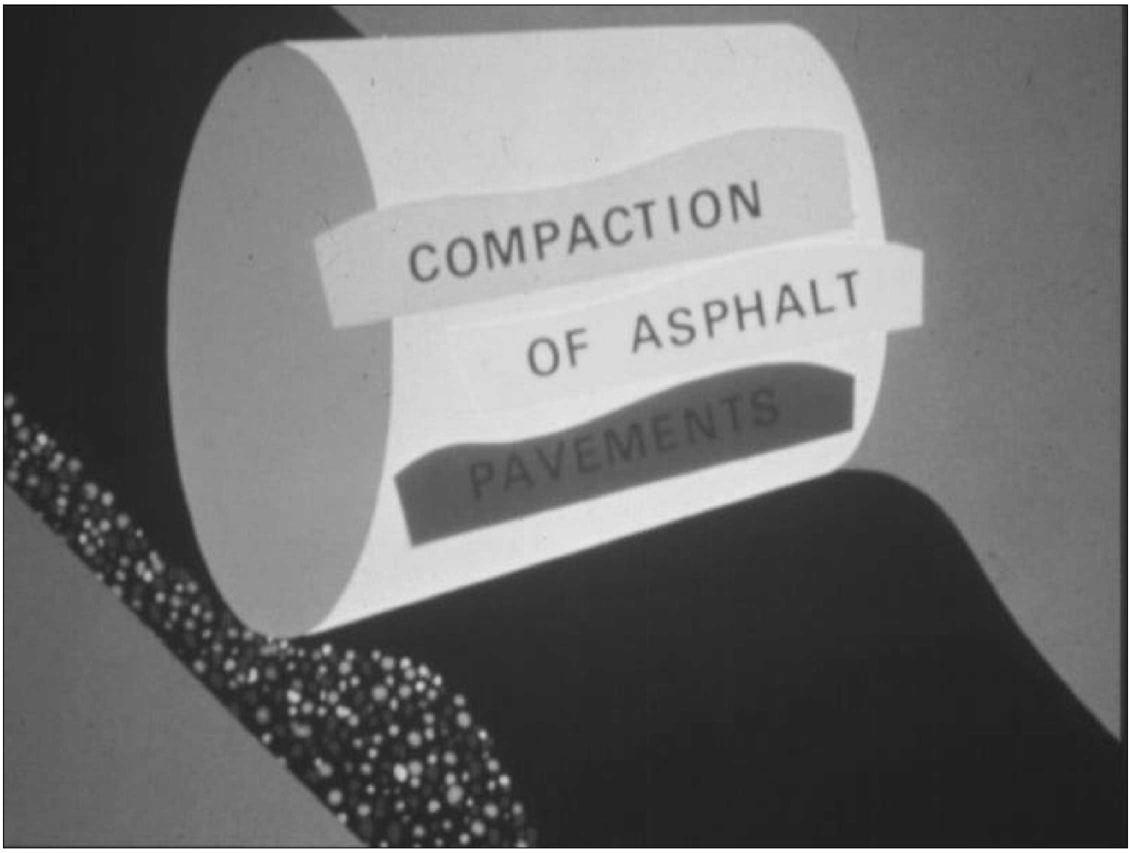
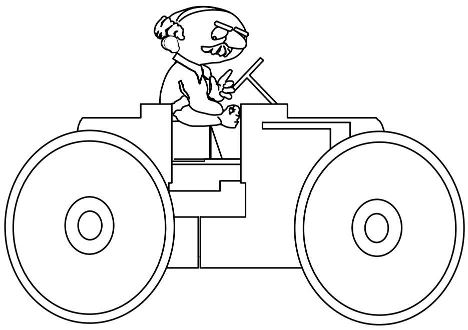
Rolling and Compaction of Asphalt Pavement



This presentation concentrates on the roller operator's job. It offers those who are new to the job, and those who have done this important work for years, the benefit of information gained from the expe-riences of hundreds of people. We hope that you take this information, build on it with your own experience, and use it to produce better quality compacted pavements.

COMPACTION

GOOD COMPACTION LEADS TO GOOD PERFORMANCE

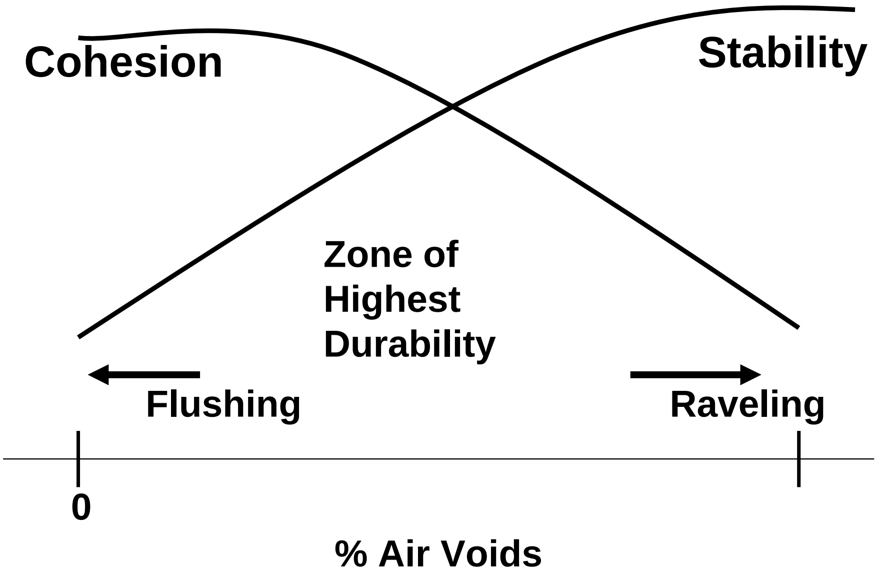


Compaction is the single most important factor that affects the ultimate performance of an HMA pavement.

Reason For Compaction

- **To prevent further compaction**
- **To provide shear strength or resistance to rutting**
- **To ensure the mixture is waterproof**
- **To prevent excessive oxidation of the asphalt binder**

Durability vs Air Voids



The goal is 4 to 7% air voids on the roadway.

Factors Affecting Compaction

- **Mix Properties**
  - **Aggregate**
  - **Asphalt**
  - **Mix Temperature**
- **Layer Thickness**
- **Environmental Factors**
- **Rollers**

A coarse harsh mix is difficult to compact - a sandy mix is easy to compact.

A stiff modified asphalt is tougher to compact than a soft low viscosity asphalt. Also a increase in the asphalt content makes the mix easier to compact.

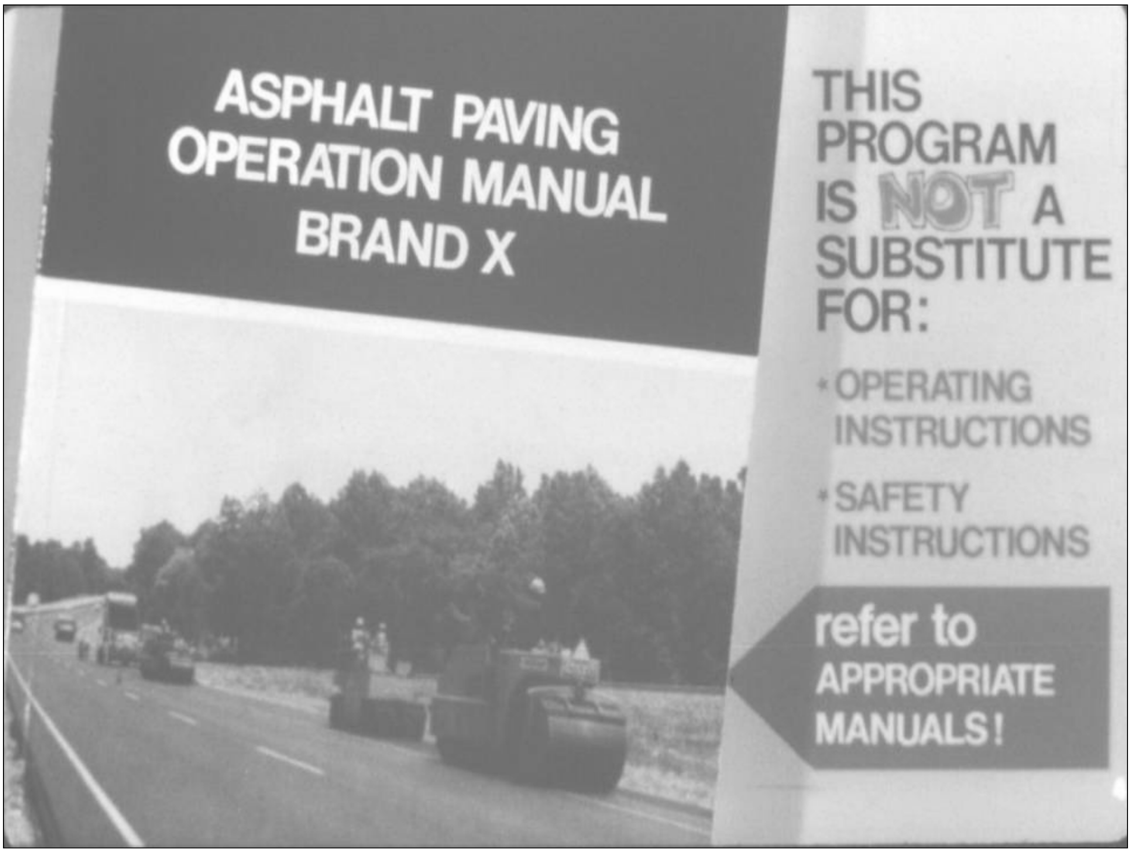
The temperature of the mix directly relates to the viscosity of the binder. Thus, the higher temperature the softer the asphalt.

The old rule of thumb was twice the maximum aggregate size for layer thickness. The new rule of thumb is that the layer thickness should be three times the nominal aggregate size.

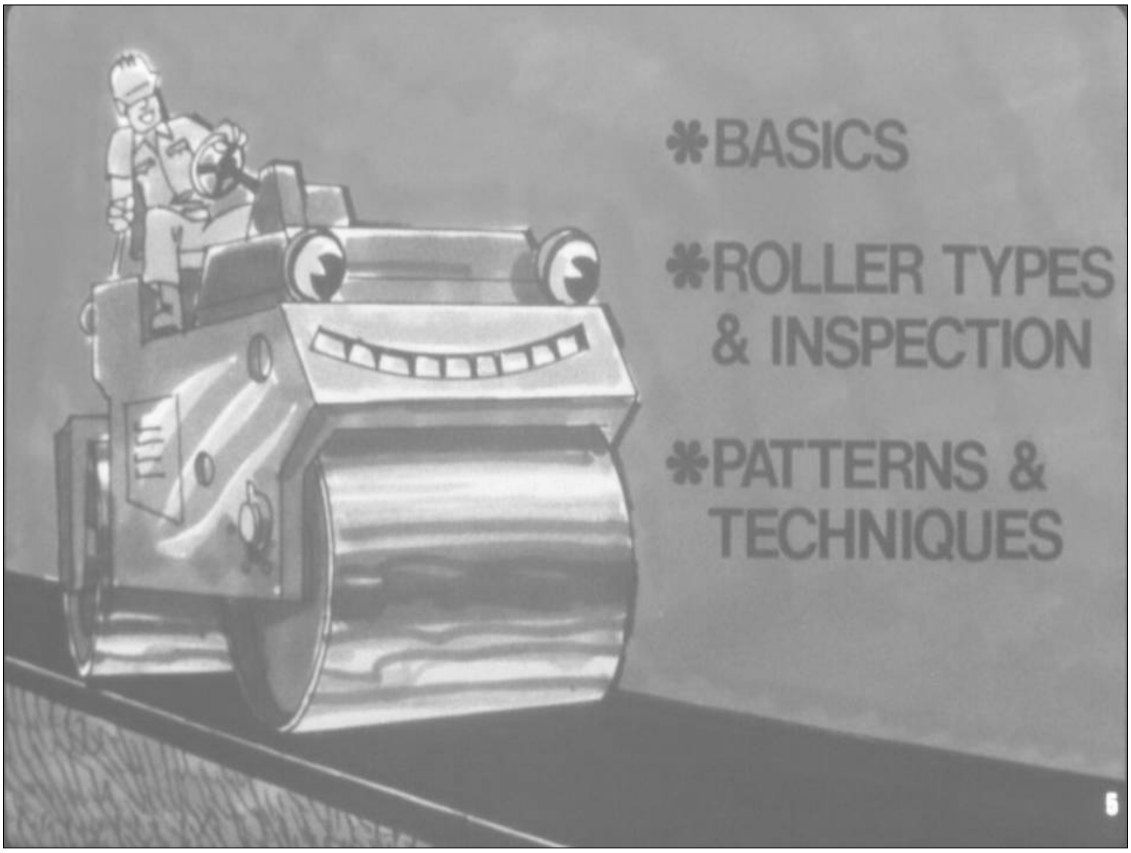
It is harder to compact a mix on a cold wet day than on a warm sunny day.

The type, size and number of rollers significantly affects the compaction operation.

Engineers, planners and many other skilled people are involved in producing a quality compacted asphalt pavement. However, it's the important last person in the paving chain -the roller operator- whose skill determines the final quality of the mat.

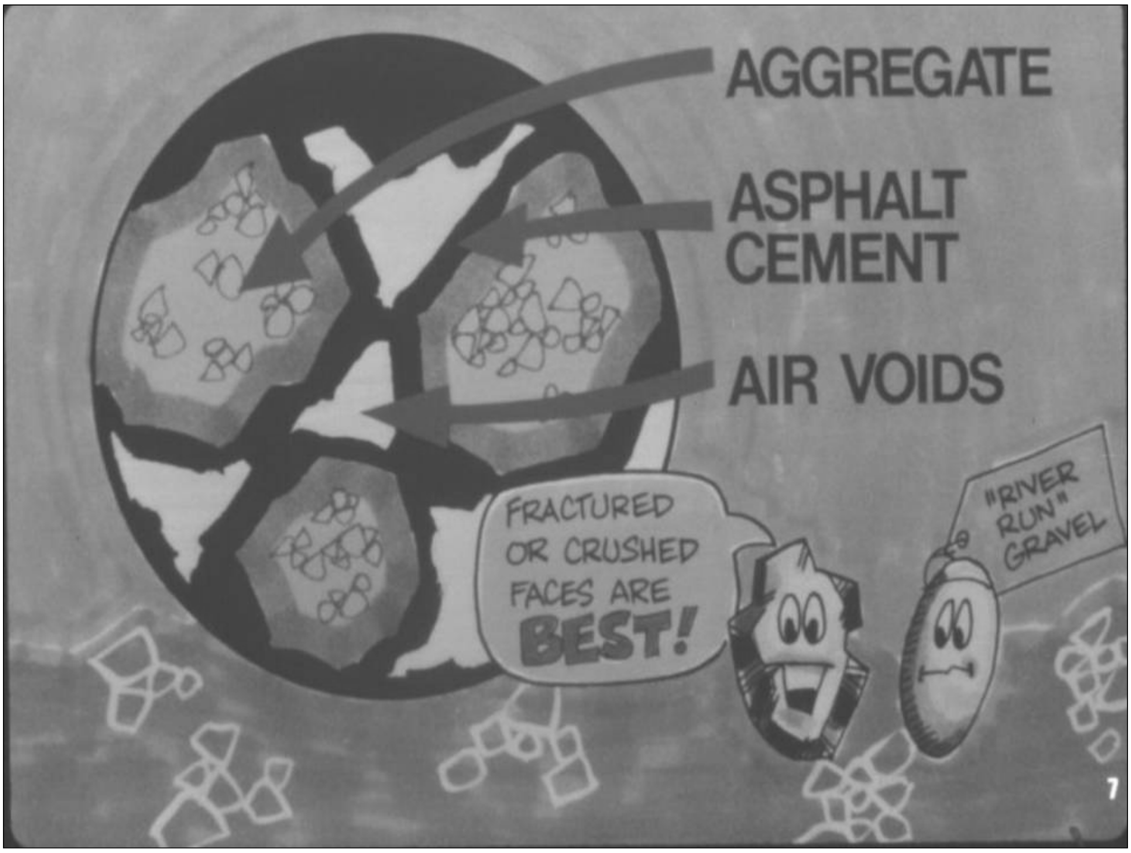


Please note that this program is not a set of operat-ing instructions for a particular roller. Nor is it a set of safety instructions for the operation of rollers in general. Always refer to the appropriate manuals for information on roller operating procedures and safety.

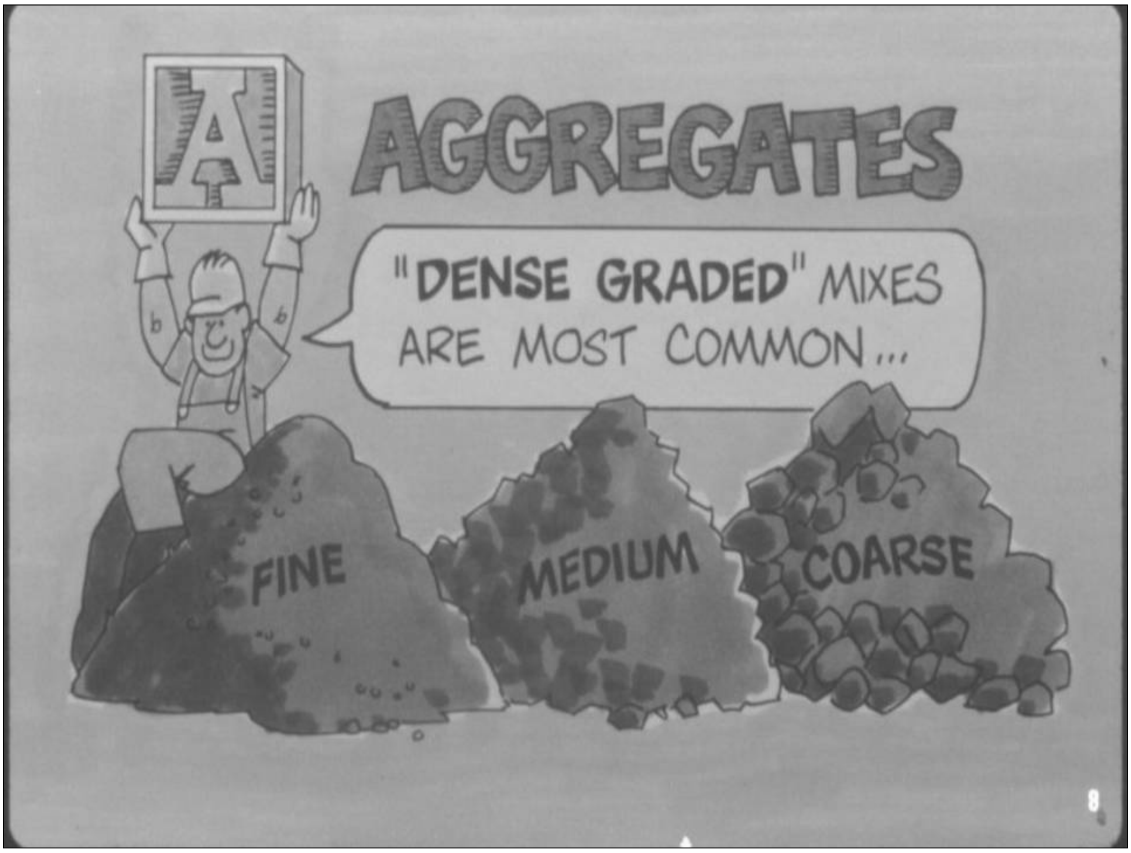


We'll start with some basic information about hot-mix asphalt and how it's compacted. Next we'll describe different types of asphalt rollers, and point out important maintenance items to check every day. Then we'll talk about the heart of the operator's job -rolling patterns and techniques-and give you information on how to choose the best, most efficient patterns for your machine and your jobs.

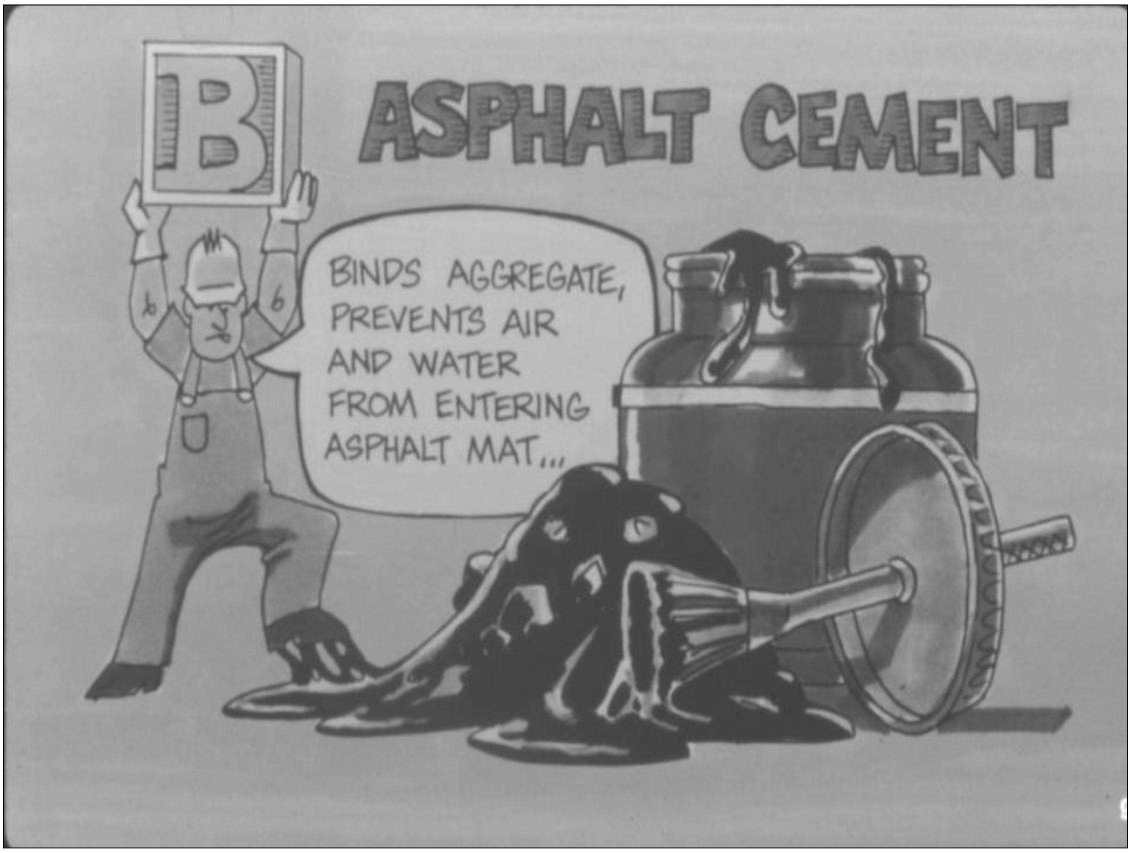
The more you understand about hot mix asphalt and its compaction, the easier it is to consistently roll high quality pavement. So let's begin with a short review of the basics



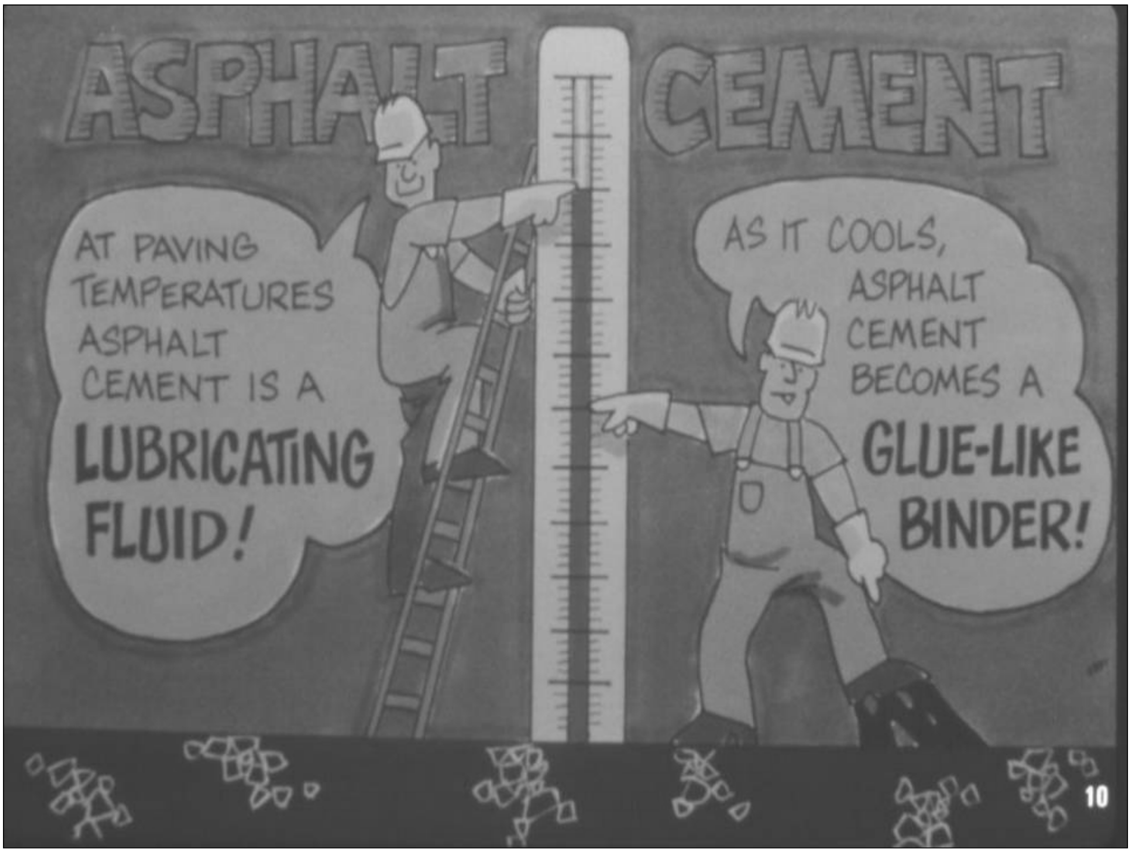
Asphalt pavement has three components: aggregate, asphalt cement, and air voids. It's the aggregate particles in a properly compacted asphalt pavement which actually carry most of the load. The force from the load is transmitted through the pavement by interlocking contact between the aggregate par-ticles. The friction at these contact points gives the pavement much of its stability. Aggregates with crushed or fractured faces or rough textured sur-faces develop this friction better than uncrushed "river run" gravels.



