked-out" of the mix. Further roller coverages may be necessary to further increase the mix density, orient the aggregate particles, seal the surface, and finally, "iron" out the roller marks.

In theory, that is how rollers compact. In practice, it isn't quite so simple because of the many compaction variables involved. In addition, most high-type asphalt concrete mixes are difficult to compact and new techniques and methods are constantly being tried to achieve the specified density. Nothing is set in stone anymore!

Static Steel Wheel Roller

Static steel wheel rollers normally range in weight from 3 to 14 tons and have compression drums or rolls that vary in diameter from approx. 40 inches to more than 60 inches. The gross weight of the roller can usually be altered by adding ballast to the roller, but this adjustment cannot be made while the roller is operating, and is not normally changed during the term of a paving project.

Contact Pressure

Effective weight or contact pressure, in terms of pounds per square inch of contact area, is the key variable for this type of equipment and is dependent on the depth of the penetration of the rolls into the mix. The greater the depth of penetration, the greater the contact area and thus the less the contact pressure.

The table below illustrates how the roller contact pressure increases as the mix's internal strength increases during the compaction process. Look at a typical ton roller. As the roller makes its first pass, the contact pressure may range from 48 to 36 psi as the drum sinks in 1/2 to 3/4 of an inch, depending on the initial stiffness of the mix. As additional passes are made, the mix becomes stiffer as the aggregate is packed together and the air voids are reduced. The drum eventually "walks out" of the mix and the contact pressure becomes extremely high. At 1/16 inch penetration, the contact pressure reaches 132 psi (A 266 percent increase over the original contact pressure at 3/4 inch penetration).

Roller Contact Pressure at Penetration Depths
In Pounds per Square Inch

Static Roller Type	1/16 in.	1/8 in.	3/16 in.	1/4 in.	1/2 in.	3/4 in.
Two Axle Tandem 270 p.l.i. – Drive 190 p.l.i. – Guide						
8.5 ton (less ballast)	96	64	53	45	33	26
12 ton (less ballast)	132	88	74	63	46	36

Operation

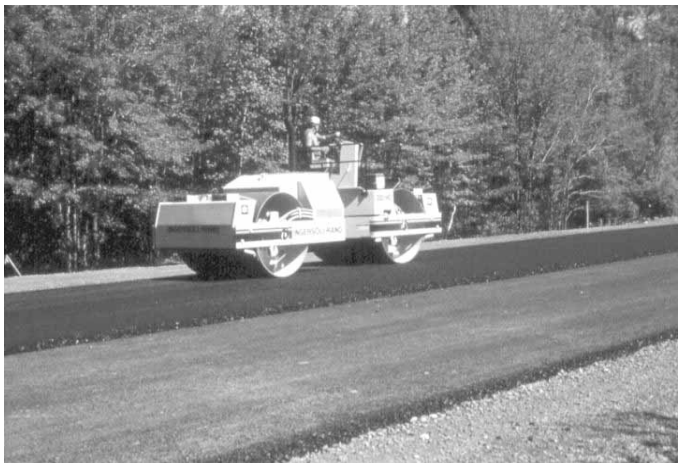
Drawbar pull is defined as the horizontal force required to move the roller forward. Rollers with large-diameter rolls have lower drawbar pull (rolling resistance) because they do not tend to penetrate as far into the mix as does a roller with smaller-diameter rolls.

Once the size and weight of a static steel wheel roller is selected, the variables under the control of the roller operator are the speed of the roller, the position of the roller on the mat in relation to the paver, operation with the drive wheel toward the paver, and the number of passes made with the roller.

