



Technical Paper T-130



LONGITUDINAL JOINTS: PROBLEMS AND SOLUTIONS

by: J. Don Brock, PhD., P.E. Astec Industries, Inc.
Tom Skinner Blaw-Knox Division Ingersoll-Rand



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INTRODUCTION

Hot mix asphalt is a proportioned mixture of graded aggregate and asphalt cement and is designed for maximum strength and durability. It is not only strong and durable but also flexible. This makes the material adaptable to a wide range of climatic conditions. Hot mix asphalt keeps its desirable properties over a wide range of aggregate variation. Additionally, it can move without cracking due to its flexibility, be placed in thin lifts, and be very durable under tough conditions. These characteristics make hot mix asphalt the material of choice for road construction.

Asphalt mixes are designed to meet a variety of applications. Lab design methods, such as the Marshall, gyratory, and various other techniques, are used to determine an optimum asphalt content for different mix designs. Asphalt mixes are constructed for base construction, binder, and for surface mixes. They must be designed for various climatic conditions to withstand temperatures from subzero up to 150° F, and they must be able to handle the expected load that the surface will be subjected to, from extremely heavy truck traffic to light loads of very smooth bicycle paths, etc.

With the development of the Superpave SHRP procedures, the design of asphalt mix has become considerably more sophisticated. Precise gradations, asphalt content, air voids, and VMA (voids in mineral aggregate) must be achieved if the mix is to perform as designed in the laboratory. Various types of proof testers, such as the rut tester or asphalt pavement analyzer (as shown in **Figure 1**), allow torturing of asphalt mix and give excellent indications of the field performance over extended loaded periods.

Even with all of these testing procedures and the increased emphasis on precise mix design, many new pavements, as well as many overlays, prematurely fail due to segregation of the mix and improper construction and compaction at the longitudinal joint. To avoid this premature failure, it is essential that construction techniques be employed that allow the mix to be uniformly placed, with the same gradation and asphalt

content as designed in the lab. Many new techniques have been developed and articles have been written related to segregation. With proper equipment and proper construction techniques, segregation can be eliminated even on very harsh gap graded mixes, but the longitudinal joint, however, has been a continuing problem for decades. With care and excellent technique, a long



Figure 1

lasting longitudinal joint can be constructed. However, with changes in the mix and changes in personnel, excellent technique has become a “lost art”, and many of our roads are prematurely failing at the longitudinal joint.

In order to understand the problems related to longitudinal joints, it is essential to understand basic principles of paving and compaction.

PRINCIPLES OF PAVING

When asphalt pavement is mixed and dumped into a truck to haul to the job, it has an initial density of approximately 75% (lab design density). Once placed on the road, it is compressed or compacted until it reaches 96% of lab density (**Figure 2**).

A rough rule of thumb says that mix must be initially placed at a thickness equal to 1.25 times the desired finished mat thickness. For example, a 2” mat (50.8 mm) will require 2.5” (63.5 mm) of mix to be spread on the road, which is then compressed or compacted to 2” (50.8 mm). **Figure 3** shows the amount of compression that must take place for different thicknesses of mix. **Figure 4** shows the relationship between mat thickness and density. The vibratory screed, which does the initial compaction of the mix behind the paver, will generally provide approximately 25% of the