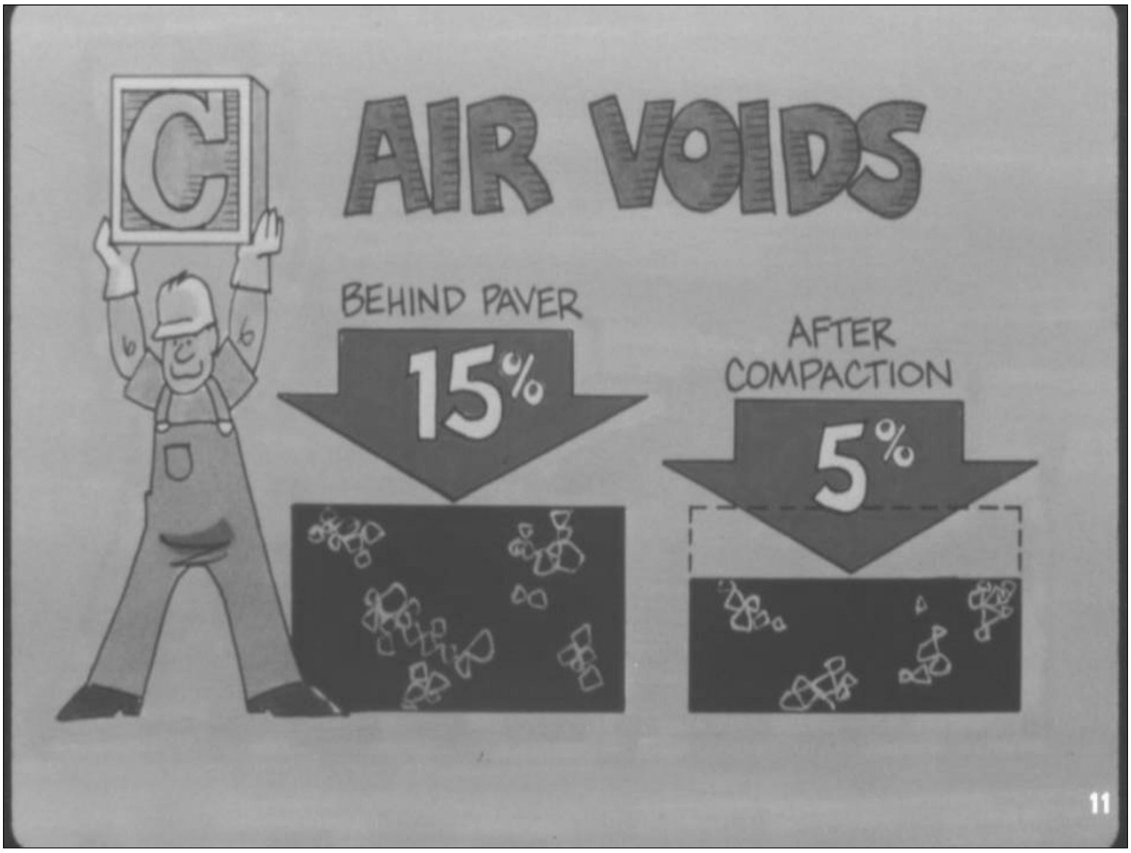
"Dense graded" mixes are the most common type of mixes. They are made with aggregate particles which range uniformly in size from coarse to fine. Dense-graded mixes are the type covered in this presentation. Special mixes called "open *graded* friction courses" or "popcorn mixes" will not be covered, since they are generally not compacted in a normal sense, but are simply rolled for smooth-ness and to seat the particles.



The second component of an asphalt pavement the asphalt cement-binds the aggregate particles together after they have been compacted. It also prevents air and water from entering the mat and damaging it.

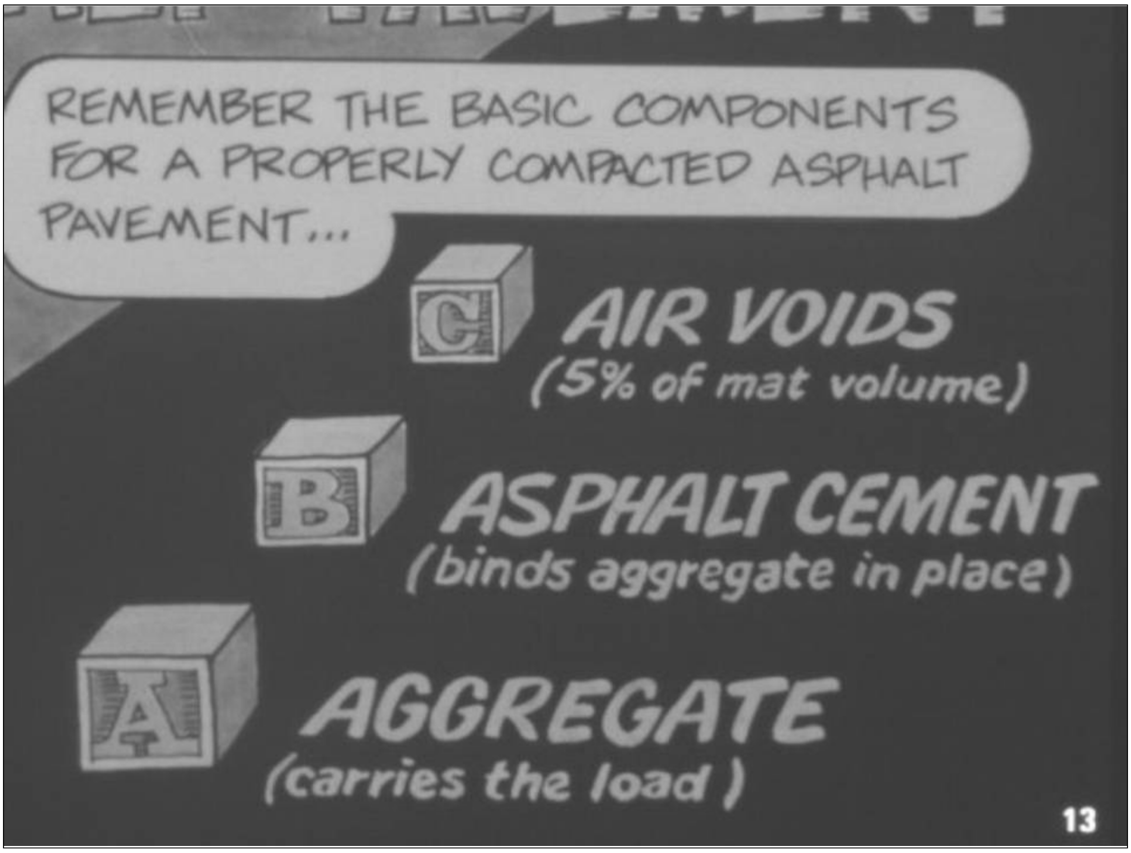


During the mixing process the asphalt cement is applied in a thin film to each aggregate particle. At paving temperatures this film of asphalt cementis very fluid and acts as a lubricant. This makes the job of spreading and compacting the mix easier. As it cools, however, the asphalt cement film becomes less fluid and acts more and more like a glue.

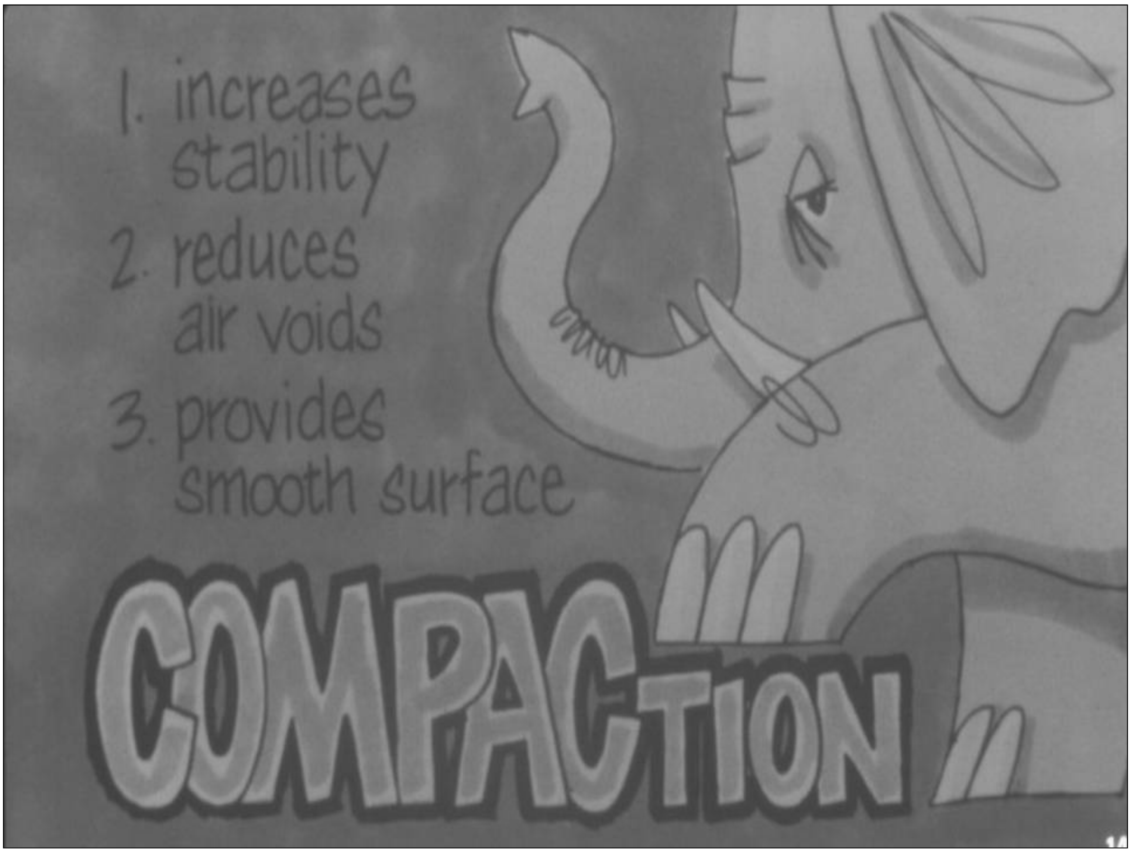


The third component of an asphalt pavement is air voids. Air voids are simply the spaces in the mix not filled by either the aggregate particles or the asphalt cement. In uncompacted hot mix, right out of the paver, air voids make up about 15% of the volume of the mat. Good compaction reduces this to about 5 % of the mat volume.

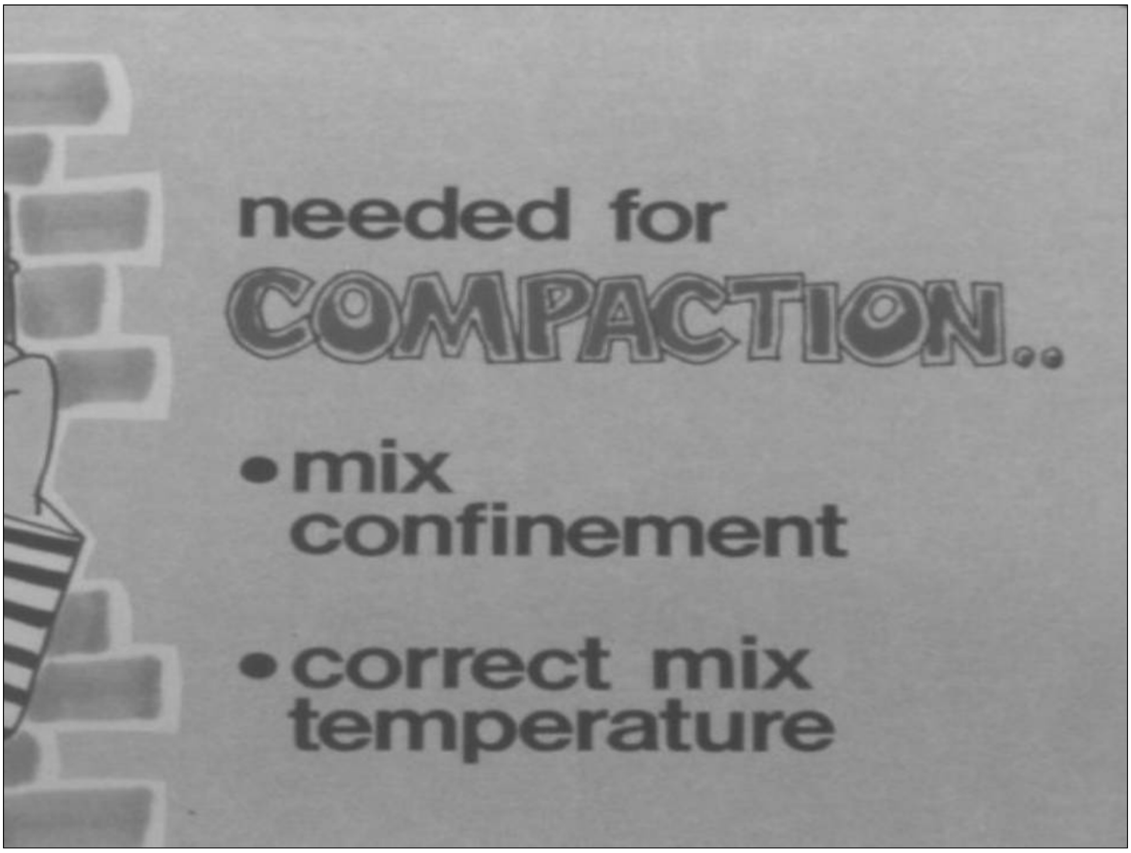
Too many voids can weaken a mat in two ways: (1) they can make the mix less stable by reducing the number of interparticle contact points; (2) they can make the mat permeable, which allows both air and water to freely penetrate the pavement and reduce pavement life. Stripping of the asphalt ce-ment from the aggregate and brittleness from exces-sive hardening are two examples of distress due to permeability.



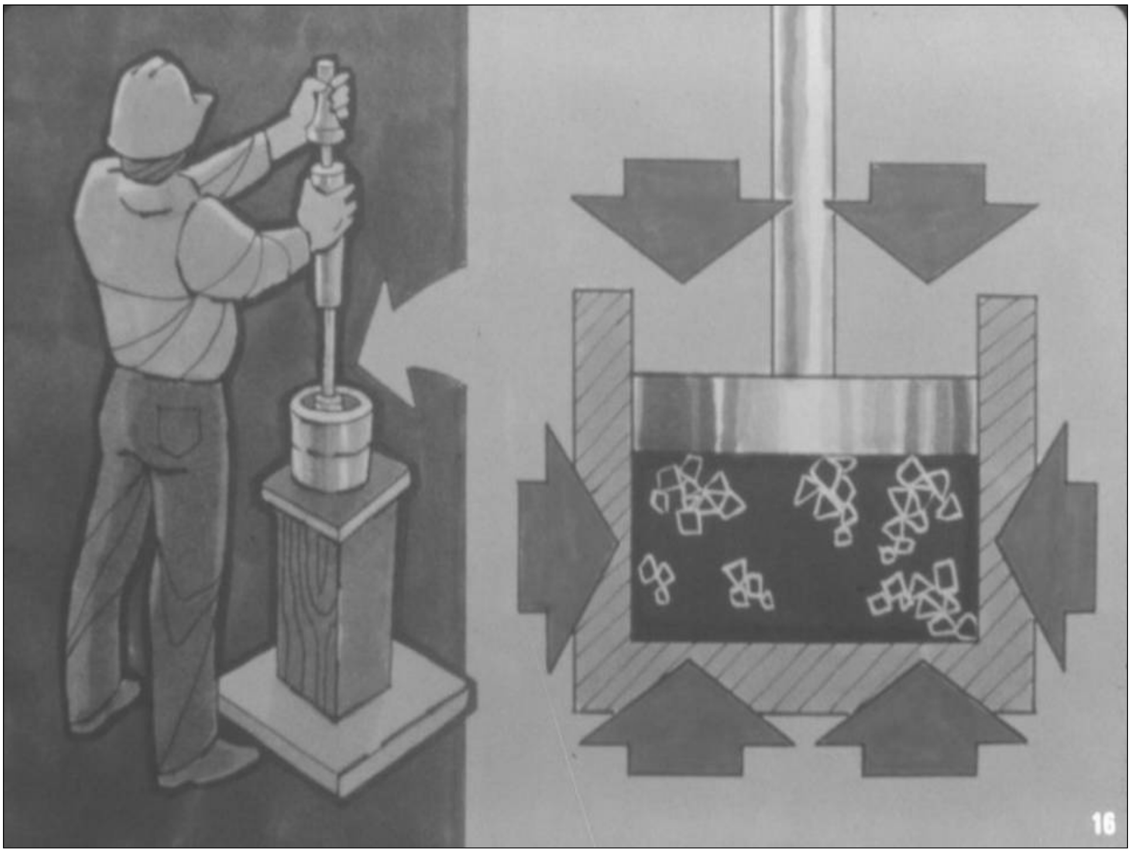
In properly compacted hot mix asphalt pavements the aggregate carries most of the load and the asphalt cement binds the aggregate in place. The air voids should represent about 5% of the total mat volume for greatest pavement life.



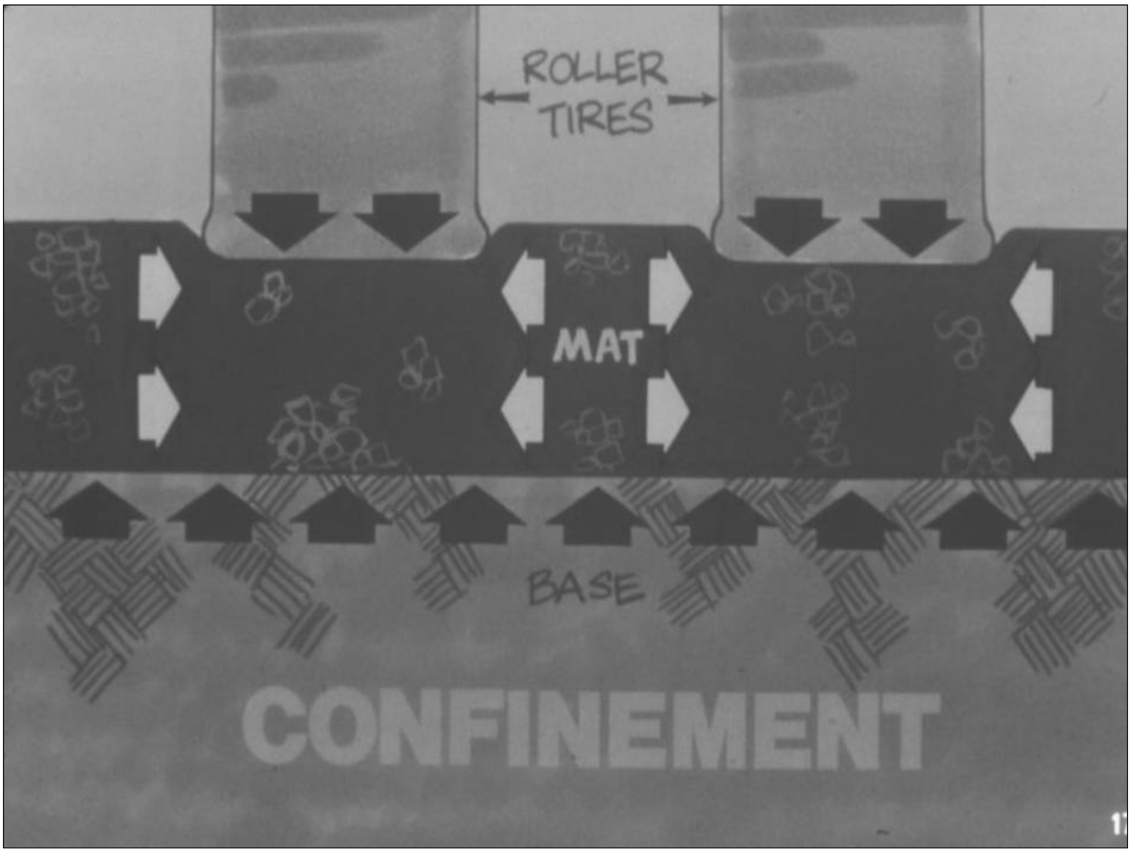
What role does compaction play in producing good quality asphalt pavement? Compaction accomplishes three things: First, it packs the aggregate into a strong, highly stable arrangement which increases the number of particle contact points. Second, com-paction reduces the air voids to about 5% to keep the mix stable and impermeable to air and water. Third, it provides a smooth surface that gives a superior ride and increases pavement life.



Even with a properly designed mix, compaction of the mat is possible only if two important conditions **exist: confinement** and correct mix temperature.