Pneumatic (Rubber Tire or Traffic) Roller

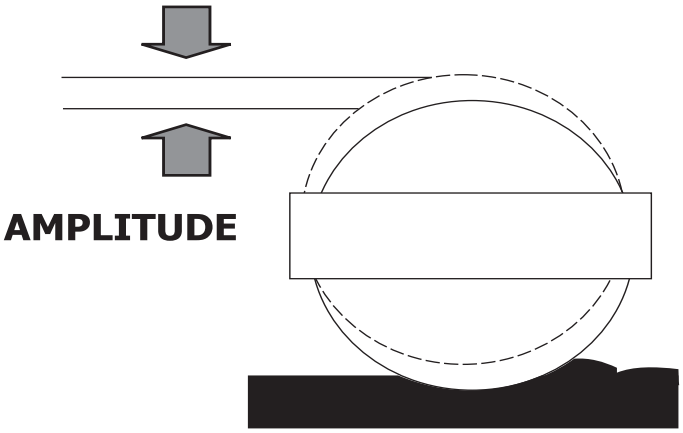
Most pneumatic rollers are operated in the intermediate roller position, behind a vibratory or static steel wheel breakdown roller and in front of a static steel wheel finish roller. These rollers are sometimes used, however, for initial rolling of the mix as well as occasionally for finish rolling.

Vibratory Roller



Vibratory rollers come in a variety of configurations. Single-drum vibratory rollers are manufactured with both a rigid frame and an articulated frame. Double-drum vibratory rollers come in rigid-frame, single-articulated-frame, and double-articulated-frame models. These rollers can be operated in any one of three modes: static (with the vibrator off), with one drum vibrating and one drum static, and with both drums vibrating. These rollers thus have two types of compactive force that is applied to the hot-mix asphalt: static weight and dynamic (impact) force. The compactive effort derived from the static weight of the rollers is caused by the weight of the roller and frame. The compactive effort derived from the impact force is produced by a rotating eccentric weight located inside the drum (or drums). As the eccentric weight rotates about the shaft inside the drum, a dynamic force is produed. Changing the eccentric moment arm or adjusting the eccentric mass has a directly proportional effect on the dynamic force.

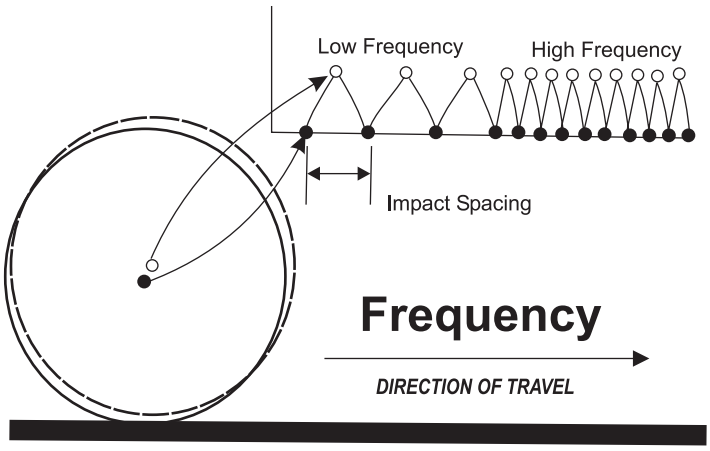
Amplitude "How High"



The elements of comparison for dynamic component of a vibratory roller are the magnitude of the centrifugal force, its vibrating frequency, the nominal amplitude, and the ratio of the vibrating and non-vibrating masses acting on the drum. The nominal amplitude is defined as equal to the weight of the drum divided by the eccentric movement of the rotating weight and is a function of the weight of the drum and the location of the eccentrics.

Normal values of nominal amplitude range from 0.01 to 0.04 inches Some rollers can operate at only one fixed amplitude. Other rollers have "high" and "low" amplitude positions. Still other rollers have 3 amplitude settings.

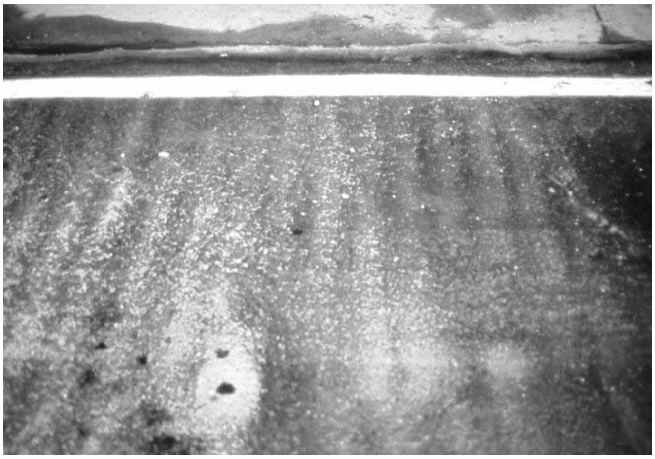
Frequency "How Often"



As the layer thickness increases, it is often advantageous to increase the nominal amplitude applied to the asphalt mix. Unless "high" amplitude is needed to achieve a particular density level, the vibratory roller should be operated in "low" amplitude.