Figure 2

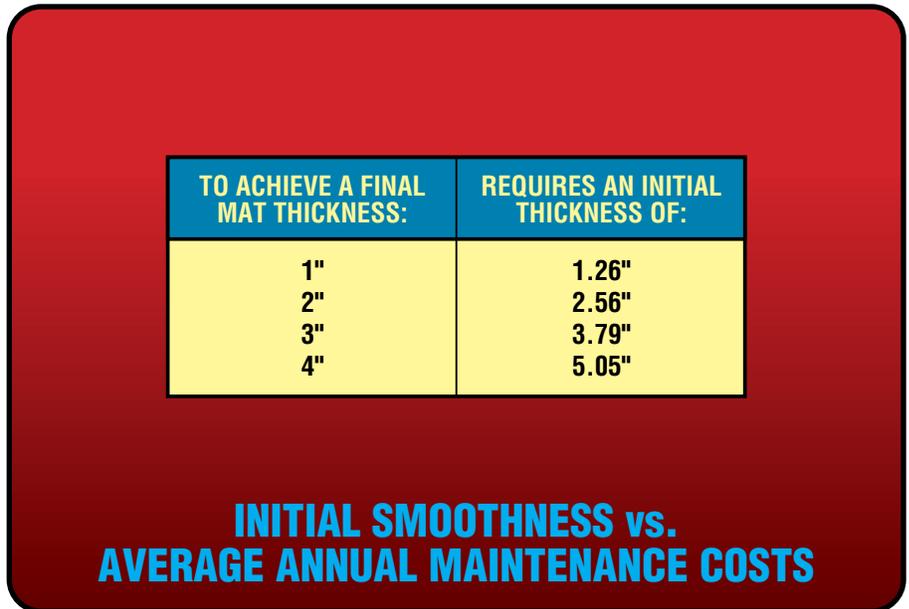


Figure 3

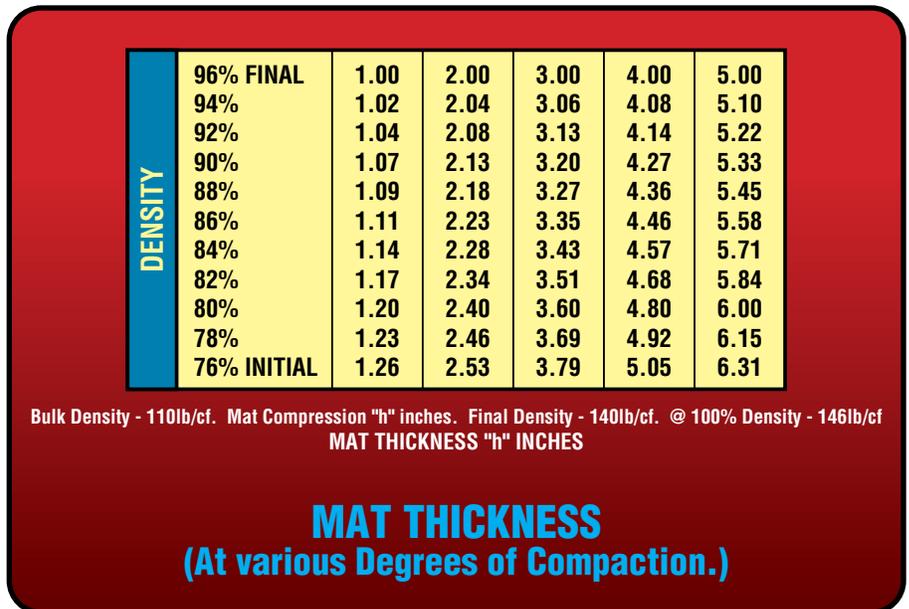


Figure 4

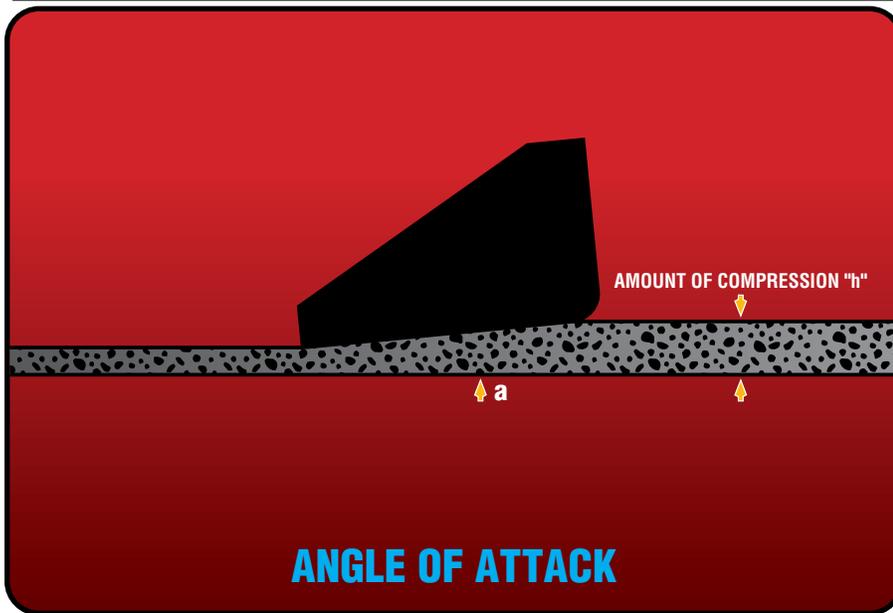


Figure 5



Figure 6



Figure 7

mat compaction or compression. Therefore, with a 2" (50.8 mm) mat, the screed will normally compact the mix from 2.53" (64.3 mm) to approximately 2.34" (59.4 mm) or 82% density. This compaction occurs through a combination of extrusion and vibration from under the screed, as shown in **Figure 5**. Final compaction is then achieved by one or more rollers operating in a prescribed pattern behind the paver.

In compacting the mat, as shown in **Figures 3 and 4**, the assumption is made that all compaction is in one direction, i.e. that the base does not move and that the sides of the mix are contained or confined. If it is assumed that the mix is contained in all directions except vertical, then only vertical compression of the mix will occur. Viewing across a 12' screed, this assumption is correct in the 10' center portion of the mat. However, since the mix is not contained on the outer edges as it is compressed, it spreads out and becomes wider (**Figure 6**). Therefore, either the desired thickness or the desired density is not achieved.

If the paver places an exact 12' wide mat, the mat becomes wider and thinner as the mix is being compressed. The screed may have placed 2.5" to 3" at the leading edge, but as the mix spreads out, this depth is not maintained or the desired density is not achieved on the outer edges, as shown in **Figures 6 and 7**. When observing the mix behind the screed, the edges of the mat have a different texture than that of the center. This shows that, as the screed starts to compact the mix on the edge where it is not contained, the mix

resists compaction and squirts out.