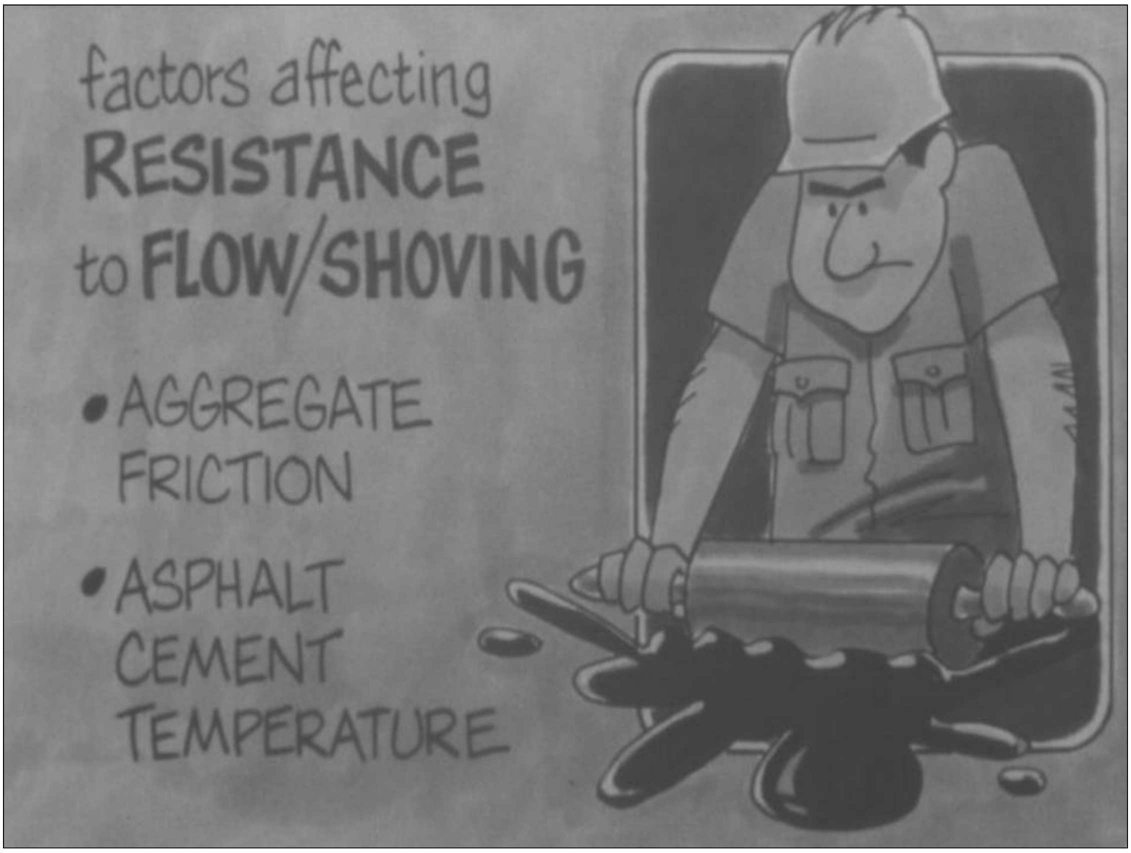
The first condition, confinement, means the asphalt mix is held in place from every direction so that it can be compressed, packing the aggregate and reducing air voids. An example of excellent confine-ment occurs in the laboratory when a ram com-presses the asphalt mix into a mold. The mold and the ram confine the mix from every direction. Unable to escape from the force exerted on it, the mix is properly compacted.



Confinement isn't so easy in the field. When com-pacting a mat, confinement from the bottom comes from whatever base is under the mat; that base must be stable. Top confinement comes from the contact of your roller with the mat. Confinement from the sides comes internally from the mix surrounding the area being compacted. The surrounding mix must resist flowing or shoving.

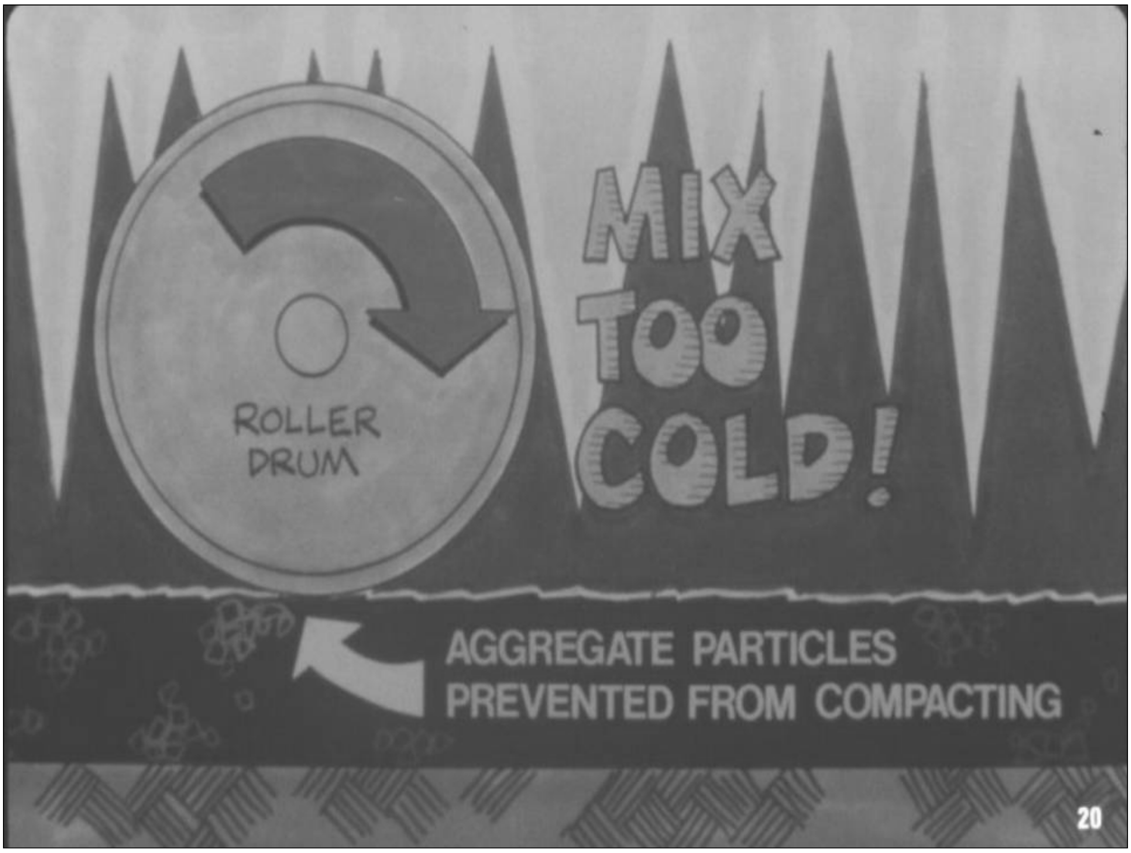
FORCES IN THE COMPACTION PROCESS

- Compressive force of rollers
- Supporting force Beneath Mat
- Forces within Mix resisting Rollers

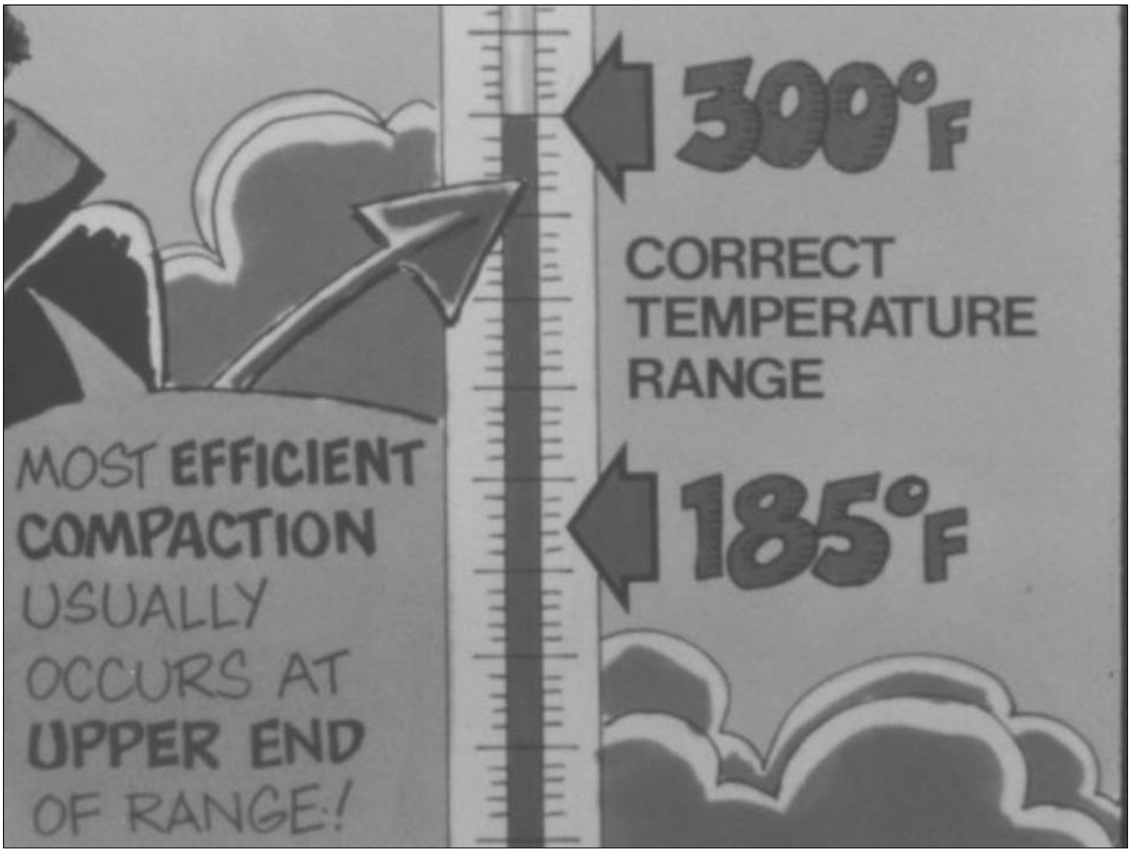


The mix's resistance to flow is very important for confinement and is directly affected by two things: aggregate friction and asphalt cement temperature. Mixes containing smooth aggregate, for example, have very low aggregate friction providing little in-ternal confinement and such mixes tend to shove out rather than compress down as you roll them. As a result, instead of compacting the mix, you simply move it around.

Mixes which are too hot also provide poor internal confinement, because the asphalt cement lubricates too much and binds too little. The aggregate par-ticles are free to flow and shift around under the force of the roller instead of compacting.

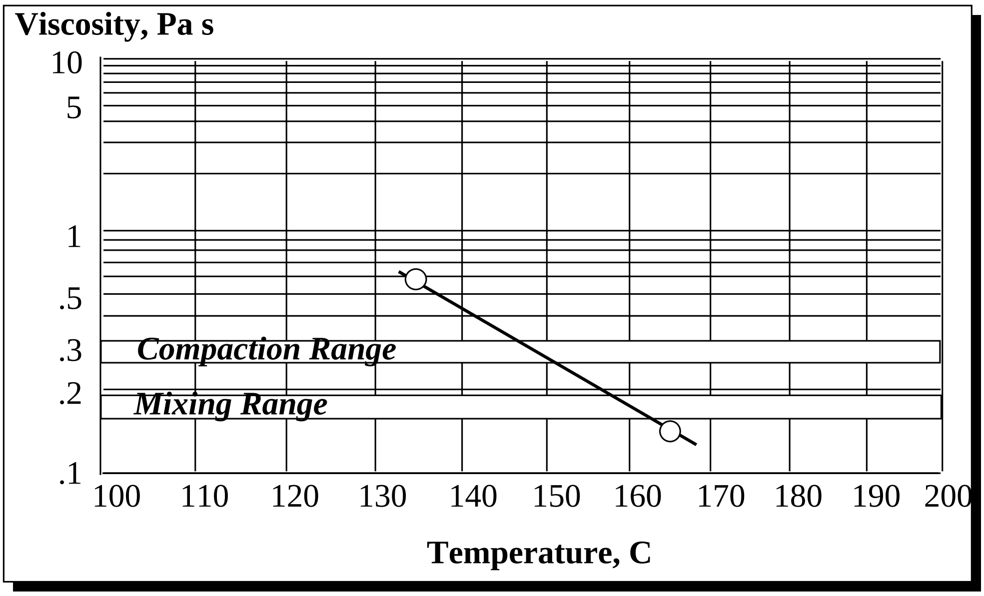


Correct mix temperature is as important for good compaction as confinement. As just shown, if the mix is too hot it is difficult to confine. However, if the mix is too cold, the asphalt cement acts too much like a glue, and the aggregate particles will not change position. The asphalt becomes so tacky that it prevents the particles from being pressed together into a denser fit. This occurs below about 185° F.

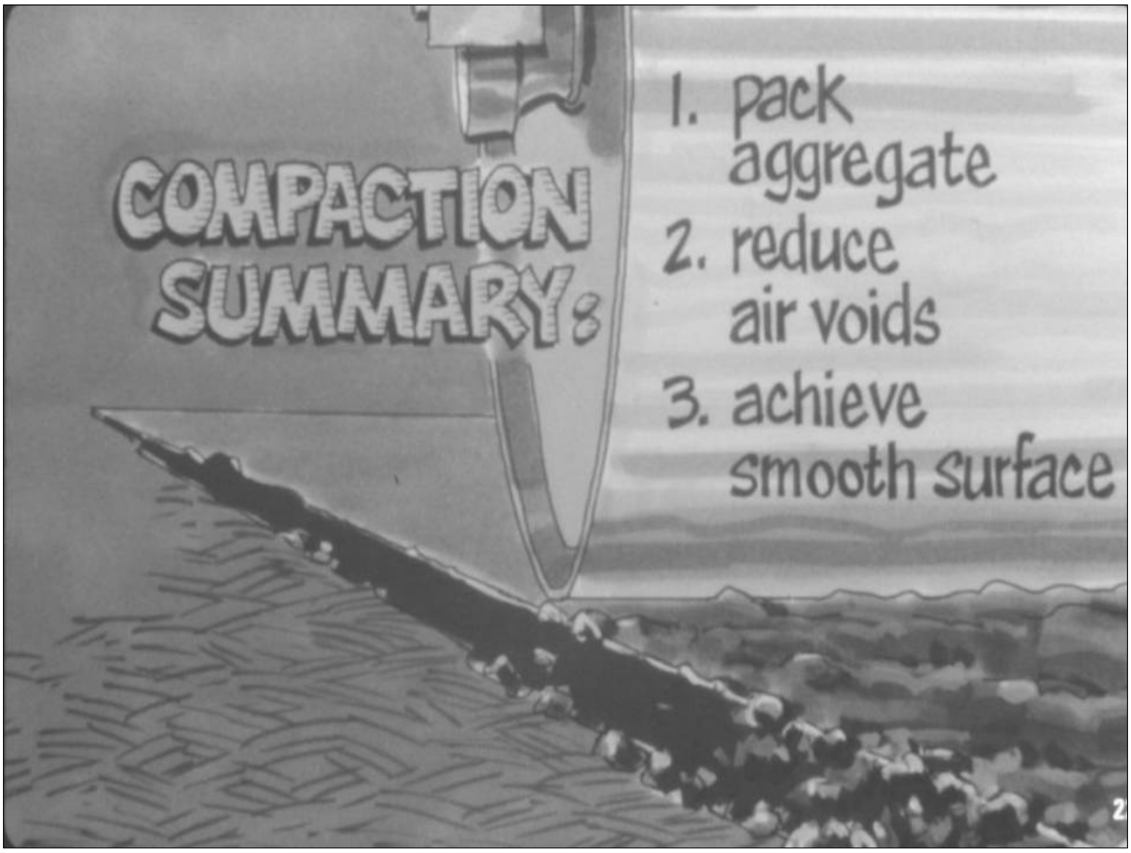


The correct temperature range for compaction is typically between about 185° F. and about 300° F. The most efficient temperature will probably be at the upper, hotter end of this range; here the asphalt cement acts more like a lubricant and the aggregate becomes easier to pack into a dense fit.

Mixing/Compaction Temps



Two different heights are used for specimens in Superpave. Superpave also recommends that two specimens be mixed for use in determine the maximum theoretical specific gravity of the mixture.

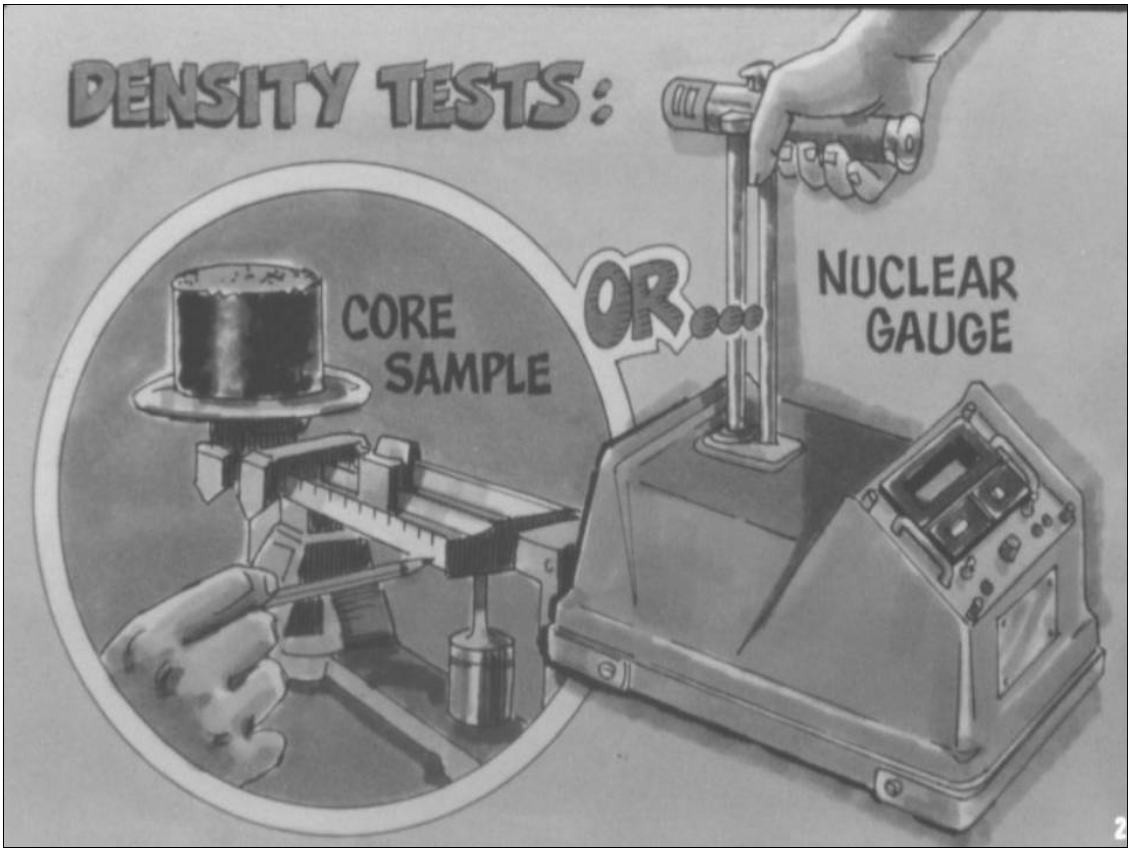


In summary, the objectives of compaction are to pack the aggregate, reduce the percentage of air voids, and achieve a smooth riding surface. These objectives are accomplished by compressing the mix, but compression can be done only when the mix is confined and is within a particular tempera-ture range. But how do you *know* whether or not a pavement has been properly compacted?

PHYSICAL FACTORS AFFECCTING COMPACTION

- Temperature of the Mix
- Contact Pressure of the Rollers
- Number of Coverages
- On-Site Conditions

The only sure way is by testing. Two primary types of tests are used for determining the effectiveness of compaction-density tests and smoothness tests. Density tests are a means of measuring the percentage of air voids and the corresponding per-centage density of the compacted mix. The test results are then compared to the density standards specified for the job. There are two types of density tests commonly used today.

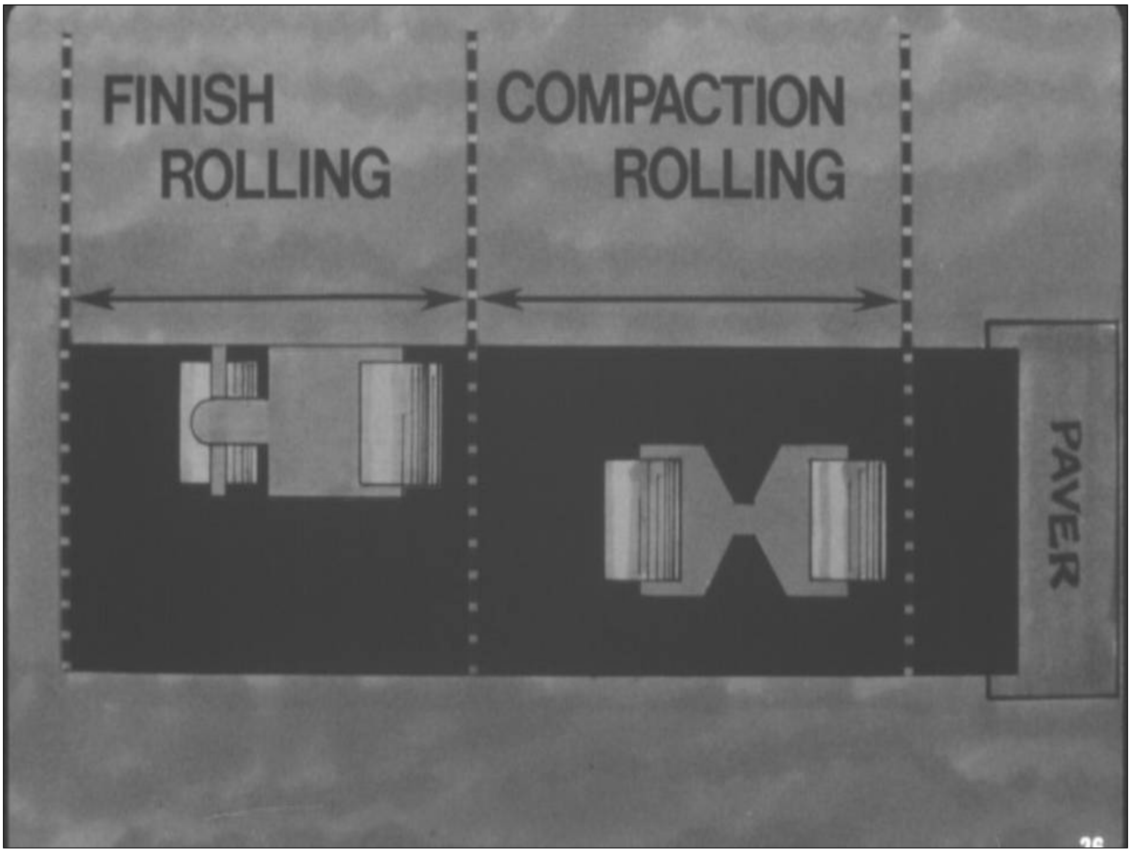


The first involves removing a sample called a core from the pavement and analyzing it in the laboratory, The second method involves placing a nuclear gauge right on the pavement surface. The gauge calculates the density automatically and displays the results.

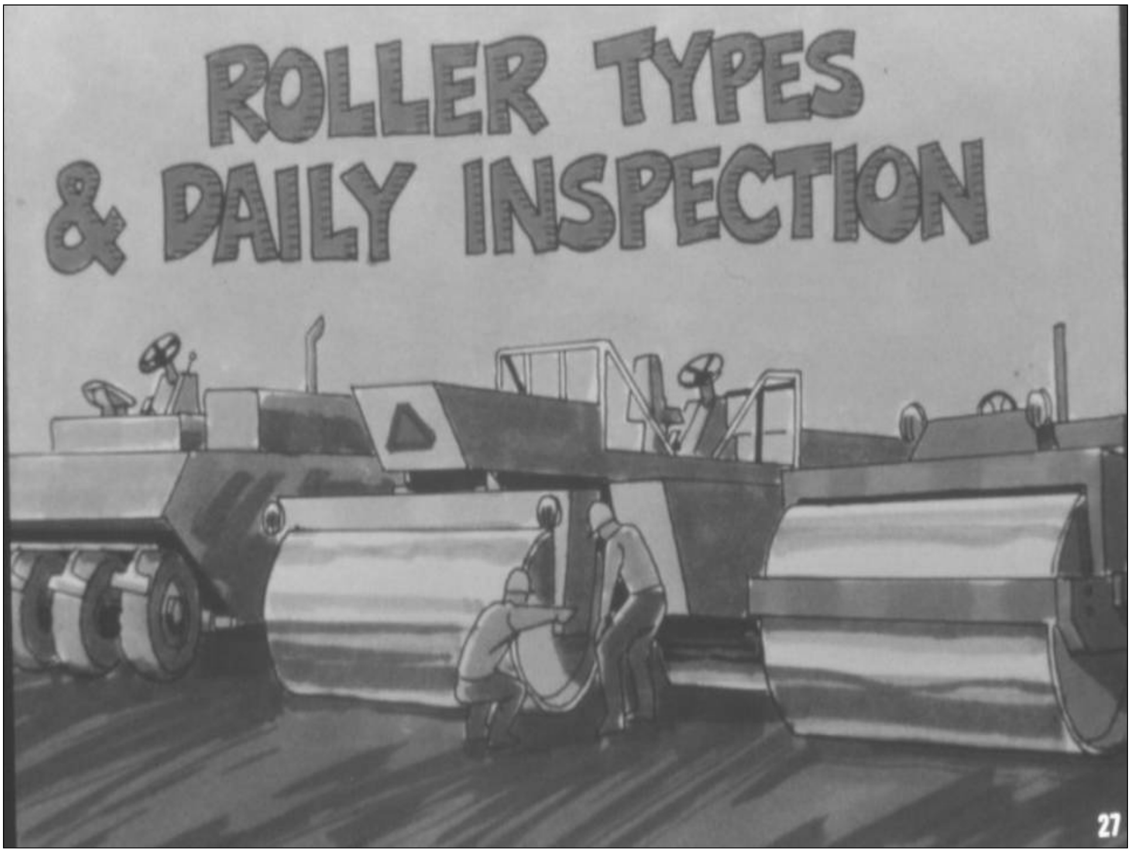
Smoothness, or rideability, can also be tested in several ways, the most common being with a straight-edge-or what's called a rolling straightedge. Den-sity and smoothness are necessary to provide the most durable and economic pavement for the ex-pected traffic loads.