The frequency of vibration is the number of complete cycles that the eccentrics rotate per minute. The faster the rotation of the eccentrics, the greater the frequency of vibration. Some vibratory rollers can operate at only one frequency or have a very limited selection of frequencies. Other vibratory rollers can alter the frequency of the applied load between 1600 and 3000 vibrations/minute. Frequencies below 2000 vibrations/minute are not normally acceptable to compact asphalt mixtures.

Impact Spacing



The spacing of the impacts of the applied force is a function of the frequency of the vibration and the travel speed of the roller. A smaller impact spacing (a greater number of impacts per foot) is thus usually preferred.

A recent survey of major roller manufacturers recommended the following impact spacing. The impact spacing should be in the range of 10-12 impacts per foot (1.2 - 1.0 in. between impacts) to ensure the highest efficiency of the vibratory rollers and reduce the possibility of leaving ripples in the finished pavement.

Remember: The combination of proper impact spacing (frequency and speed) and amplitude settings is the key to maximizing the efficiency of the specific vibratory roller.

In general, the vibratory roller should be operated at as high a frequency as possible. The use of the highest possible frequency of vibration increases the number of impacts per foot at a given roller speed.

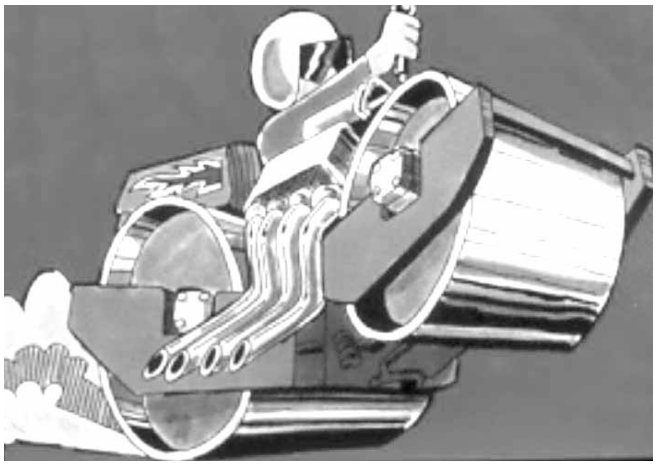
Operation

The roller operator is in control of more variables when using a vibratory roller and thus should be well educated in the proper selection and interaction of the variables. In addition to the roller speed, location on the layer being compacted, and number of passes made, both the nominal amplitude and the frequency of the vibratory impact can be varied. Roller speed and vibratory frequency are combined to determine the impact spacing. Further, for double-drum vibratory rollers, the operator can vibrate either one or both rolls. Care should be taken when operating a vibratory roller in areas where buildings are nearby. In addition, the use of vibration on the roller when underground utilities and drainage structures are directly under the pavement layer being compacted needs to be considered carefully.

Compaction Variables

The primary compaction variables for all types of rollers that can be controlled during the rolling process are: (a) roller speed, (b) number of roller passes, (c) rolling zone, and (d) roller pattern. In addition, for vibratory rollers, vibration frequency, vibration amplitude, and direction of travel are also under the control of the operator. Each of these factors has an effect on the level of density achieved under the compactive effort applied to the mix.

Roller Speed



The faster a roller passes over a particular point in the new asphalt surface, the less time the weight of the roller "dwells" on that point. This in turn means that less compactive effort is applied to the mixture. As roller speed increases, the density achieved with each roller pass decreases. The roller speed selected is dependent on a combination of factors: productivity, layer thickness, and the position of the equipment in the roller "train".

Static steel wheel rollers can normally operate at a speed between 2 to 5 miles/hr (176 and 440 ft. /min) Pneumatic tire rollers typically run between 2 to 7 miles/hr (176 and 616 ft/min), whereas vibratory rollers can operate at speeds between 2 to 31/2 mile/hr (176 and 308 ft/min).