On the shoulder side of the road, this unconfined edge is generally sloping towards the shoulder to allow water to drain away. While the density is low in this area, density is not as critical at the edge as it is at the center since water can drain away on the sloping shoulder. In the center of the road, when the second lift is paved, the edge of the first lift confines the new mix and prevents it from spreading. This results in good density on the second lift at the center of the road. The unconfined edge of the first lift (in the center), however, now is at a lower elevation, and a minor depression occurs in the middle of the road. This area (from the first lift) also has not been sufficiently compacted and displays higher air voids. Therefore, the combination of the depressed area and a high void mix allows water to accumulate in this area, and when freezing occurs in cold weather, it will lead to pavement failure at the center.

LONGITUDINAL JOINT CONSTRUCTION

The simplest way to avoid problems with the longitudinal joint is to not have a joint to begin with. This could be done by using a full width 24' wide paving machine, which eliminates the need for a longitudinal joint. Today, most of the asphalt work done in the United States is maintenance and rehabilitation type work and must be performed while traffic continues to flow. This means closing and paving one lane at a time. **Figure 8** shows a typical longitudinal joint construction and the challenges in making a sound longitudinal joint.

These challenges are addressed currently by:

- (A) - Steering a straight line while laying the first pass will help to hold overlap when laying second pass. When matching joint while laying the second pass, hold the overlap to the minimum required steering tolerance of 1/2".
- (E) - Have sufficient material for roll down. Automatic controls help to hold the preset amount of mix needed for density at the joint.
- (B) (C) & (D) - These have not been addressed in current joint matching.
- (F) - This is a machine operation problem. Run auger speed, add confinement, and reduce segregation.