STAGES OF ROLLING

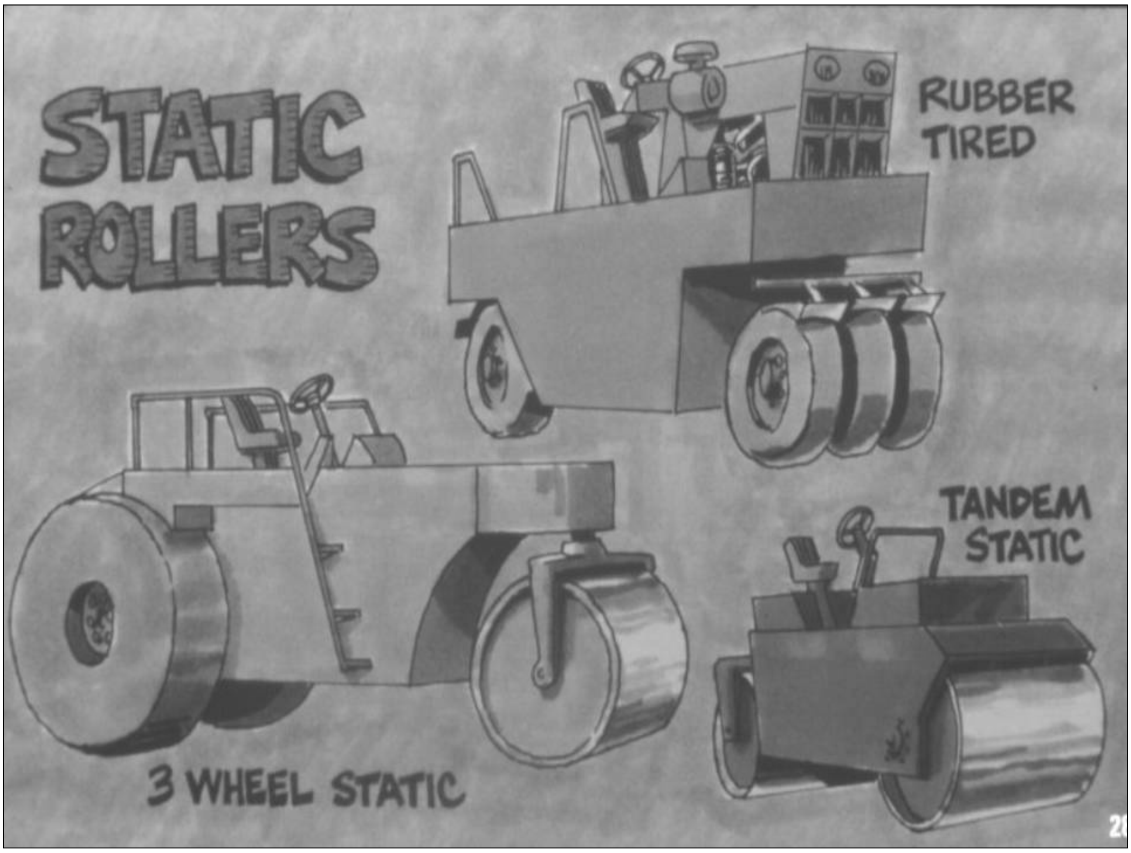
- Breakdown Rolling
- Intermediate Rolling
- Finish Rolling



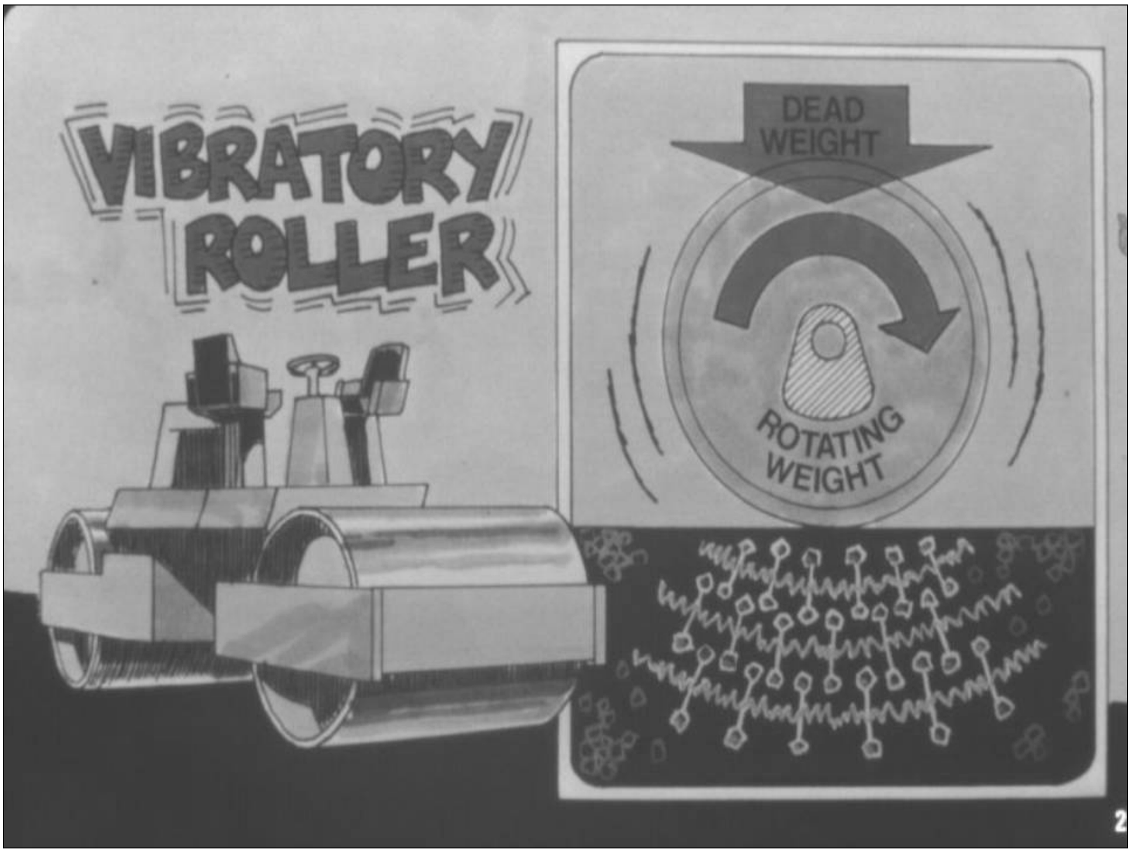
There are two phases in the rolling process, compac-tion rolling and finish rolling. Virtually all of the density and impermeability, and most of the smooth-ness, are developed in the compaction rolling phase. Finish rolling, the second phase, simply irons out the marks left in the mat from the compaction rolling. Finish rolling is done while the mat is warm enough to allow removing the rolling marks, but cool enough to avoid making new ones. Finish rolling generally doesn't increase the density of the mat, and if overdone can actually decrease the density.



Now that we've learned a few general facts about asphalt pavement and compaction, let's look at the rollers used to do the compacting. First, we will dis-cuss the basic types of machines, then we will talk about daily inspection, a very important part of the job of operating any roller.



Rollers are divided into two basic types: static and vibratory. Three common types of static rollers are the tandem, the rubber tired, or pneumatic, and the three-wheel. Static rollers compact asphalt mixes by their dead weight alone. On some rollers this dead weight can be increased with ballast. On pneumatic rollers the contact area between the tires and the pavement can be varied by adjusting the tire pres-sure or by adding ballast.



Vibratory rollers are made with one or two steel drums, and have rotating weights in the drums. These weights vibrate the drums, creating a dynamic force that adds to the dead weight of the machine and increases the compacting force. The vibration also helps reduce friction between aggregate par-ticles in the mix, making it easier to move the parti-cles past each other for better compaction.

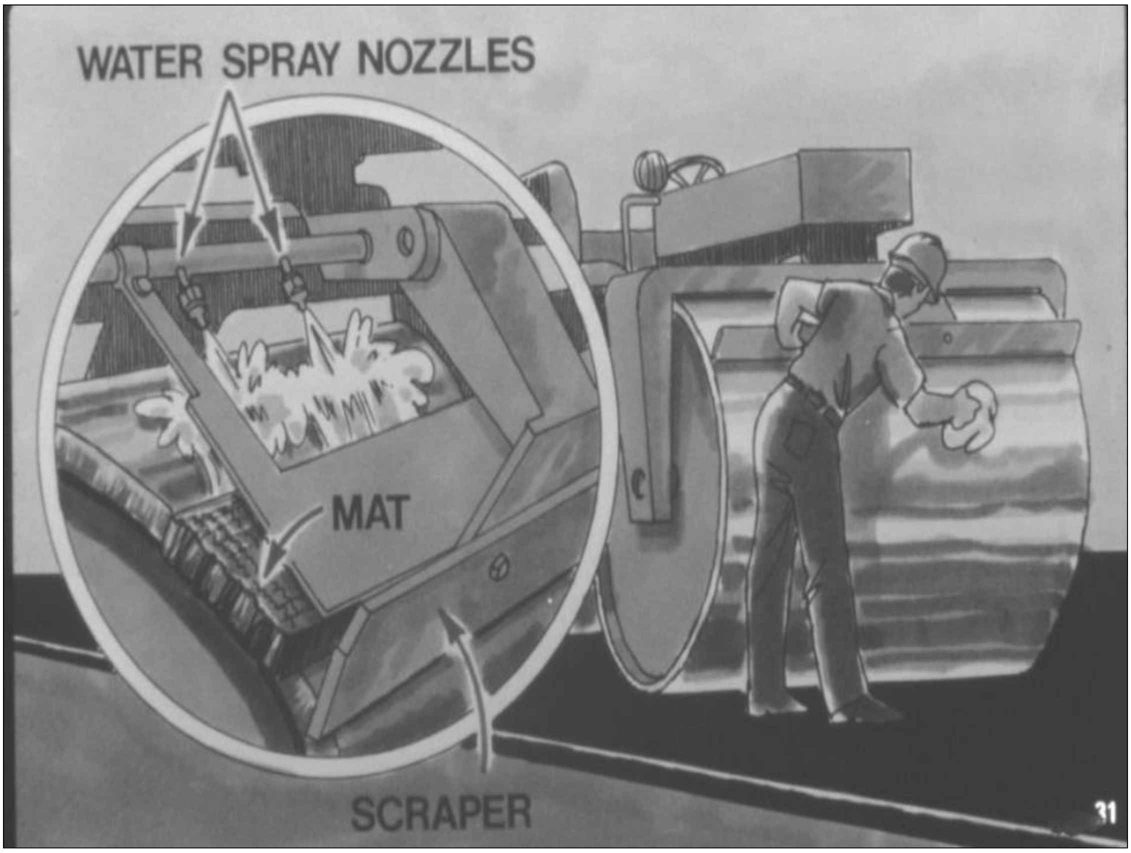
REASONS FOR VIBRATORY ROLLER POPULARITY

1 Accomplish desired compaction in fewer passes
2 A dual vibratory roller can be operated in 4 different modes

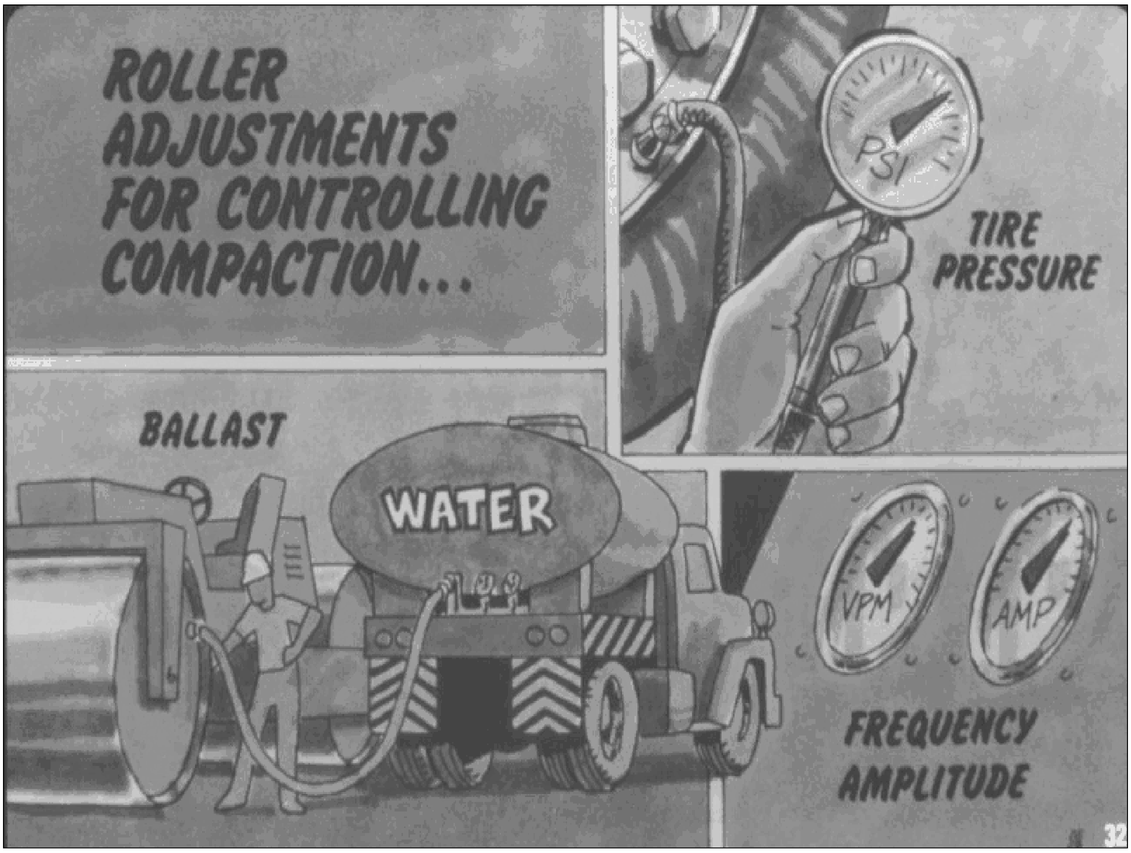
Factors Affecting Vibrating Compaction

- Roller Weight
- Impact Forces
- Mix Response

A static roller or a vibratory roller must be kept in the best possible condition to produce a quality mat. Each day before you even start rolling, there are a number of things you should do. First and foremost are the manufacturer's recommended daily maintenance and inspection checks. These checks are prescribed specifically by the people who de-signed and built your roller. Performing these checks on a regular daily basis helps you get the best performance and service life out of your equipment.



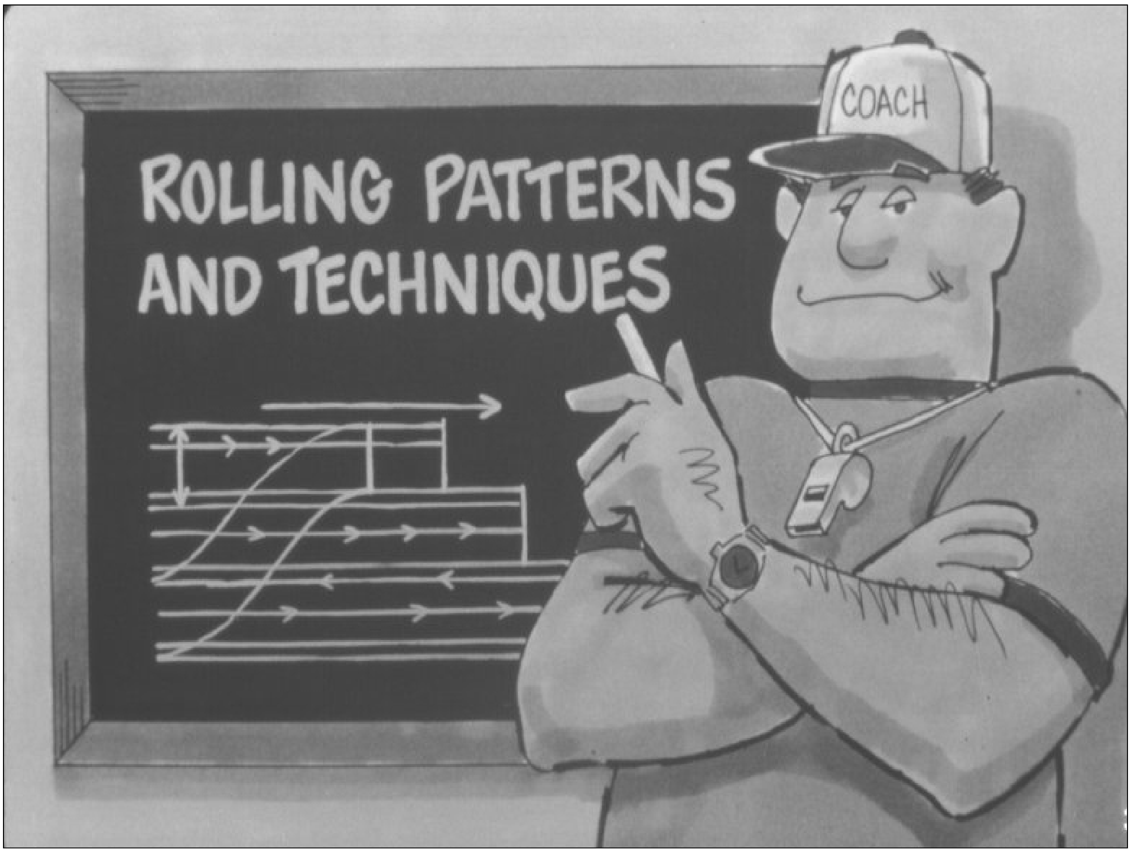
Check your scrapers and water spray. Scrapers and mats must be properly positioned and adjusted; water spray nozzles must be clear and able to spray their areas of the wheel, drum or tire. Clean any grease or oil off your drums or steel wheels; properly clean your pneumatic tires or rubber drive wheels to prevent pick-up.



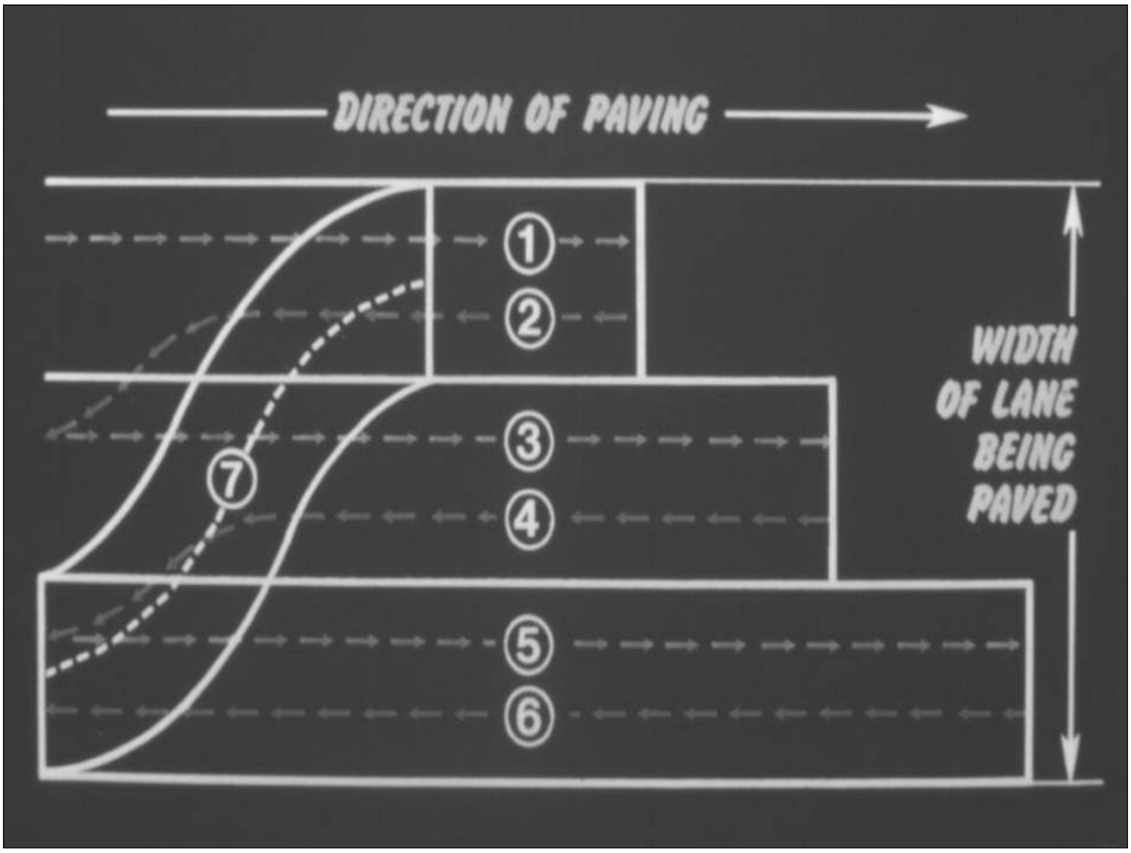
Remember also that most rollers can be adjusted to control the compacting force applied to the mat. Such adjustments include increasing or decreasing ballast, tire pressure, vibrator amplitude, and vibrator *frequency*. Before moving onto the mat each day be certain your equipment is properly adjusted for the mix and the mat thickness you're working on. If any of your daily checks turn up a problem, fix it immediately or notify your supervisor so it can be fixed as soon as possible.