The following table provides an indication of the range of roller speed for three different types of rollers and three different operating positions:

TYPE OF ROLLER	TYPICAL RANGE OF ROLLER SPEEDS, IN MILES PER HOUR		
	Breakdown	Intermediate	Finish
Static Steel Wheel	2 - 3½	2½ - 4	3 – 5
Pneumatic	2 - 3½	2½ - 4	4 – 7
Vibratory	2 – 3	2 - 3½	-----

Compactive effort is significantly improved at slower roller speeds. Roller speed will also be governed by the lateral displacement or tenderness of the asphalt mix. If the mixture moves excessively under the rollers, the speed of the compaction equipment should be reduced. In addition, for vibratory compactors, roller speed also affects the impact spacing. Roller speed is usually established by the speed of the paver. Varying the speed of the compaction equipment merely causes variations in density. "Slow and steady" is the key to proper compaction.

Number of Coverages

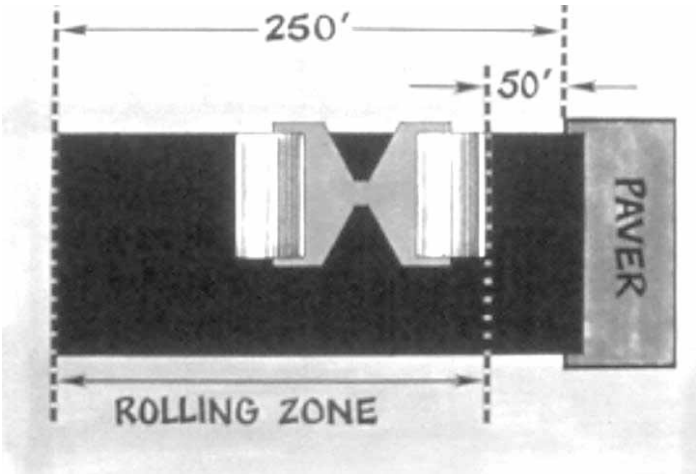
To obtain the target air void content and uniform density in an asphalt mixture, it is necessary to roll over each point in the pavement mat a certain number of times. The actual number of passes

depends on many variables. The type of compaction equipment is one very important consideration. The capabilities of each type of roller vary, however, with mat thickness, mix temperature, mix design (asphalt content and aggregate characteristics) and environmental conditions. In addition, the number of passes required depends on the position of the rollers in the roller train.

To determine the minimum number of roller passes needed to achieve proper density levels, a test strip should be constructed at the start of any major paving project. A number of different combinations of rollers and roller patterns should be tried to determine the "optimum" combination of compactive efforts as efficiently as possible. Rarely will the first combination of rollers, roller passes, and rolling zones tried provide the most economical rolling sequence unless the mix is one with which the contractor is thoroughly familiar. **Remember -the first pass is always made toward the paver.**

A nuclear density gauge can be employed to determine the optimum number of roller passes necessary to obtain the required density level. If this piece of equipment is used, however, a proper correlation to the actual density of the asphalt pavement layer, measured by cores, must be completed to assure that the density measured by the nuclear gauge is equal to or greater than the specifications requirements.

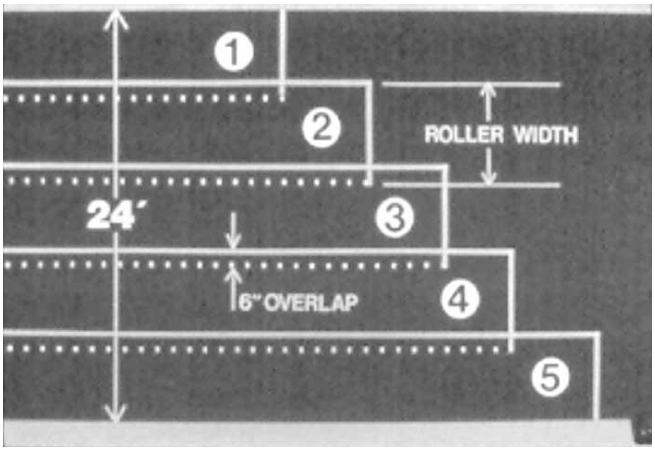
Rolling Zone



Compaction must be achieved while the viscosity of the asphalt cement in the mix and the stiffness of the mix is low enough to allow for reorientation of the aggregate particles under the action of the rollers. In other words, the mat must be hot for effective compaction. The rule of thumb commonly used is that the proper level of air voids should be obtained before the mix cools from laydown temperature to 175°F. To reach the required density level the quickest, initial compaction should occur directly behind the laydown machine. If the stability of the asphalt mixture is high enough, breakdown rolling can be carried out very close to the paver, while the mat temperature is still high. More density is obtained with one pass when the mix temperature is 250°F than with a similar pass when the mat is at 220°F.