Neglecting edge containment at the first pass insures a poor joint when the second pass is placed. As the first pass of the pavement is placed, the screed compacts the mix, and the mix tends to push out, resulting in low density at the edge. As the second lift is

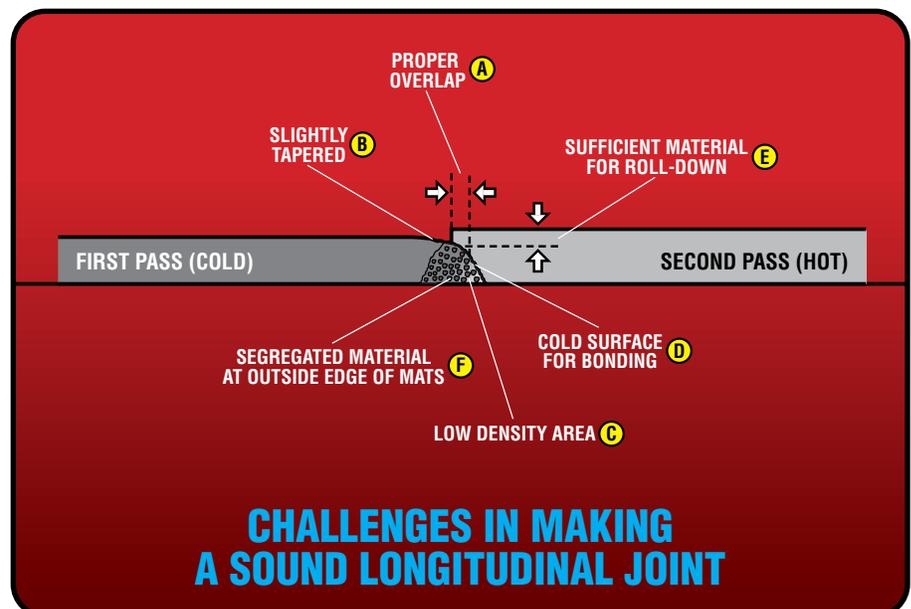


Figure 8

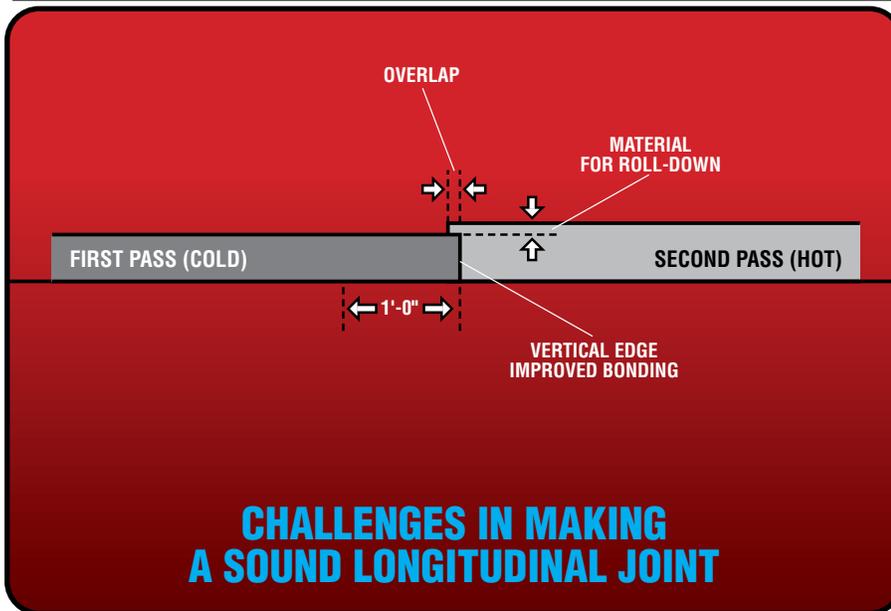


Figure 9

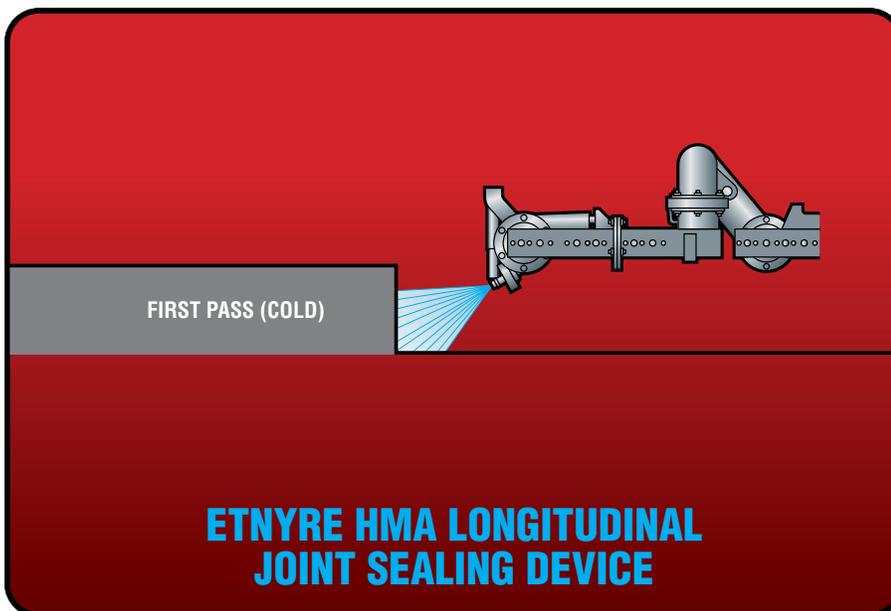


Figure 10

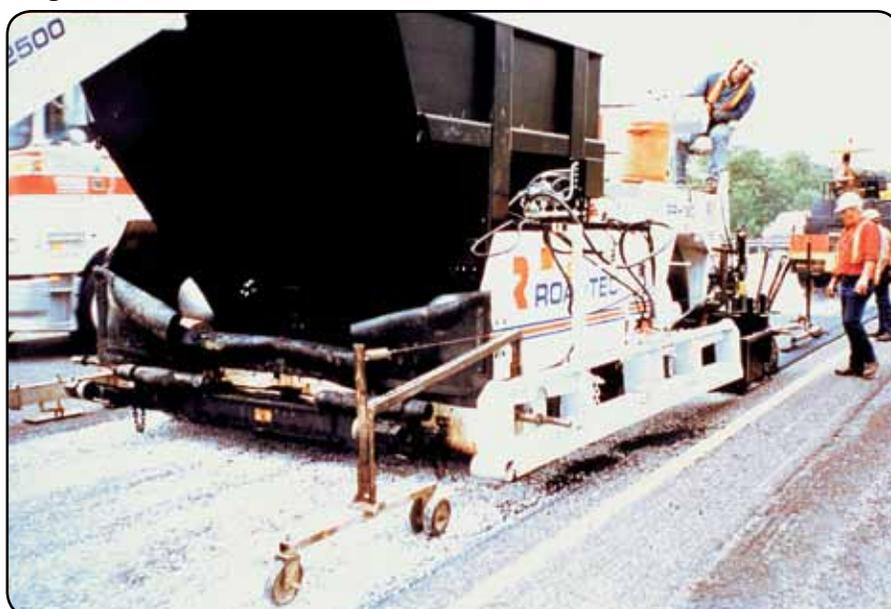


Figure 11

placed, it does not spread out since it is being trapped by the edge of the first pass. As some of the mix overlaps, a certain amount of the depression from the first pass can be corrected. However, the low density in that area allows water to be entrapped there. The water freezes in winter and causes the joint to fail at this point. Referring again to **Figure 8**, the following proposed changes could be used to address these challenges:

- (B) - Increase density of outer one foot of the mat during the placement process, using vibration and a screed end gate. Reduce or eliminate slight taper.
- (C) - Eliminate the low density area as well as the slight taper. Extend end gate to confine the material into near vertical edge
- (D) - Cold surface should be almost vertical, and dense, improving bonding process.