<u>CONSIDERATIONS FOR ROLLERS DURING COMPACTION</u>

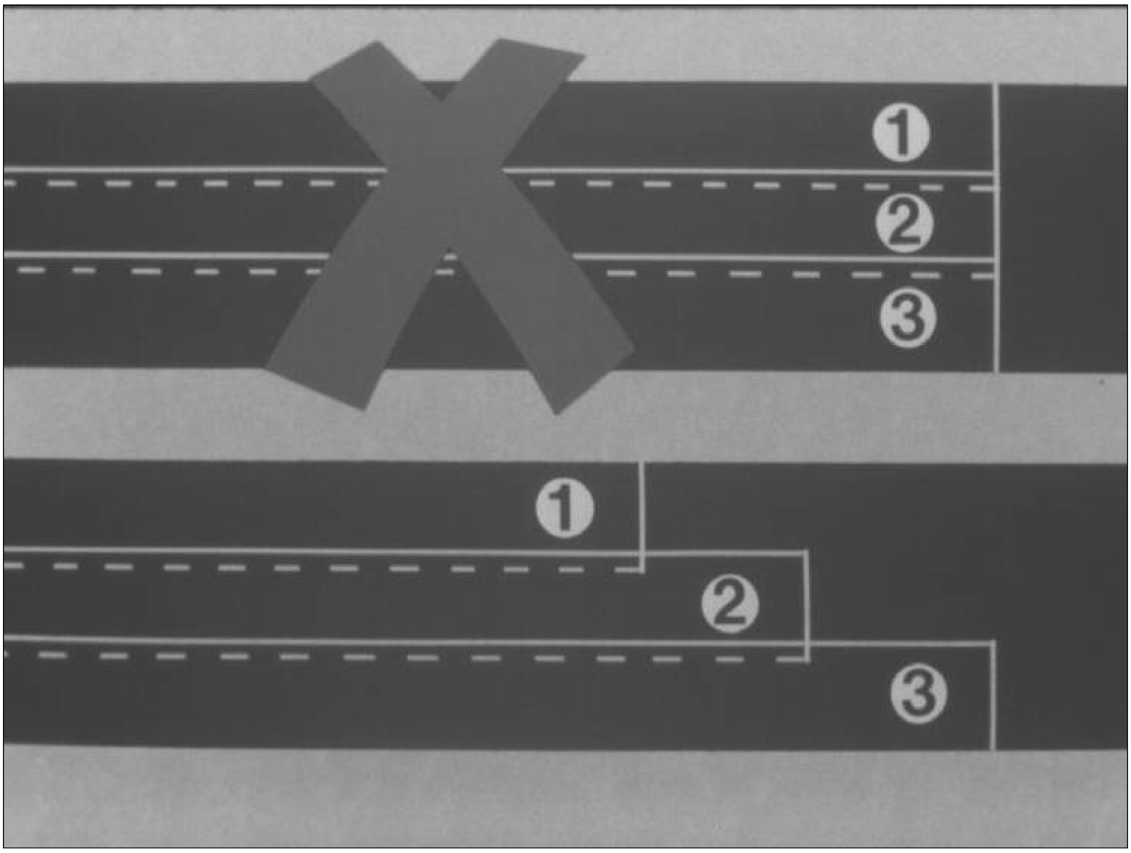
- Speed of Roller < 3 MPH
- Establish Roller Pattern
- No Stopping or Turning on Fresh Mat
- Use of a Proper Watering System



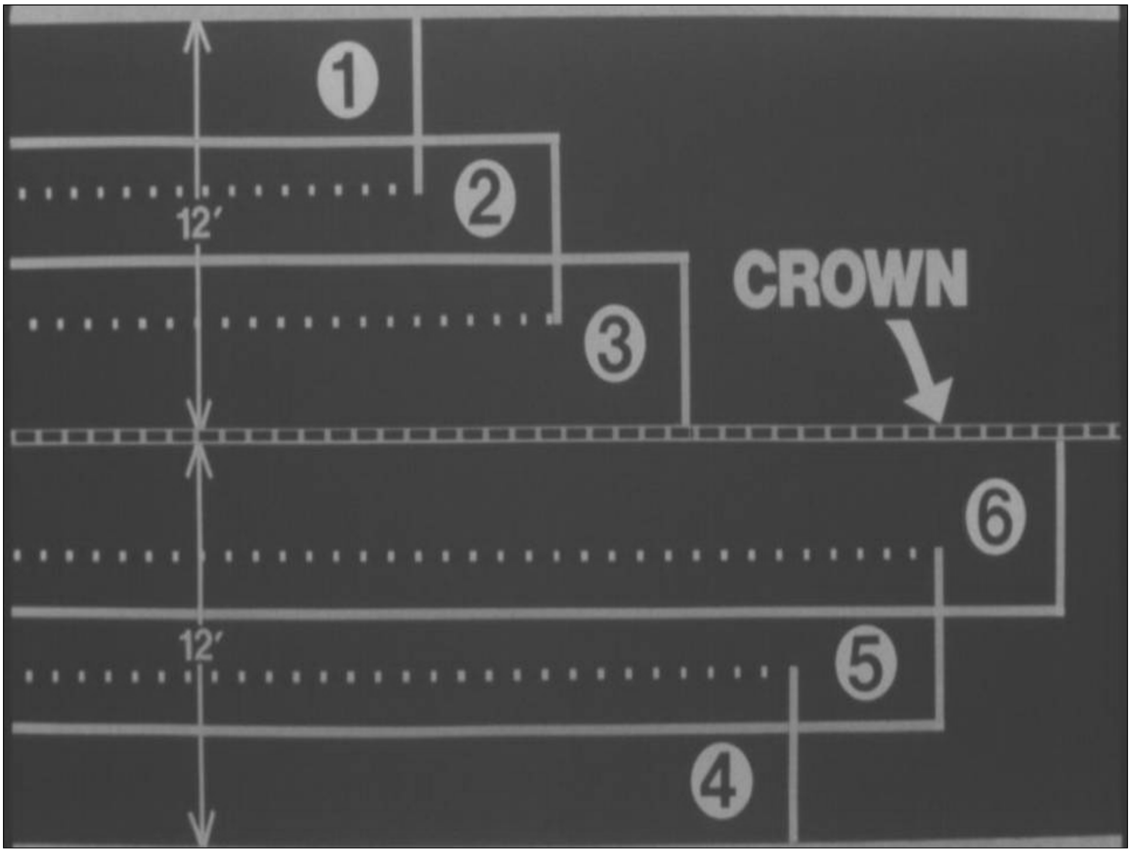
We've reviewed the basics on asphalt pavement, com-paction, and rollers; now let's see how we can use this knowledge to produce better quality pavement. First, we will talk about rolling patterns and how they're a handy way of applying what you know about rolling. Then we'll cover some techniques to help keep your rolling as easy, smooth, and efficient as possible.



A major reason for poor compaction is inconsistent rolling: too fast or too slow; too few passes or too many; mix rolled too cold, or too hot. A good rolling pattern helps avoid these kinds of problems. A good pattern gives you the uniformity and efficiency needed to meet your density and smoothness re-quirements and still keep up with production.



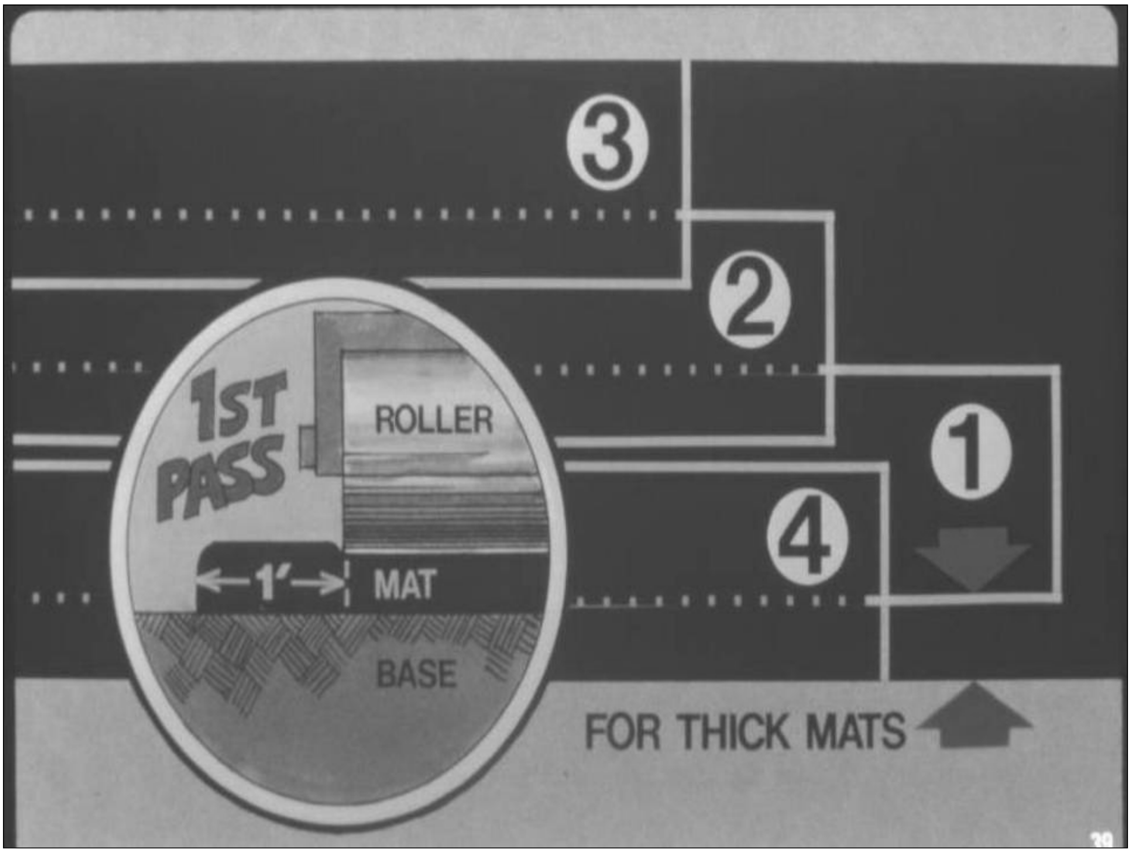
When making multiple passes down the mat, do not end all the passes at the same place, as shown here. The paver is farther away from the roller when the second pass is rolled, and even farther away on pass three. To stay in the same temperature zone for each part of the mat, you have to roll farther on each suc-cessive pass. Reversing the roller in the same spot on each pass can also leave shove marks across the entire width of the mat at one point, producing an unpleasant bump.



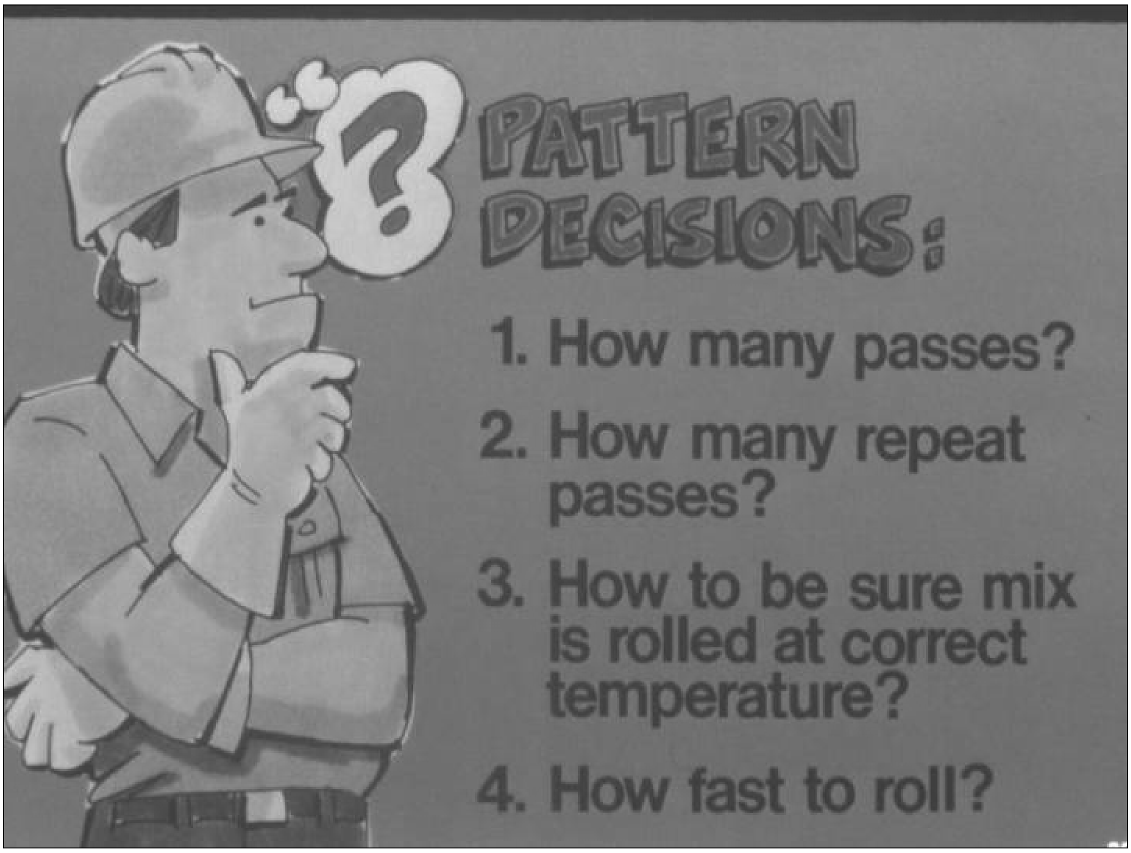
How many passes are needed to cover the width of the mat once?

To answer that question, compare the width of your roller to the width of the mat. Allow for an overlap of approximately six inches. Using this information figure out the minimum number of passes needed to roll the full mat width.

Several conditions affect how many passes you choose to cover the mat. If there was a crown down the middle of the road in our previous example, we'd have to run six passes-three on either side of the crown-to avoid flattening it.



If the mat is *thick* and has an unsupported edge, that is, an edge that's not laid against a curb or an-other mat, the edge may shove excessively because it's not confined very well. Adjust your passes so that the first pass near the unsupported edge is a foot or so inside it; this builds confinement in the mix without shoving it excessively. Follow-up passes can then roll the edge with less shoving.



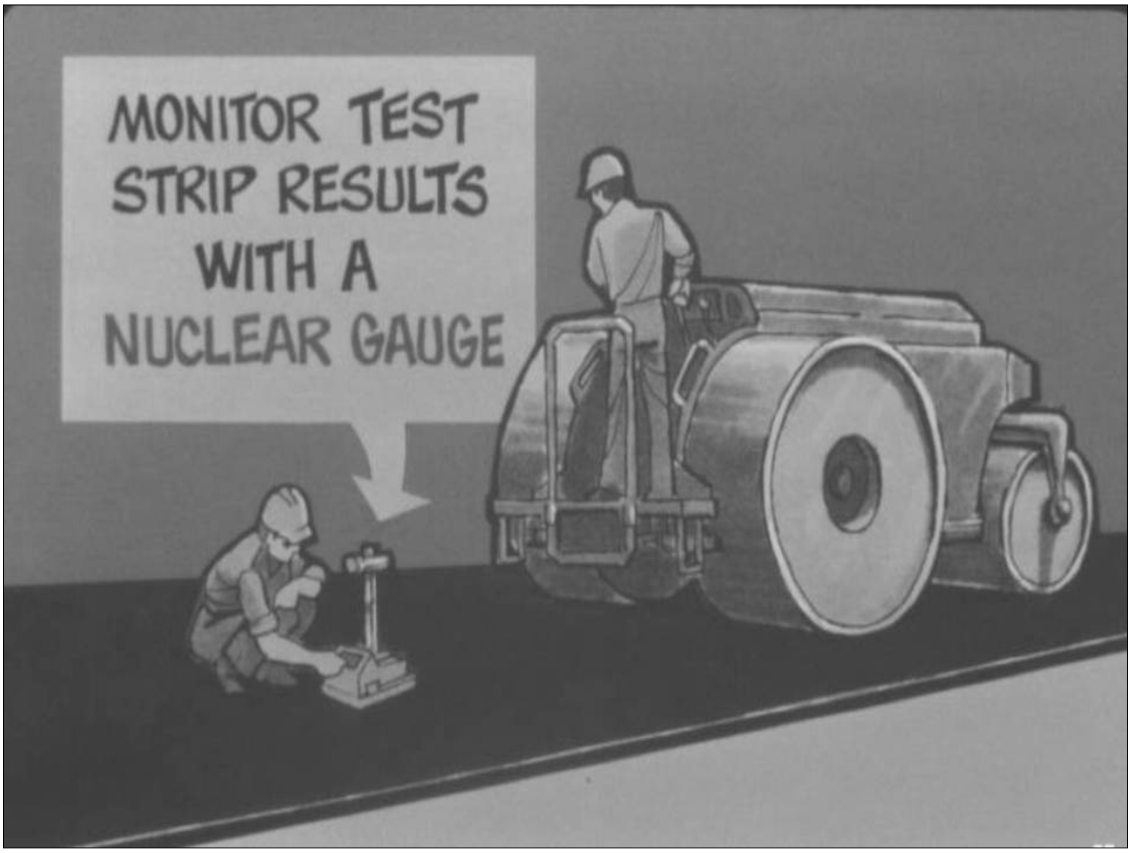
The only way to figure out the right pattern for a job is step by step. No matter what type roller you use-static or vibratory-you must first determine four things:

(1) How many passes are needed to cover the width of the mat once?

(2) How many repeat passes are required?

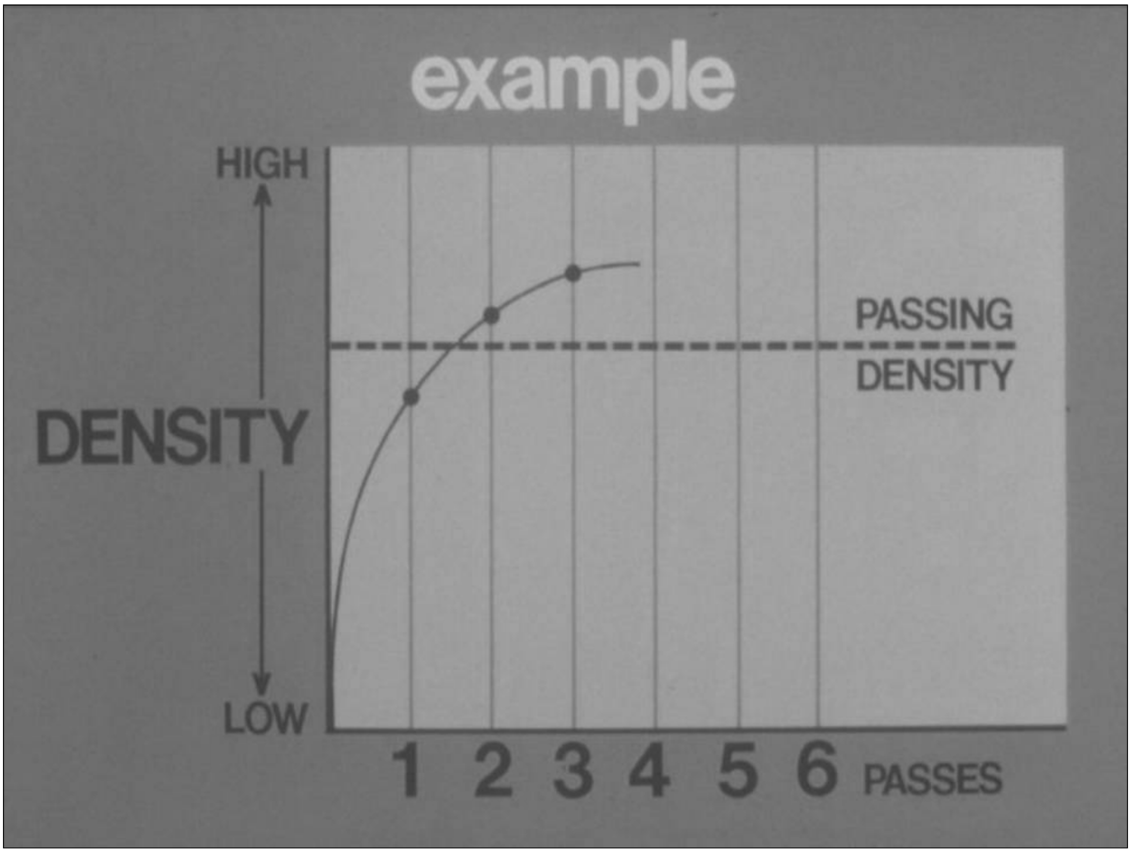
(3) How to make sure the mix is rolled while in the correct temperature range?

(4) How fast to roll?

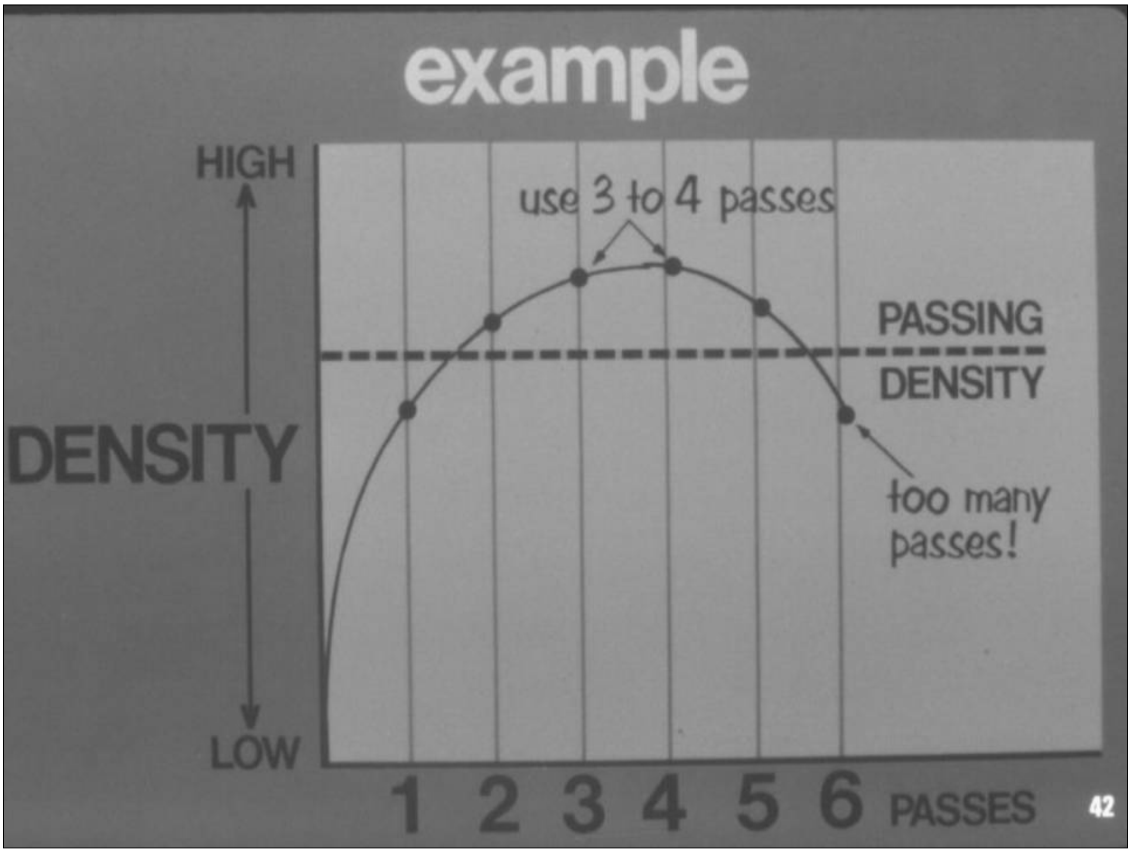


The best way to determine the correct pattern for a job is to roll a test strip and monitor the results with a nuclear gauge. Even if you can't set up a test strip, you can select a good pattern to help you do a better job.

The second question on our list is, How many repeat passes are required? Because compacting is generally more effective if done before the mat cools, you should cover the mat width once-that is, get a "coverage" - as soon as possible. But one cover-age often is not enough to do the job. How many more do you make?



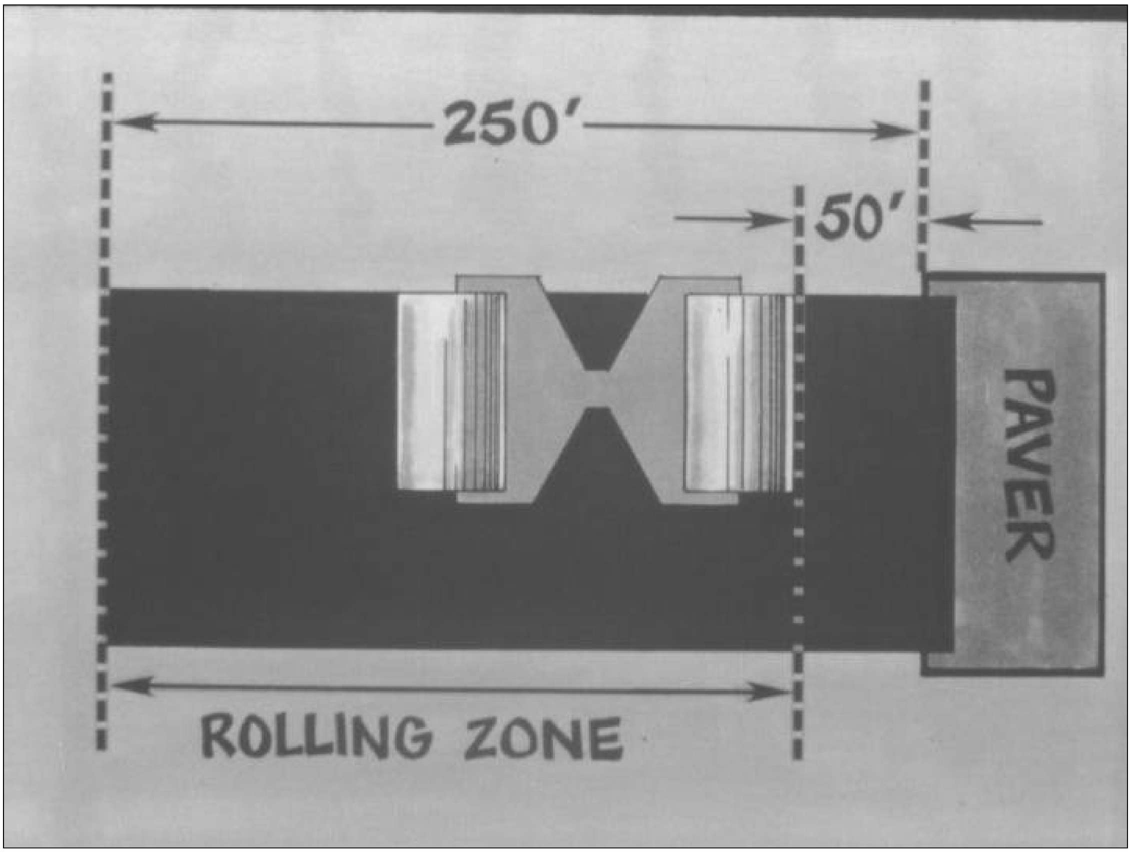
Past experience with the mix and lift thickness helps, but the best way to calculate the most efficient num-ber of passes is to monitor the density with a nuclear gauge. This graph shows typical nuclear gauge read-ings taken after each roller pass. In this example, two roller passes are enough to get passing density. Note that each succeeding pass adds less and less to the density. This is because the more compacted the mat becomes, the harder it is to pack it tighter.