Sometimes when a tender mix is placed, the initial rolling is delayed (the rolling zone is lengthened) to avoid excessive shoving or checking of the mix by the rollers. Depending on the characteristics of the mix, it is still often possible to obtain the required level of density of the mix as long as the proper combination of rollers and compactive effort is applied to the mix. In some cases, however, the mix is so tender that rolling must be delayed to the point that the desired density level cannot be achieved. In this case, other solutions need to be tried. A method estimating how long this zone should be is discussed later, but in general it is about 250 feet.

Rolling Pattern



Rollers are "busy" most of the time on a paving project. The question is whether they operate correctly and effectively. Generally, compaction is applied, but not necessarily in the right place. Numerous compaction studies have shown that the middle of the width of the paver pass typically receives more compactive effort that the edges of the pavement. This is unfortunate, because traffic uses the wheel path areas and travels near the edge of the pavement more often than in the center of a lane.

Operating Techniques

Transportation

Equipment must be transported safely and in accordance with manufacturers recommendations. Some states do not allow steel drum rollers to travel on bridge decks. In this case, adequate transportation must be in place to move rollers as the project requires.

Test Strip Construction

The actual rolling pattern to be used to compact the mix on a paving project should be determined at the start of the project through the construction of a roller test strip. This strip should be located at a convenient point where the pavement layer will remain as part of the final pavement structure. The mix should be representative of the material to be produced for the project; generally the plant should produce mix for a short period of time before mix is made for the compaction test section. The thickness of the layer compacted should be the same as that to be used for the rest.. The test strip should be constructed within the same time constraints and temperature as the rest of the project. The time between the initial laydown and finished compaction should be as close to possible to normal construction time. This is necessary to achieve the same mix temperatures under each pass of the roller as will occur during normal construction.

After the rolling pattern is established, a control strip is then utilized by some specifications to establish a correlation between nuclear and core density as will be discussed in a later chapter.

Simulating Actual Production Conditions

Due consideration should be given to the selection of rollers that are to be employed to densify the pavement layer. The combination of rollers used on a previous project might not be the most cost-effective for the variables involved in the present job. Although vibratory rollers are usually used for breakdown rolling and pneumatic tire rollers for intermediate rolling, a greater degree of density with a lesser number of total roller passes might be obtained on some mixes (e.g. when a large pneumatic tire roller is used in the breakdown position with the vibratory roller following in the intermediate position). Determination of the "optimum" combination of rollers and roller patterns might require the construction of two or more test sections.

Establishing Roller Pattern

Different mixes may require considerably different levels of compactive effort and thus different compaction equipment and rolling procedures. An asphalt mix containing large aggregate, for example, may need different types of rollers to achieve a required level of density than an asphalt concrete mix made with smaller-size coarse aggregate.

Selecting Compaction Equipment

For each roller employed on a project, the mat width can be divided by the width of the compaction rolls to determine the number of passes needed to cover each transverse point in the surface. A pass is defined as one trip of the roller in one direction over any one spot. Multiple passes are needed to completely compact the transverse width of the lane being paved as well as over each point in the pavement surface to assure attainment of the required level of density. If a large pneumatic tire roller is used in the breakdown position, it is generally difficult to determine the degree of density obtained in the mat through the use of a nuclear gauge because of the rough texture of the mat after the first several passes of the pneumatic tires. Nuclear readings must be taken after the mix has been smoothed out with the intermediate roller.

Width of Paving

Standard paving widths of 10, 12, 14, and sometimes 16 feet can affect the efficiency of certain rollers. Ideally, the roller that can cover the width of paving with the fewest number of passes will be the most efficient. other smaller width rollers are routinely used, but the number of total passes will increase.