Figure 9 shows that if a compacted edge could be achieved as the mix is being placed, then improved density would occur and a vertical edge could be used to improve bonding. Results would be:

- 1) Improved density should practically eliminate any taper at outside edge of pavement.
- 2) Extended edgers or end gates should produce almost a vertical edge, improving bonding of materials.
- 3) Sharp edges will enhance ability to maintain proper overlap and depth of

second pass to give the precise amount of material for density after rolling.

The joint could further be enhanced by applying tack to the vertical joint as the tack coat is being sprayed. **Figure 10** shows a longitudinal joint sealing device, which is attached to the spray bar on the distributor to allow spraying of liquid onto the vertical joint.

Another alternative is an infrared heater attached to the paver (**Figure 11**). The heater softens the poorly compacted mix at the edge

of the first pass, allowing the mix from the second pass to be rolled into the softened area, thereby increasing its density. In principle, this concept is sound. However, to work properly in practice, the paver must be operated at a slow, constant speed. Practically, this can only occur when using a transfer machine between the truck and the paver.

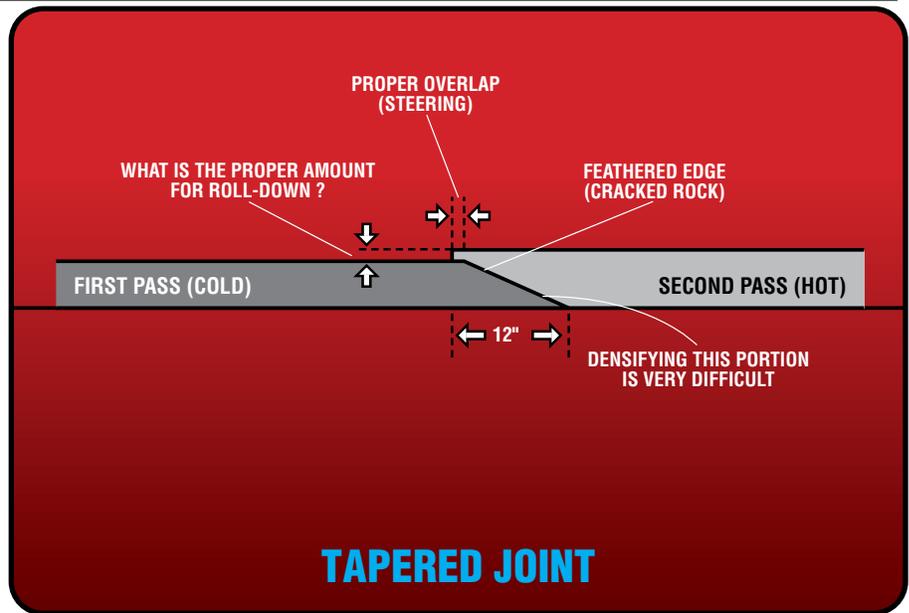


Figure12

LONGITUDINAL JOINT RESEARCH

The National Center For Asphalt Technology (NCAT) undertook a study on longitudinal joints in the early 1990s. Various joint techniques were studied, and cores were pulled on both sides of the joint to determine where failures were occurring. NCAT researchers found that the area of low density was created on the unconfined edge as shown in **Figure 8**, as the first lane was placed. The area from the center of the joint over 6" to 8" was found to be low in density and high on air voids. This allows water to run into this uncompacted area. Cold weather freezes the water, breaking out the asphalt and leading to premature failure.

Other techniques, such as a taper joint shown in **Figure 12**, have been developed and are being used in various states. The problems associated with the tapered joint are:

- How to densify the tapered portion of first pass?
- With tapered edge, steering of the paver is difficult since there is no definite edge to follow. It is difficult to maintain proper overlap.
- Feathered edge cracks rock especially on base mixes and drags voids in the mat. (Poor appearance)
- Proper amount for roll down changes along the taper.
- Assuming the ideal world where a compactor could be developed to compact the tapered edge, the second problem occurs in placing the proper amount of mix on a tapered surface to achieve compaction and