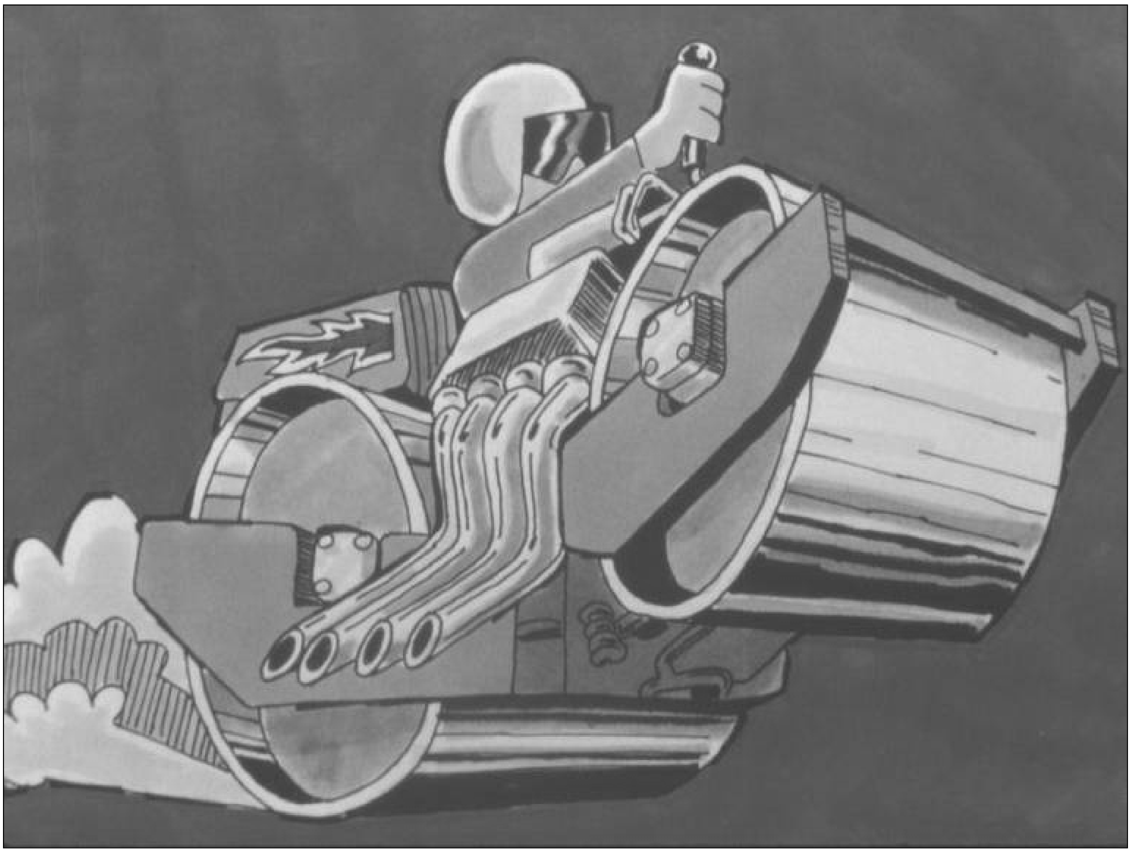
If the roller operator makes unnecessary extra passes, the mat may decompact and lose density. Here we see the previous graph extended to show this. Maximum density occurred after two compac-tion passes and two finish passes, four passes total; further passes decompacted the mat. This decompac-tion can occur with both static and vibratory rollers. Remember, though, that if your vibratory roller achieves passing density with fewer passes than a static roller it can also decompact the mat with fewer extra passes.

FAILURE OF TEST PATTERN

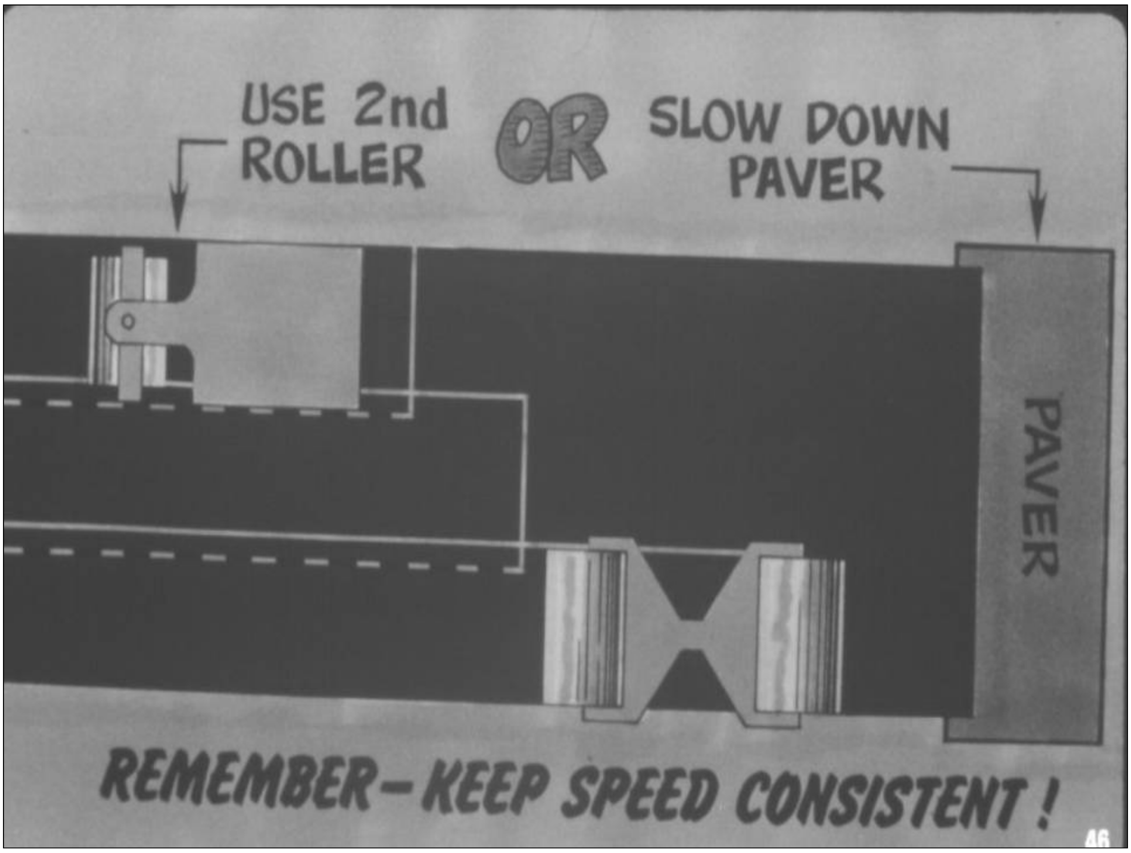
- CHANGE ROLLER SPEED
- TAKE A 15-SECOND NEUCLEAR COUNT
- INCREASE MIX TEMPERATURE WITH CAUTION
- INCREASE COMPACTION EFFORT BY INCREASING TIRE PRESSURES OR ADDING WEIGHT, WHICHEVER IS APPROPRIATE
- COMPARE PLANT PRODUCED MIX TO LABORATORY PREPARED MIX



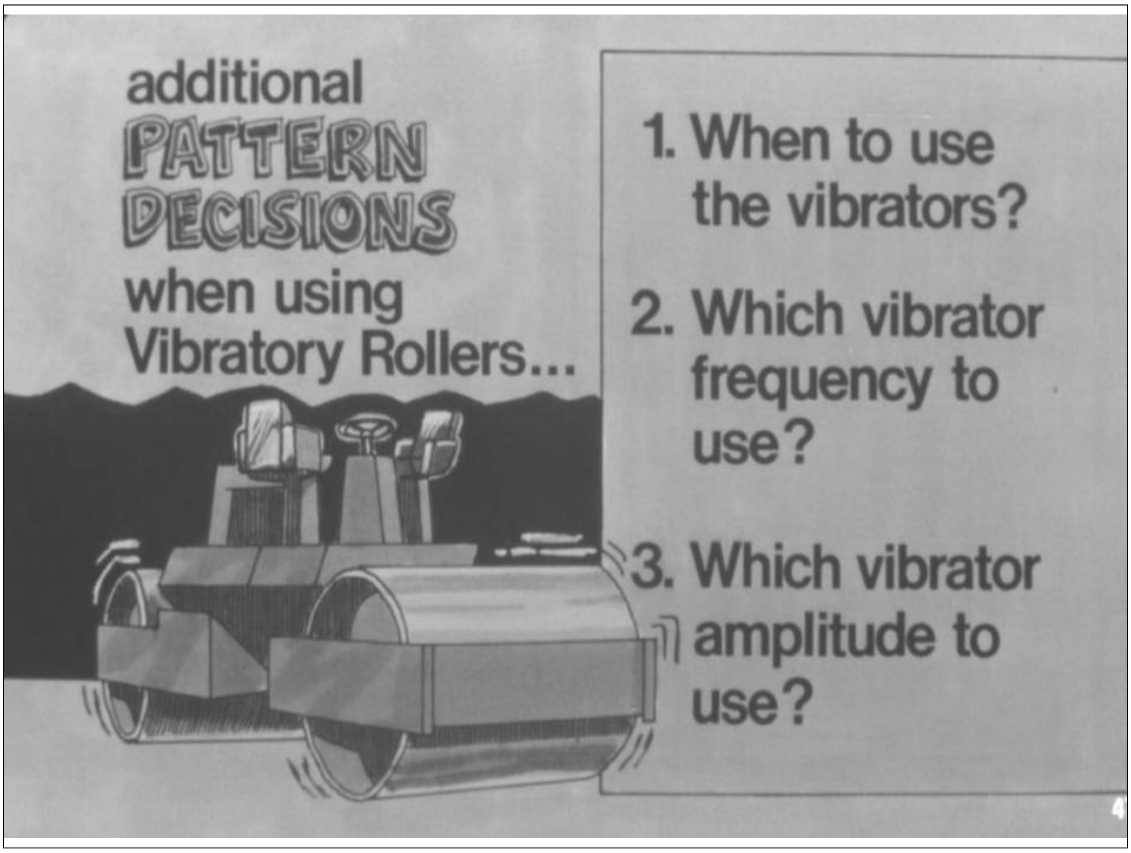
The third question is: How to make sure the mix is rolled while in the correct temperature range? Re-member that the mix can only be compacted while it's in a particular temperature range, and that com-paction is usually easier at the high end of that range. If the paver speed is fairly uniform, the rolling zone idea is very useful. The rolling zone behind the paver is determined by the type and temperature of the mix. In general, the roller should work as close to the paver as possible, provided the mat doesn't shove or crack. It may work as far behind the paver as neces-sary to achieve density and a smooth finish in the fewest passes. In this example, the mat is too hot to roll for about 50 feet behind the paver, but still hot enough to get compaction 250 feet behind the paver.



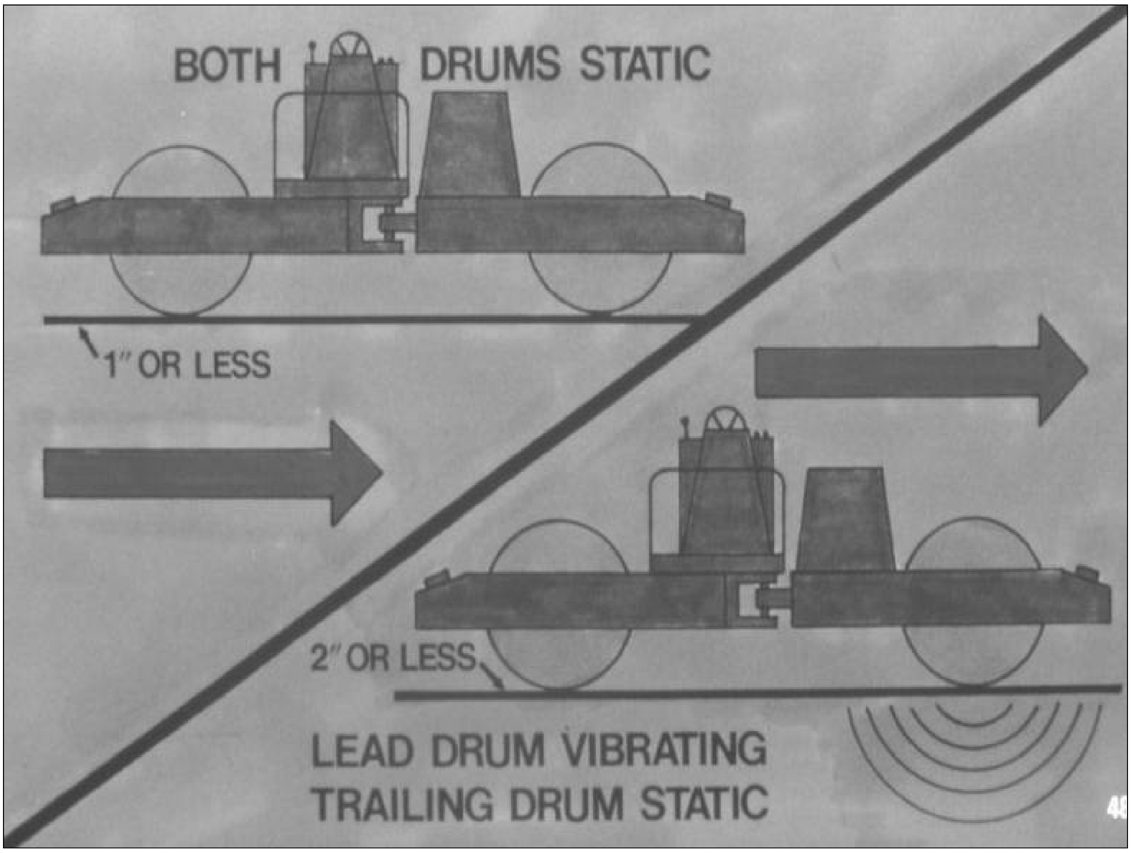
Now, how do you determine how fast to roll the mat? Rolling too fast is one of the most common causes of poor compaction. Why? Because it takes time for aggregate particles directly under the roller to slide past each other into a denser fit -a small but defi-nite amount of time. If you roll too quickly over a spot, the mix simply will not have the time it needs to compress under the force of the roller; in addition, you may shove the mat. If your roller is vibratory, rolling too fast may cause other problems to develop as well. We'll discuss these a little later. You will seldom be able to roll more than 3 MPH during com-paction rolling; you may often have to roll slower.



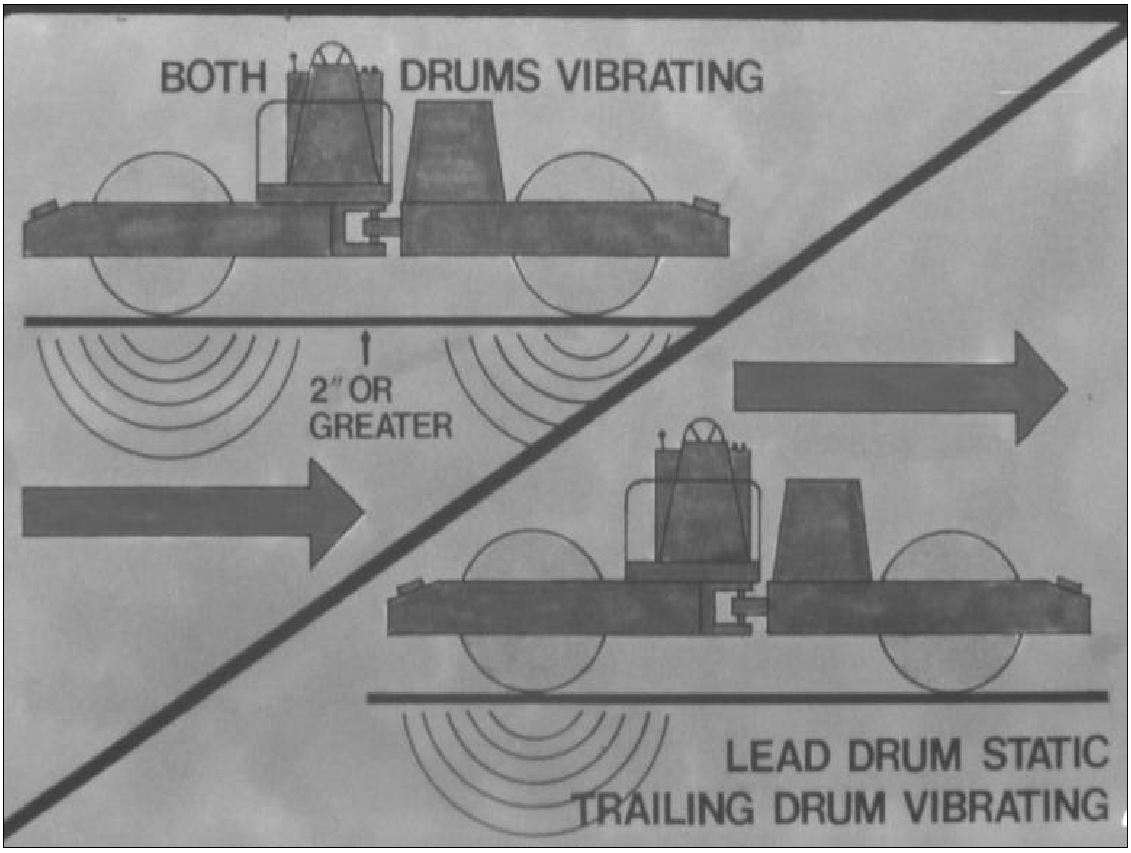
Once you've picked a speed for your pattern, stick with it! If it isn't fast enough to keep within the proper rolling zone, use a second roller or slow the paver down. You might also check with a nuclear gauge to see if you're making unnecessary passes that could be eliminated. Rolling too fast just to keep up with the paver is self-defeating.



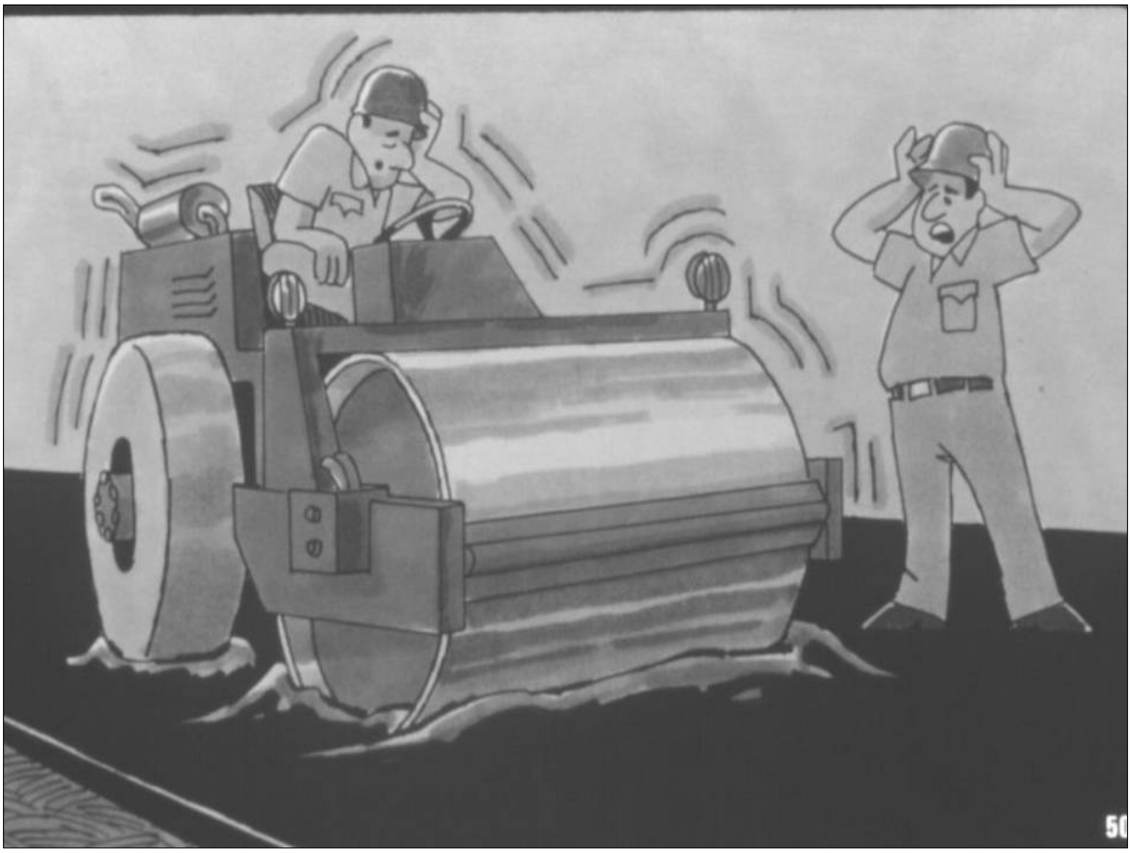
We've just discussed the four decision steps you have to go through to choose a pattern for any type of roller. If your roller is vibratory, there are three addi-tional decisions to make:1) When to use the vibrators?2) Which vibrator frequency to use? and 3) Which vibrator amplitude to use? We'll look at these decisions now.



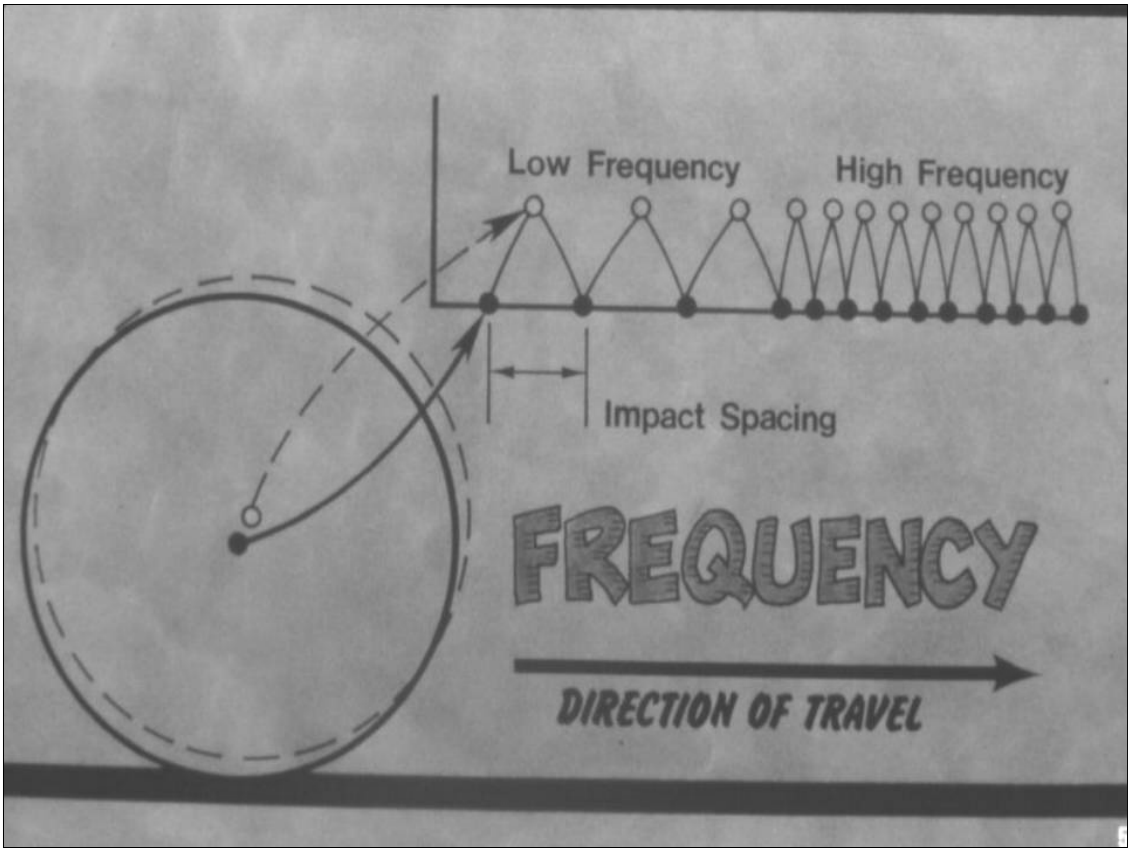
First, when to use the vibrators? Let's consider a double drum vibratory roller. On thin overlays of one inch or less you generally should not use the vibra-tors. Run the roller in the static mode. Do the same when using a vibratory roller for finish rolling. On some difficult mixes and mats of less than two inch thickness, it may be best to run with the lead drum vibrating and the trailing drum static.