Number of Repeat Coverages to Achieve Density

The number of roller passes needed over each point on the pavement surface is a function of a large number of variables. One of the most important variables is the level of density required in the pavement layer. If a certain percentage of laboratory density or theoretical maximum density is needed, the higher the required percentage, the more compactive effort that will have to be applied to the pavement layer.

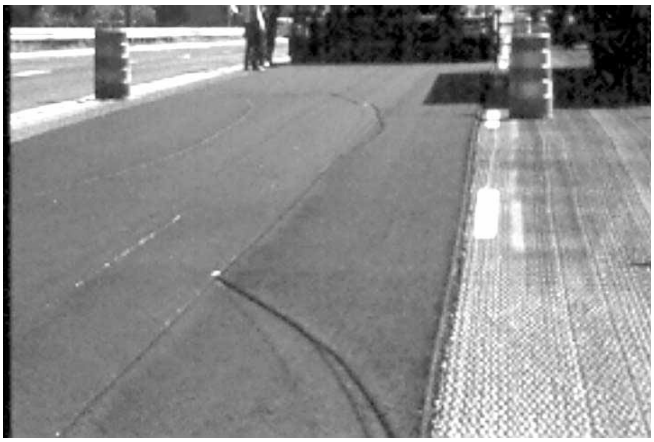
Monitoring with a Nuclear Gauge

The most common method for monitoring changes in density with roller passes is through the use of a nuclear density gauge. Density is estimated by transmitting gamma rays into the mix and measuring the amount of radiation reflected back to the device in a given amount of time. The count data that are obtained can be related to the relative density of the layer. Nuclear gauge readings should be taken after each pass of each roller, and the rate of increase in density after each pass determined. When no appreciable increase in density is obtained with the application of additional roller passes, the maximum relative density for that mix has been obtained. When a pneumatic tire roller is used in the compaction process, particularly in the breakdown mode, it is often very difficult to obtain an accurate density reading with a nuclear gauge. One or more passes with a steel wheel roller may be necessary before a valid nuclear gauge reading can be obtained.

Types of Thermometers

There are several types of thermometers available but all do the same thing - they measure temperatures. The more expensive ones tend to do it faster. Whichever model you decide, make sure it reads the range you need for compaction say 50°F to 350°F, and the increments are reasonable (no more than 5°F intervals).

Breakdown Rolling



Breakdown rolling is the first interaction between the roller and the mat. It can be a friendly or a troublesome meeting. Most Contractors use steel drums to breakdown the mix, increase the mat density, and establish the mat smoothness. Some use rubber tired rollers for breakdown of HMA. Rollers should always stop and start slowly on uncompacted mix and angle the drum when stopping to reverse. The majority of the density is obtained during breakdown rolling so it is important to keep this roller moving as much as possible. When the roller does stop, it is best practice to park on a cold mat. Parking on the hot mat, especially near the paver, will leave roller marks that are difficult to remove.

Compacting Transverse Joints

Good practice is to make an initial breakdown pass and then check the joint with a straightedge. In case the new mat is too high, the mix can still be reworked and then recompacted. It is important to understand that the first pass will still leave the mat slightly high, but experience will determine if it is too high. The goal is to produce a transverse joint that rides as smooth as the rest of the mat.

Transverse Rolling

As discussed earlier, ideally it is best to compact transverse joints in the transverse direction. However, it is not always possible. If rolling in the transverse direction, run-off boards the thickness of the mat may be needed to keep the roller level. This drum should overlap the new mat with most of the drum on the cold mat and pinch the joint. Some contractors use multiple passes, each pass placing more of the drum on the hot mat. Again, the method that produces a dense, level joint most efficiently is the one to use.

Longitudinal Rolling

If a transverse joint is to be compacted in the longitudinal direction, it is important the first passes of the roller be made at very slow speeds. Higher speeds may force the new mix away from the joint creating a void or weakness. Some only roll in with one drum on the new mat and then reverse back. Angling the drum while entering the new mix can be effective also.

Summary: There is no one right way to roll a transverse joint; the method that works most efficiently and consistently is the one to use.

Compacting Longitudinal Joints

There are three main methods to compact a longitudinal joint. Each method can produce similar densities. The best practice is to compact a joint consistently and efficiently.