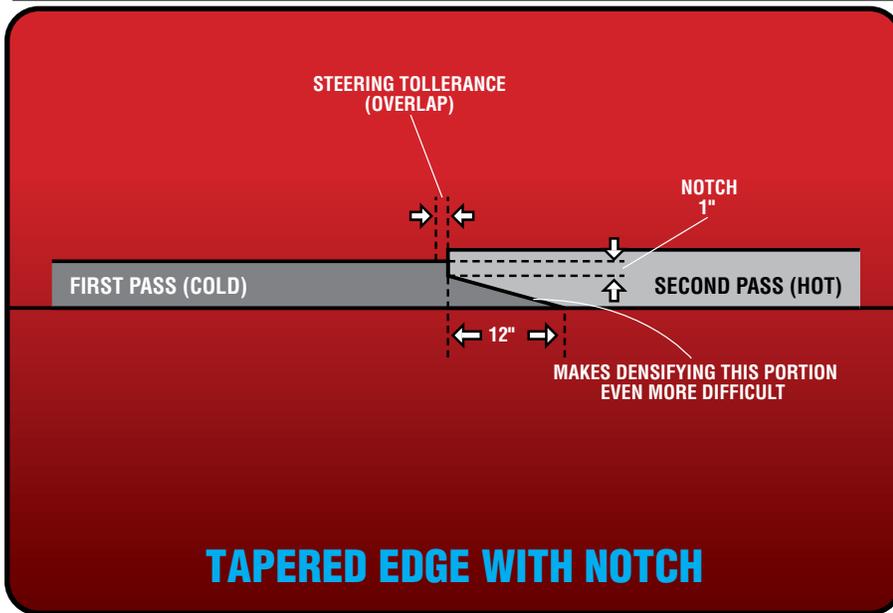


Figure 13

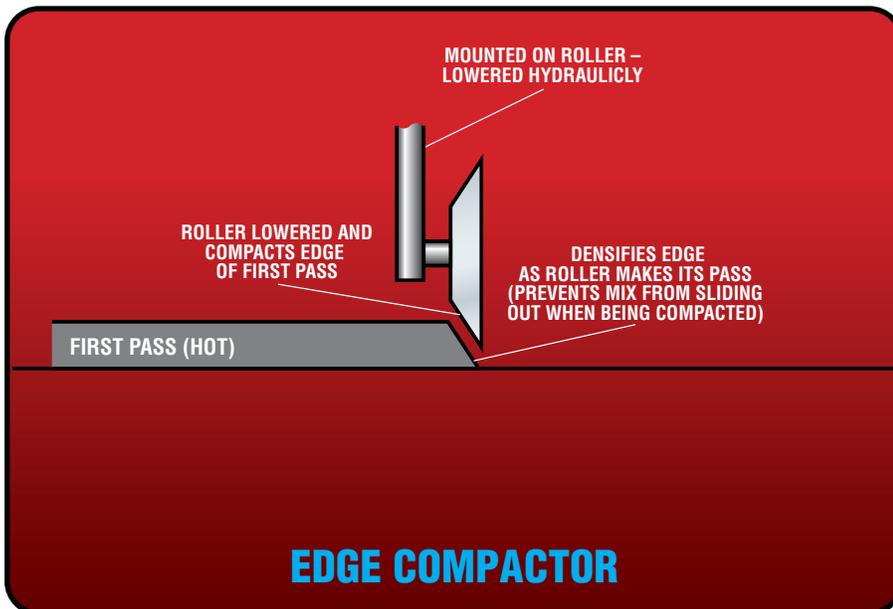


Figure 14

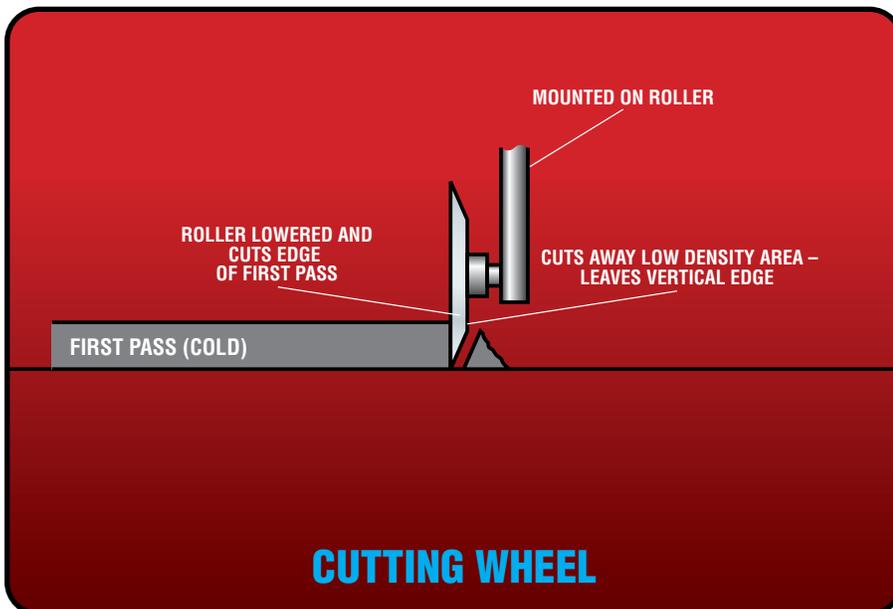


Figure 15

ending up with a horizontal surface above.

Figure 13 shows a variation of the tapered joint that leaves some vertical edge, which assists in solving the problem of controlling the amount of mix placed on a tapered surface to achieve a horizontal finished surface. This type of joint addresses some, but not all, of the problem areas—

- Improves feathered edge or rocks cracking. (Appearance)
- More difficult to densify taper when notch is added.
- Steering improved, different edge to steer from.
- Proper amount for roll down changes along taper.

Figure 14 shows an edge compacting device that is attached to a roller. This device can be hydraulically lowered and holds the edge in place as the roller compacts the material. This device, in conjunction with a confined edge or longer end gate on the paver, can achieve good results. However, it has the following problems:

- Steering a straight line
- Varying mat thickness

Figure 15 shows a more precise way of correcting the problem. A cutter wheel mounted to the roller can be lowered and the uncompacted edge completely cut away. This achieves excellent results but has the problems again of:

- Steering a straight line
- The expense of the lost

material, associated clean-up, and time required for the procedure

Proper rolling techniques can also substantially improve the joint. When the first pass of the breakdown roller is made, it should not be closer than 6” to the edge of the mat. By compacting the material away from the edge first, as succeeding passes are made the roller is supported from the previously compacted area and reduces the amount of squeeze-out of the material on the edge, since this material has cooled somewhat. When the second lane is placed, since the hot material is being contained by the edge of the first pass, the roller can roll on the cold side overlapping 6” to 8”, pinching the material into the joint prior to making the second pass away from the joint.