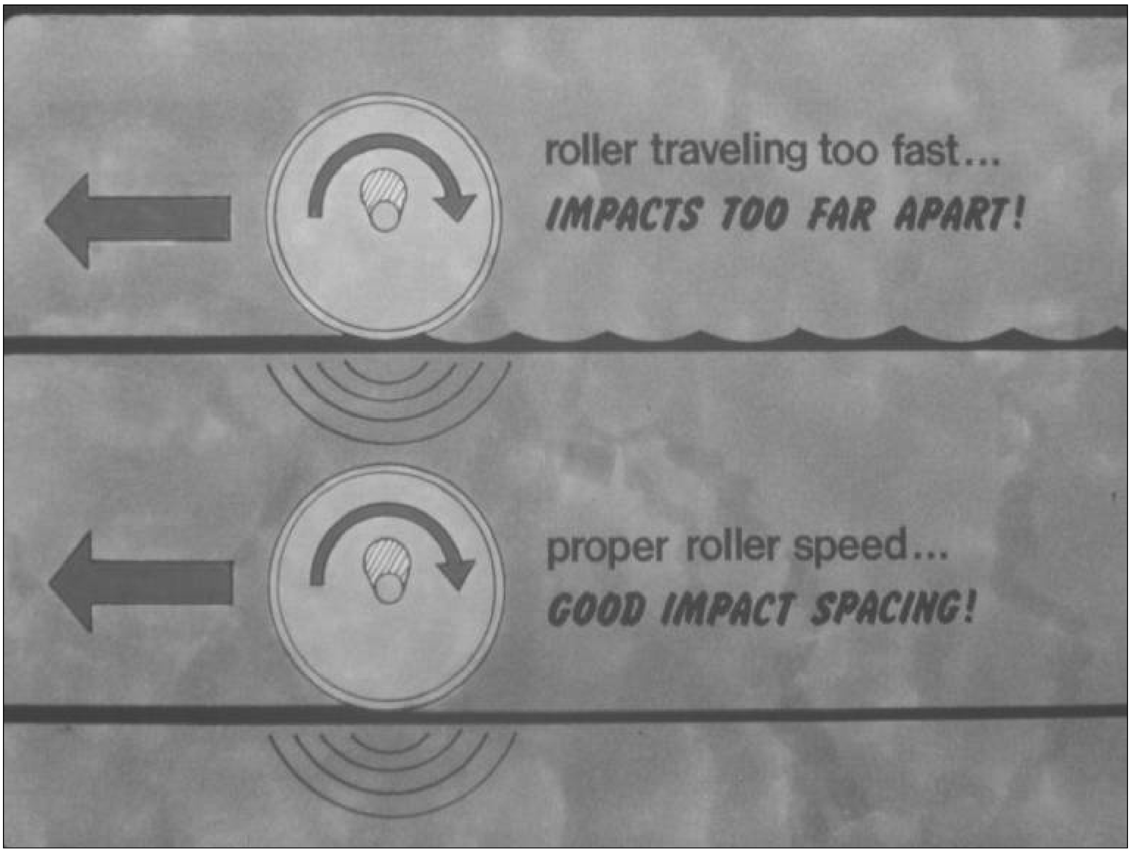
If the laydown thickness is 2" or greater, it is gener-ally best to roll with both drums vibrating for maxi-mum compactive effort. On some mixes which are particularly difficult to compact, it may be advan-tageous to run with the lead drum static and the trailing drum vibrating.



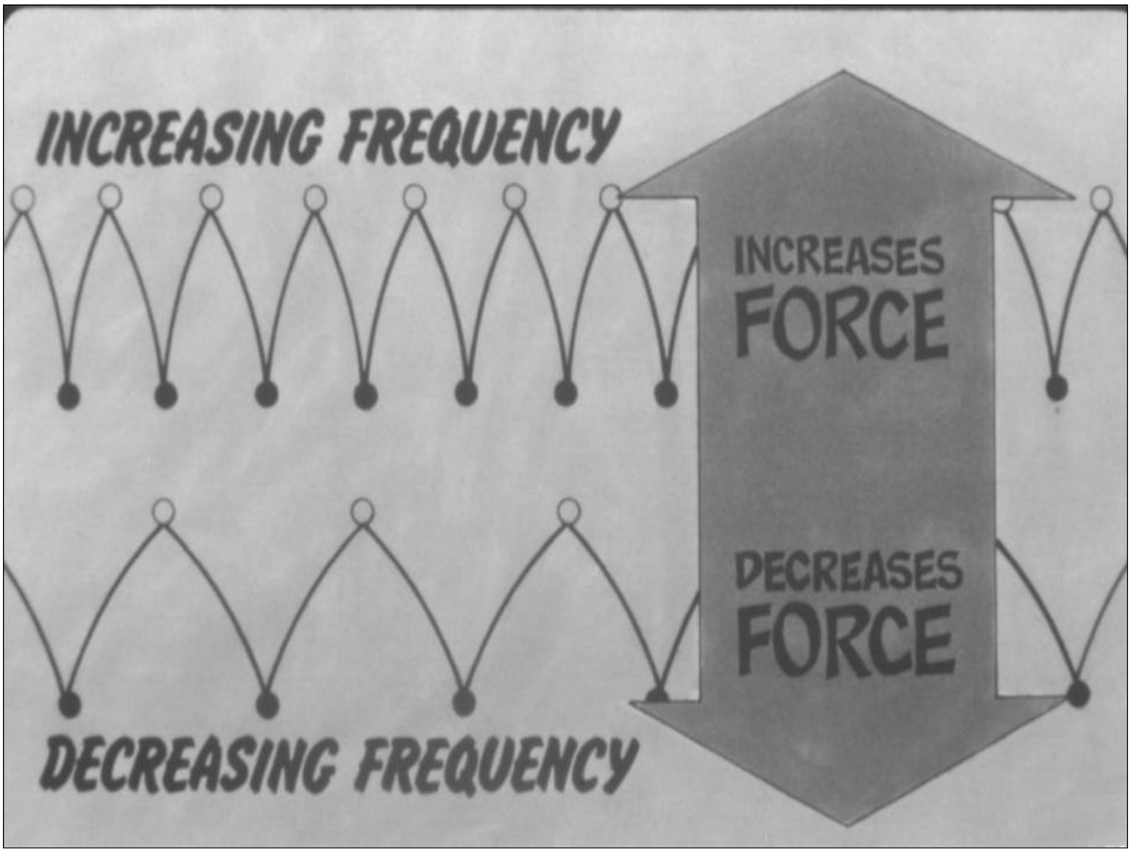
Shut off the vibrators whenever you slow to a stop, even when slowing to reverse, and keep them off until you begin rolling again. Otherwise you'll leave a mark where you stopped. On most machines the vibrators can be set to turn on and off automati-cally.



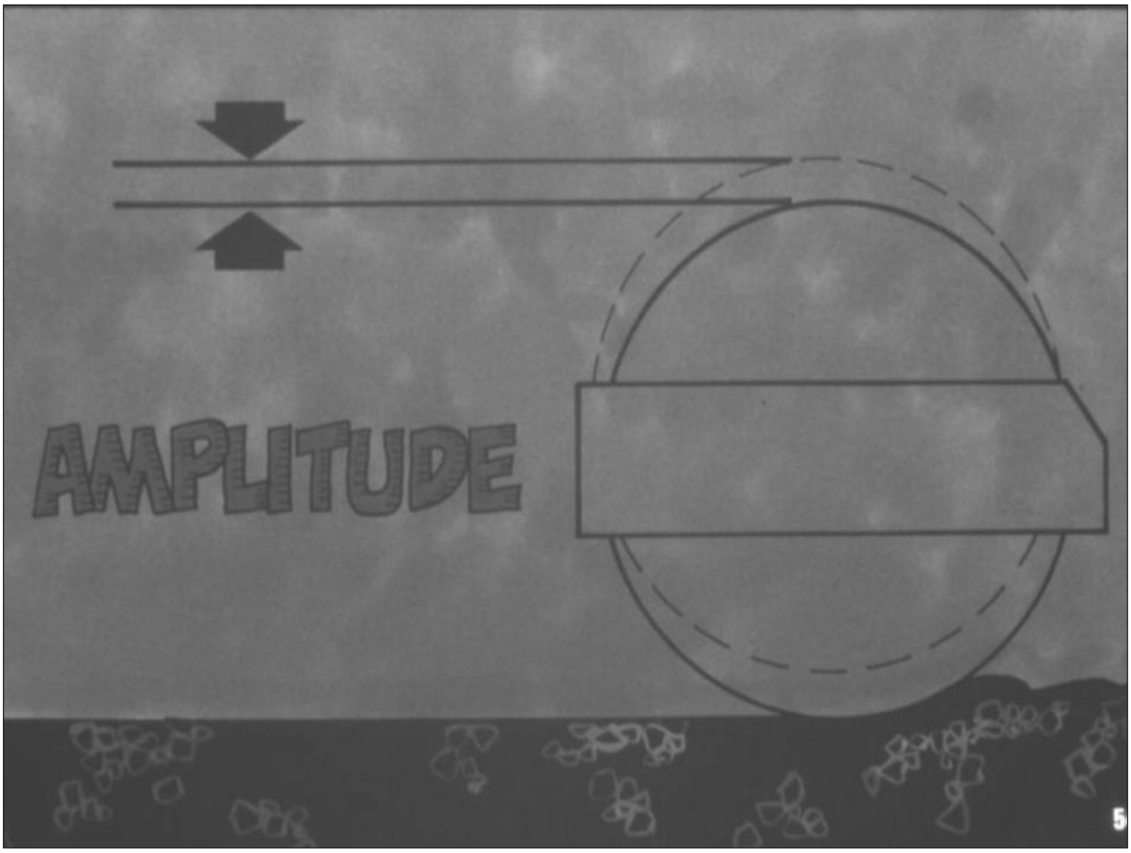
How do you determine which vibrator frequency to use? Recall that rotating weights in the drum produce vibration. This vibration is actually an up-and-down movement of the drum. Each complete movement up and down is one vibration. "Frequency" is the word used to describe how often the drum goes up and down in a given period of time. It is commonly meas-ured in vibrations per minute, or VPM. On most asphalt rollers, the frequency can be varied; common frequencies range from about 1500 to about 3000 VPM.



Since the roller moves forward as the drum moves up and down, it is obvious that the **down movements, which produce the compaction, will be spaced ac-cording to both the frequency of** the drum and the speed of the roller. If the frequency is too low, **the roller speed is too high,** or both, the downward im-pacts fall too far apart. This reduces the amount of compaction that the mat receives and may also cause ridges on the mat surface. Increasing the vibrator frequency or reducing the roller speed or both, will overcome these problems. Therefore, it is usually recommended that the vibrators be run at maximum frequency or VPM **for greatest efficiency in compact-ing the** mat.



Not **often understood is the fact that the frequency directly affects the amount of compacting force** that the drum exerts. The lower the frequency, the lower the force. As a result, you can vary the compactive force by adjusting the frequency. More often, how-ever, the frequency is left at maximum and the vibra-tory force is adjusted by changing the amplitude of the vibrators.



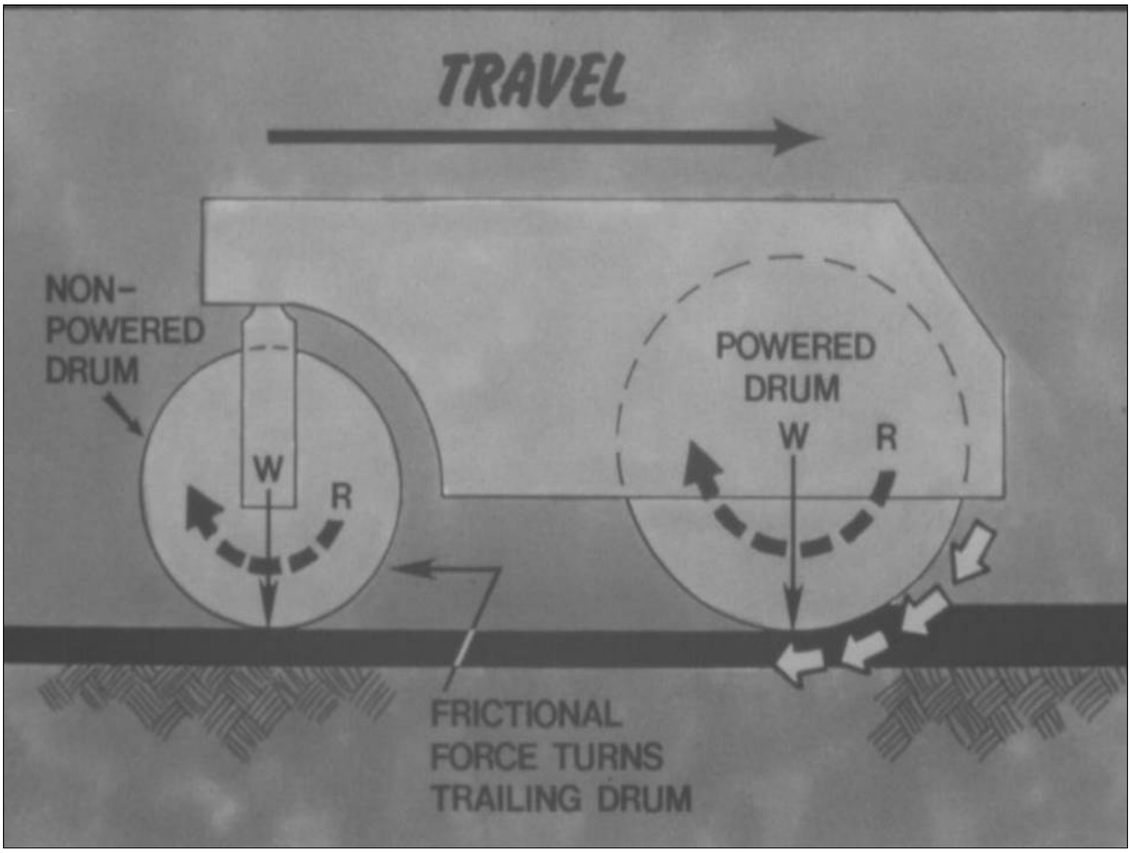
"Amplitude" is the word used to describe the height of the up and down movement of a vibrating drum. It **is adjustable on many rollers and directly affects the force applied to the** mat. Higher amplitude settings produce more force and are recommended for **effi-ciently compacting thicker and harsher mats; lower amplitude settings are often necessary for thinner and more tender mats, which may shove under ex-cessive force.**

PROPER USE OF VIBRATORY ROLLER

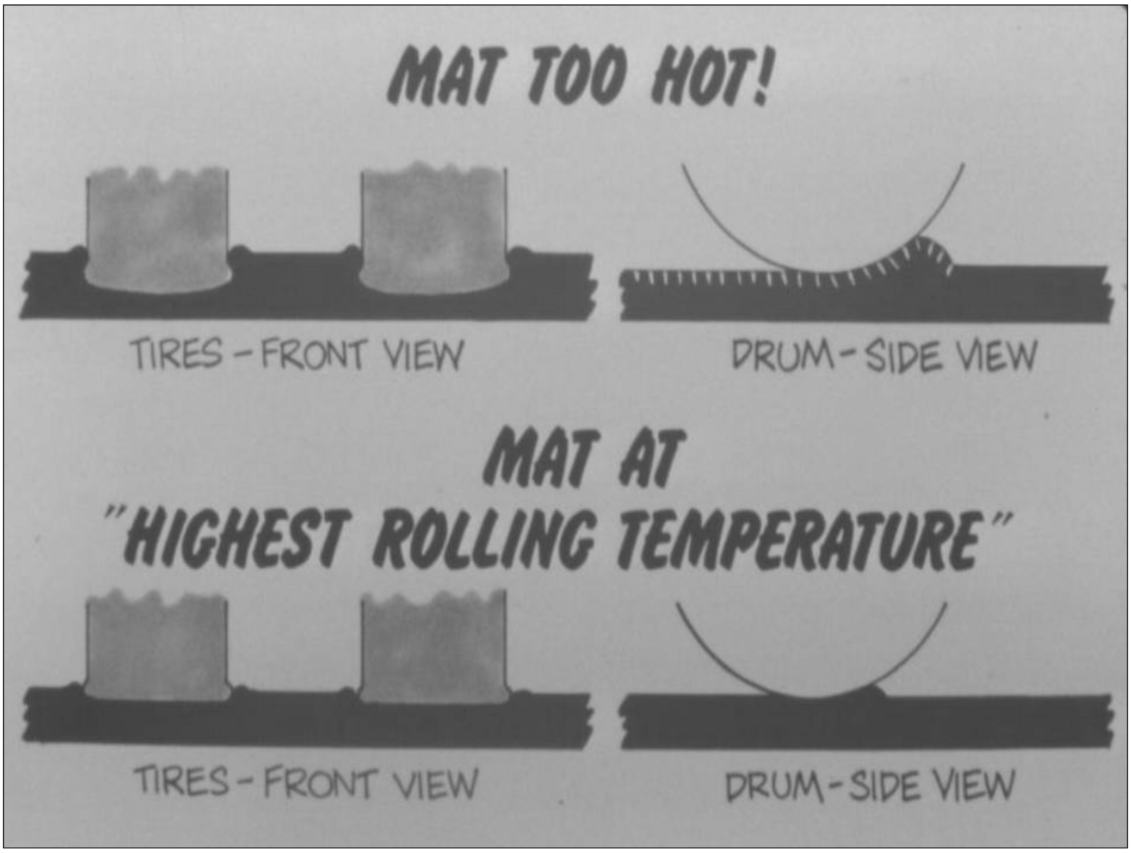
1. Minimum of 10 impacts per foot
2. Proper amplitude
3. Constant speed
4. Overlay of only 3 to 6 inches
5. Do not vibrate in place
6. Very strict compliance with rolling patter

CONSIDERATIONS FOR ROLLERS DURING COMPACTION

1. Drive Wheel should always be first to the Mat
2. No Ballast in the Tiller Wheel



If roller has a drum or tires which are not pow-ered, operate the roller with that end away from the paver. The drive wheels or drum facing the paver will tend to tuck the hot mix under the roller rather than shove it out of the way. When operating uphill, however, you may have to put the drive wheels in the rear for adequate traction.



There are several clues which can help you to deter-mine if the mat is too hot to roll. The roller will pro-duce an excessively large "bow wave" ahead of the drum, excessively high ridges alongside the drum, or too large of a hump alongside the tires if the mat is too hot.

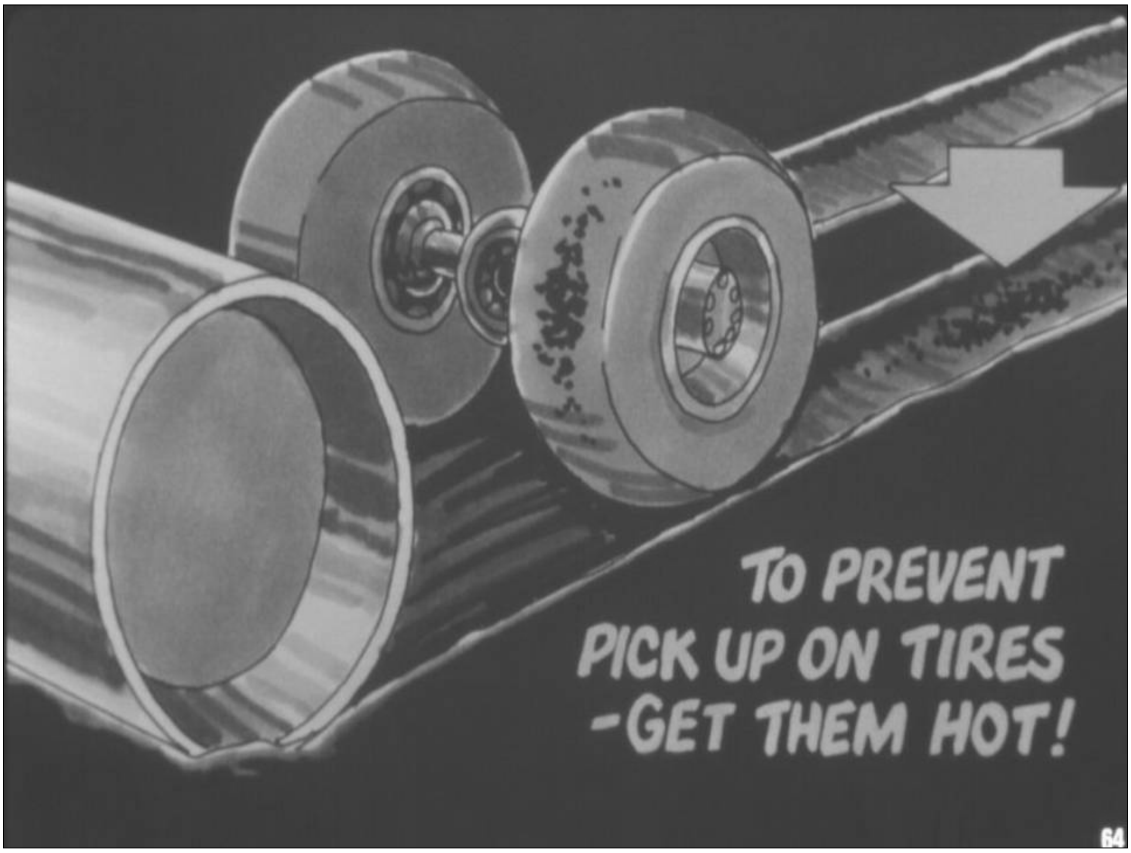
Temperature is critical

One of the most important factors is the mat temperature. Too cold and the mix cannot be compacted - too hot and the mix will not support the rollers.