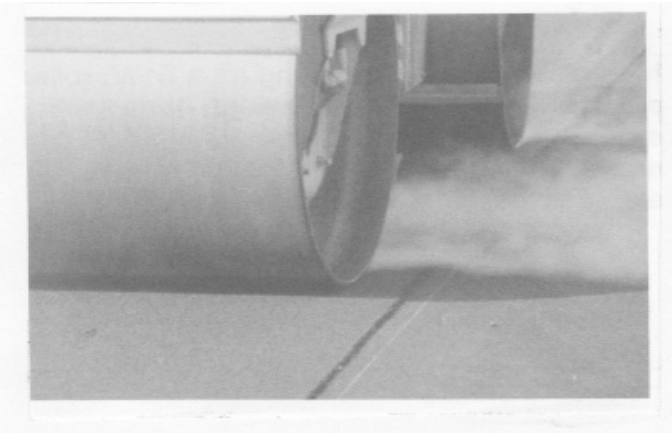
Rolling from the Cold Side

The oldest method is to roll the joint from the cold side with most of the drum on the previously placed mat, overlapping approximately 6-12 inches. The problem is that this is the most inefficient method since most of a roller pass is wasted. Vibratory rollers should not operate in the vibratory mode on this first pass. Of the three methods, this one produces the lowest density on the joint.

Rolling from the Hot Side - "Normal Overlap"

Rolling from the hot side places most of the roll on the hot mat and overlapping approximately 6 inches on the cold mat is the most efficient method. Vibratory rollers, in the vibratory mode, can be used in this mode since the drum will not impact on the cold mat.

Rolling from the Hot Side - "The Modified Pinch"



An additional method that can be tried is to roll from the hot side but hold the drum away from the joint about 6 inches, leaving a ribbon of uncompacted material. A subsequent pass will be made to compact this ribbon with an attempt to force more mix into the joint area and allow the mix to remain in contact with the joint longer prior to compacting. However, this method does require an additional pass and is not as efficient as rolling from the hot side.

Intermediate Rolling

Intermediate rolling may or may not be required on a project. If adequate density cannot be achieved with the breakdown roller, an intermediate roller may be needed. Some states require an intermediate roller, typically a pneumatic tire for surface texture and kneeding action. Intermediate rollers can typically be operated at higher speeds than a roller in a breakdown mode. Intermediate rollers should follow a roller pattern and not concentrate on running down the middle of the mat.

Finish Rolling

Finish rolling is the last step of the operation and is normally used to "iron" out any roller marks left by a breakdown or intermediate roller. This roller is typically a static steel wheel roller, or a vibratory roller operating in a static mode. Some contractors equip the finish roller operator with an infrared thermometer so that finish rolling can occur within a range of temperatures. Finish rolling is not the place to bet on obtaining additional density. It is a cosmetic process.

To check the temperature of the asphalt pavement you must use a reliable infrared thermometer which has been calibrated.

Opening to Traffic

If the mix hasn't cooled below a mix specified temperature before opening to traffic, additional densification can occur in the mix, primarily in the wheel paths. It is possible that heavy traffic could over-densify the mix and cause rutting. Therefore, agreement should be reached in the pre-construction meeting as to the minimum temperature (surface or internal) before the pavement is opened to traffic. Intersections, night paving, and ramps are key areas. In some areas, a water truck has been used to cool the pavement temperature.

CHAPTER 5
COMPACTION
Study Questions

1. The density of a material is simply the weight of the material that occupies a certain volume of space.

   A. True
   B. False

2. A pass is defined as the entire roller moving over ____ point(s) in the mat one time.

   A. one
   B. two
   C. three
   D. four

3. A dense-graded aggregate may be easier to compact than a mixture with any other aggregate gradation.

   A. True
   B. False

4. A thin layer of mix will cool more quickly in a strong wind than when there is little or no wind.

   A. True
   B. False

5. The primary compaction variables for all types of rollers that can be controlled during the rolling process are:

   A. roller speed
   B. number of roller passes
   C. rolling zone
   D. rolling pattern
   E. all of the above

6. Compactive effort is significantly improved at slower roller speeds.

   A. True
   B. False