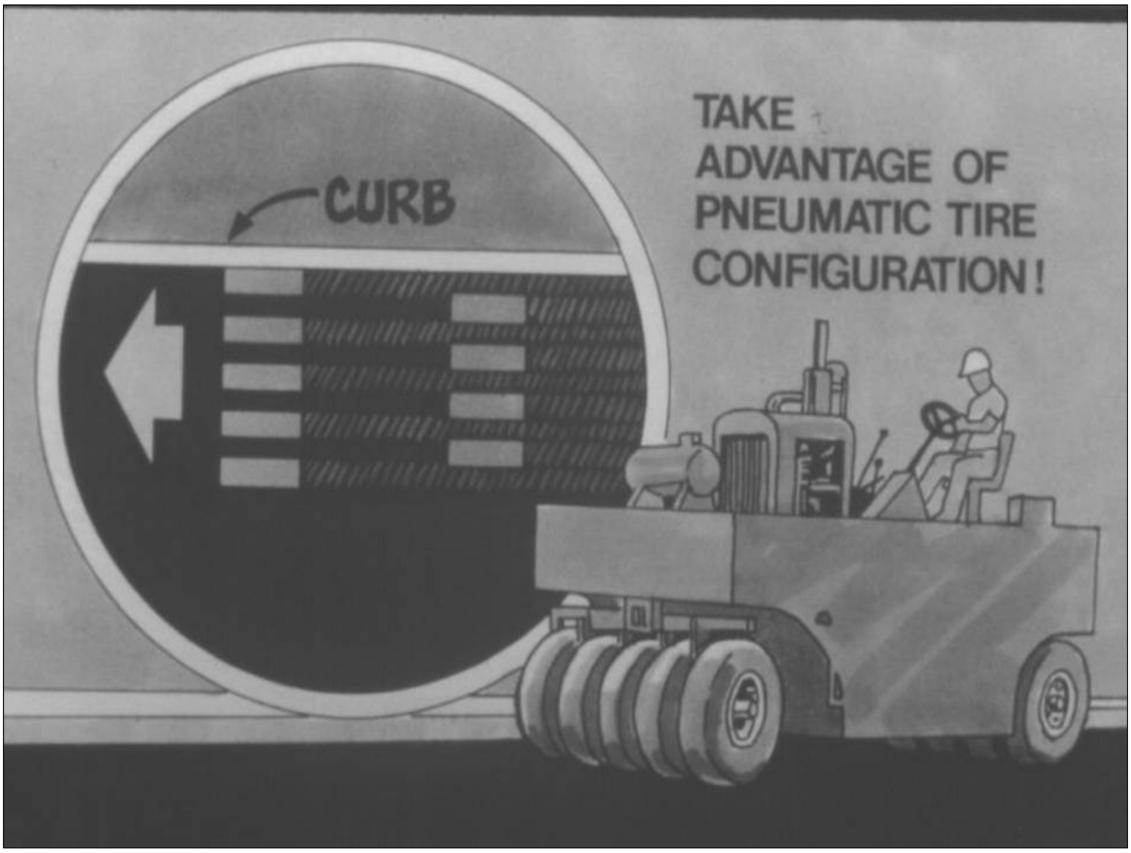
The drum or tires often pick up a mat that is too hot, even if the spraying system is working correctly. Ob-serving the mix while in the truck can also be helpful. If the mix gives off a blue smoke while in the truck or being dumped into the paver, it could be too hot.

SIMPTOMS OF PROBLEM MIXES

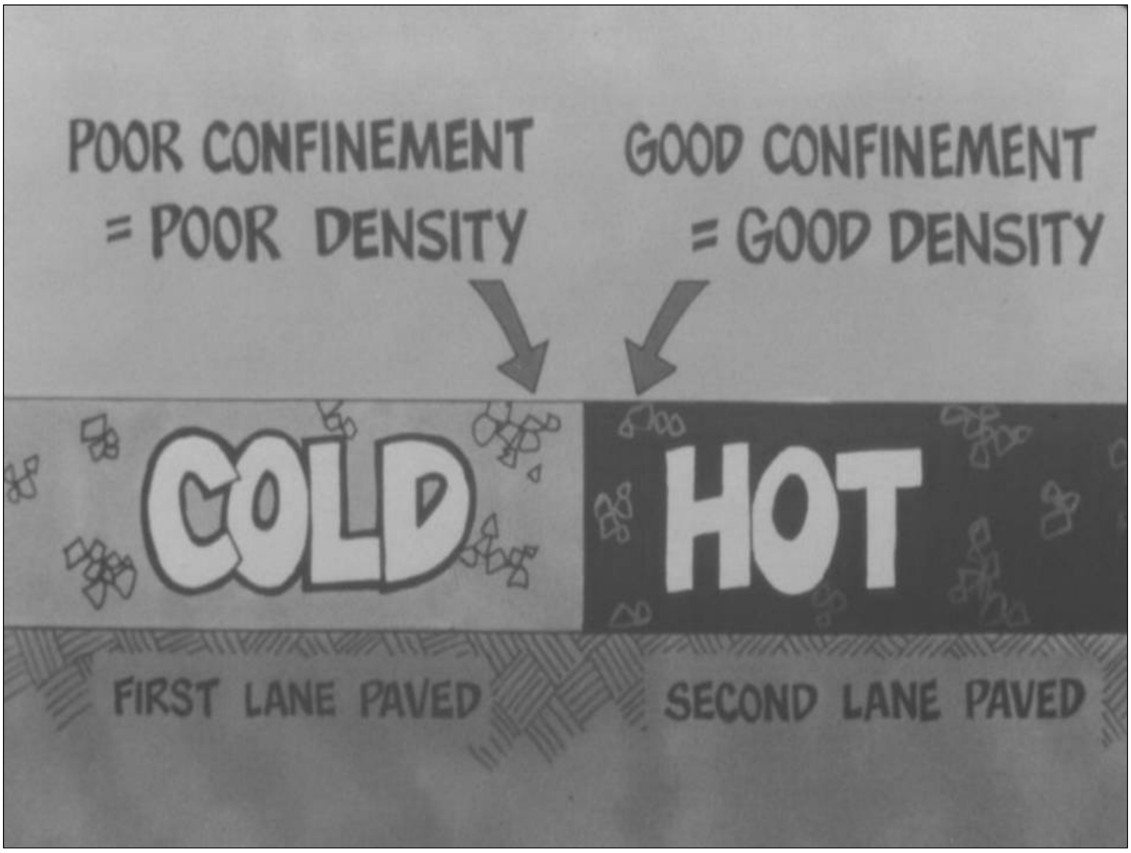
- Blue Smoke
- Stiff or Slumping Mix
- Aggregate Not Coated
- Shiny, Wet Appearing Mixture
- Dull Brown Color



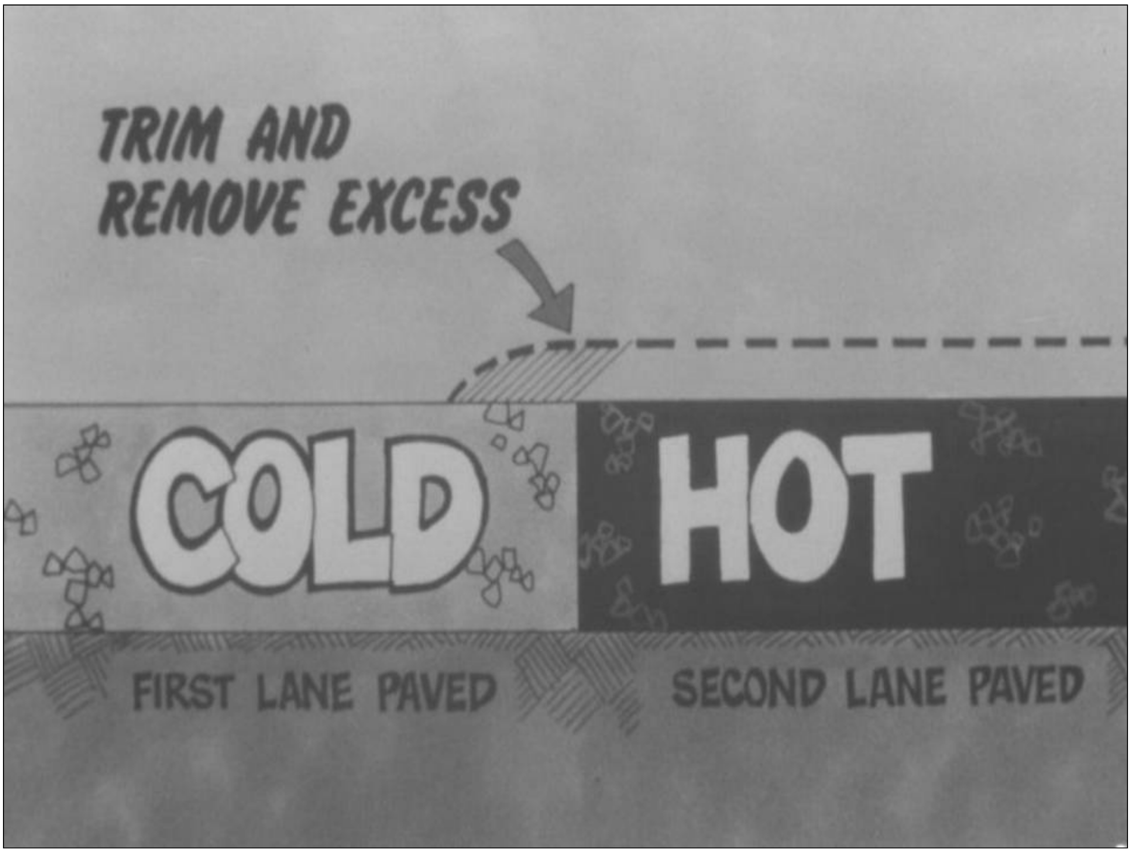
The secret of preventing pick up on tires is to get them hot. Once sufficiently hot, they should not pick up. Applying water or solvent to tires cools them, and makes the pick up problem worse. So avoid wetting them while on the mat. Let the scrapers and the mats clean off the tires until the tires are sufficiently hot.



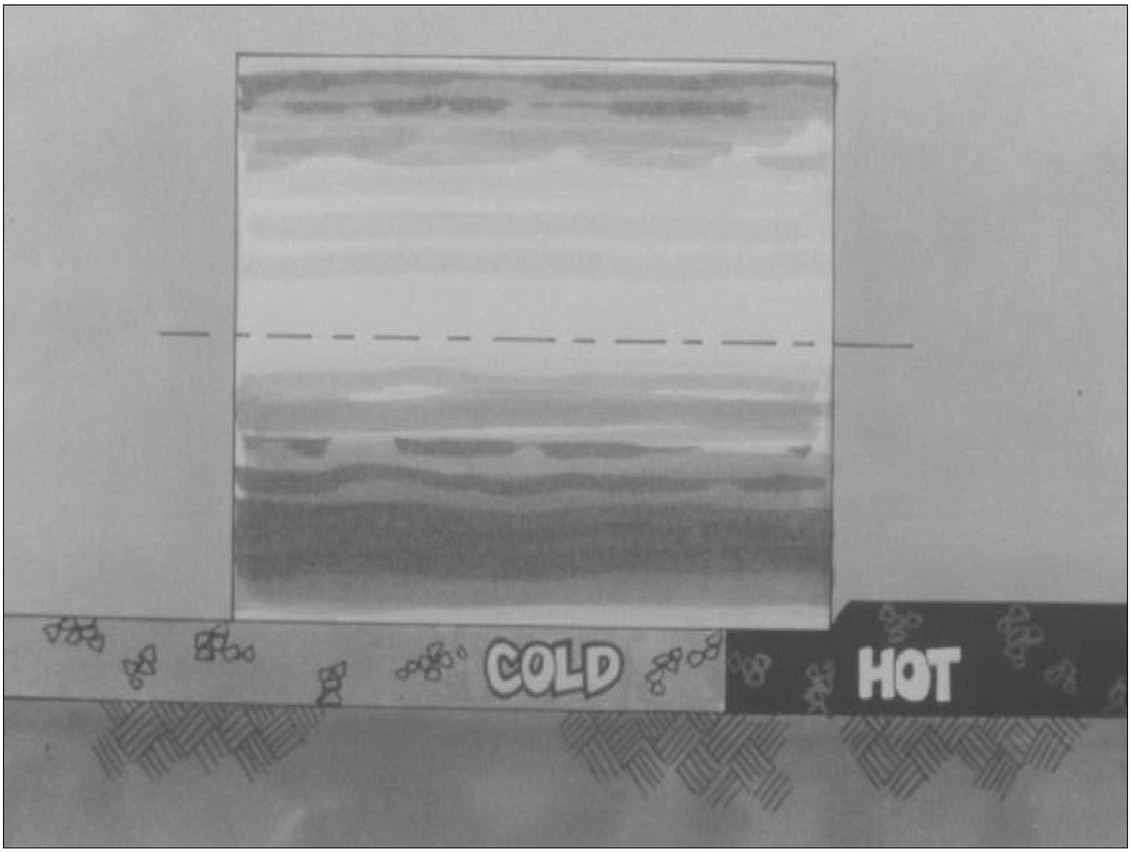
When rolling along a curb with a pneumatic roller, take advantage of the fact that one end of the roller is wider than the other. If you have a 9-tire roller, for example, roll along the curb with the wider 5-tire end forward. That way, you won't have to be looking over your shoulder to prevent the outside edge of the roller from riding up on the curb.



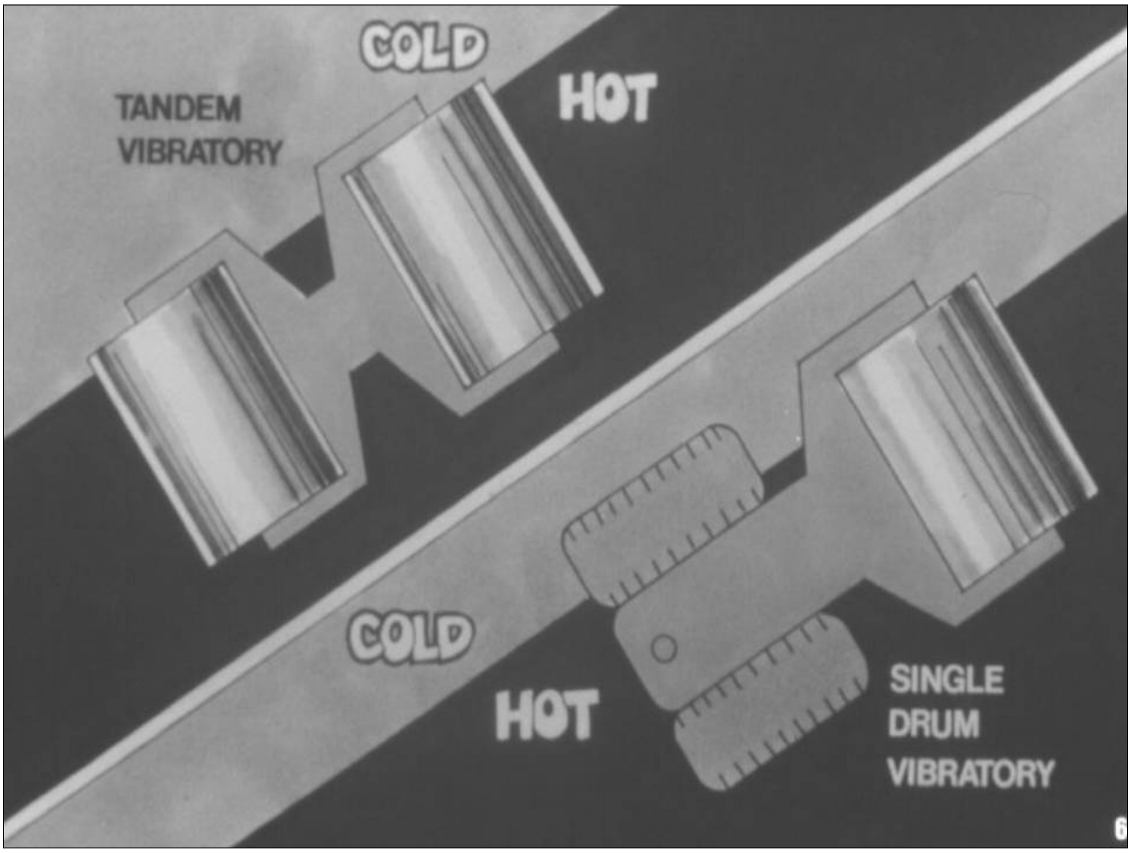
Joints are critical areas which often suffer from poor compaction. It takes a lot of cooperation between the paver operator, the rakers, and the roller operator to get a good joint. Studies show that longitudinal joints, unless paved in echelon, normally show a lower density on the cold side of the joint because the cold side lacked edge confinement during com-paction. However, the cold side confines the hot side of the joint, creating a higher density on the hot side.



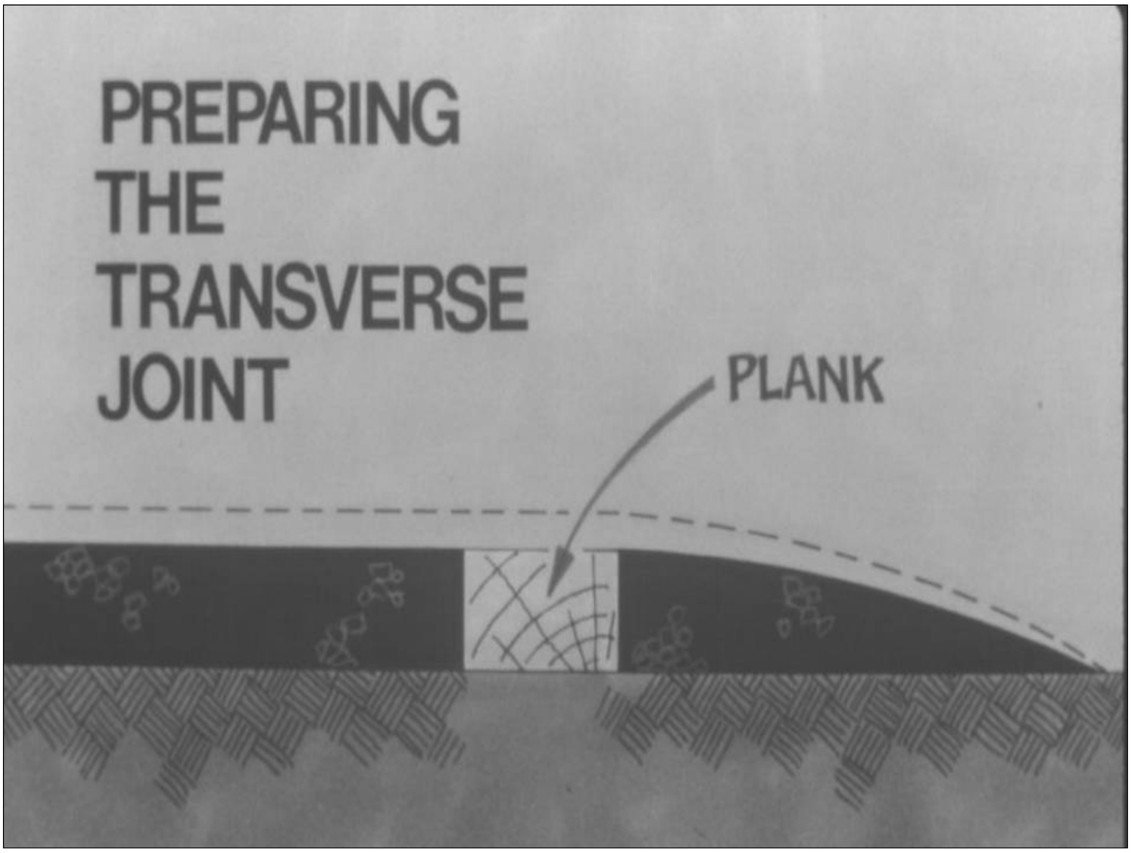
When paving and rolling an asphalt mix joint, the asphalt mix should be extended slightly over the existing surface being joined. The excess asphalt is then trimmed back to the joint and excess material is removed. The roller then rolls the joint in the longi-tudinal direction being very careful to compact the mix against the cold edge.



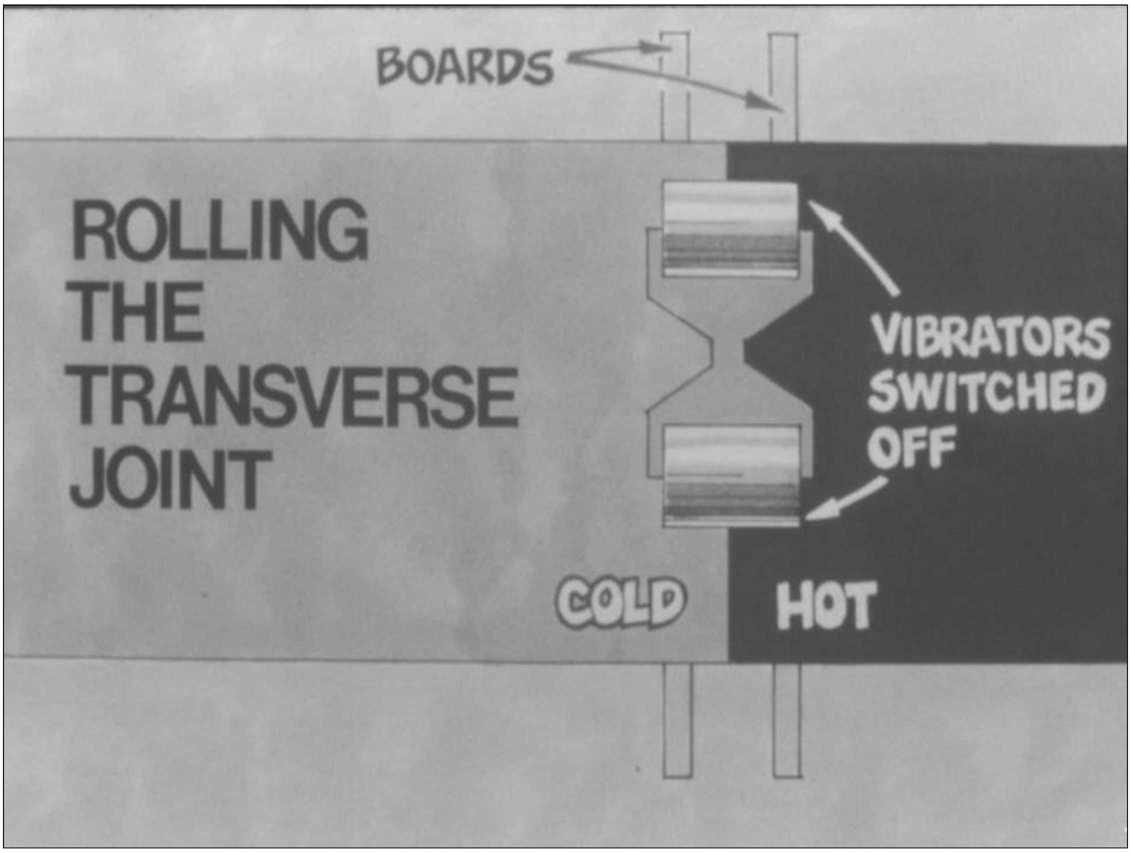
Techniques for rolling joints depend a lot on the type of roller used. When using a static steel drum roller or a vibratory roller with the vibrators turned off, place most of the roller on the cold mat with about 6" lapping onto the hot mix.



For rolling a longitudinal joint with a vibratory roller, position the roller so that a smooth joint is obtained while keeping as much roller on the hot mix as possi-ble. This prevents damaging the cold mat with vibra-tion. However, if you're using a single drum vibratory and the drive wheels are rubber make sure that more than 75% of the tire width is on the COLD side of the joint. Again, work closely with the rakers.



What about transverse joints? At the end of a day's work, a plank equal in thickness to the compacted thickness of the mat is placed at the edge of the mat. Asphalt is then feathered to a short distance beyond the plank and rolled. At the beginning of the next day's work, the plank and the excess asphalt are removed, revealing a clean sharp edge.



To begin the new day's work, the joint is made by the paver and/or by hand spreading. The roller is set up to transversely straddle the joint and the joint is compacted. Vibrators should not be used. Gradually overlap the rollers onto the hot side of the joint farther and farther on succeeding passes until the entire roller is on the hot side of the joint. Boards may be used to allow the compactor to run off the mat. Again, operator discretion and location of the joint are determining factors. Smoothness is of prime importance. When the roller then takes up its normal longitudinal rolling of the mat, any vibrators should be switched off manually upon reaching the cold pavement.

METHOD OF ACCEPTING ROADWAY DENSITY

1. Percentage of maximum theoretical density (MTG)

2. Percentage of laboratory compacted specimen

3. Percentage of test strip density

<u>WHEN TESTS INDICATE MAT HAS LESS THAN 4% AIR VOIDS.</u>

Check for Possible Errors, Such as:

- High Asphalt Content
- High Minus 200 Material
- Testing Error

REMEMBER

ADDITIONAL COMPACTION WILL OCCUR

DURING THE FIRST THREE SUMMERS

MAT PROBLEMS

Defects that occur in mix during placement and/or compaction

- Rough Mat
- Nonuniform Texture
- Screed Marks
- Roller Marks
- Mat Tears
- Checking
- Shoving
- Bleeding