NEW DEVELOPMENTS

As can be seen from all of these techniques, considerable care and consistency are called for to insure correct joint construction. Unfortunately, with the increase in production volumes in the industry and the retirement of many “old timers”, good joint construction is becoming the exception rather than the rule. In an effort to try to make joint construction more consistent, reliable, and “fool proof”, five highway paver manufacturers agreed at the 1996 NAPA convention, with the encouragement of the NCAT Steering Committee, to form a cooperative committee. The aim of this committee was to build a device that would insure an excellent joint through mechanical means, as the mix was being placed.

The five highway paver manufacturers on this committee were —

- Barber-Greene/Cat
- Blaw-Knox
- Cedarapids
- Champion
- Roadtec

The committee met and agreed to share technology in designing and manufacturing an extension that would attach to existing and new screeds and improve longitudinal joint construction. This group met again in May 1996 and in September, at the NAPA committee meetings. In September, two of the manufacturers had produced a version of an attachment and conducted preliminary field testing.

Considering that the proper amount of mix is placed into the mat at the leading edge of the screed in the precise width of the mat, the mat on which the mix is being placed must be level and uniform and the mix cannot be allowed to spread out if uniform density is to be assured. From this observation, it is apparent that the screed of the paver must be equipped with an end gate extending to the back of the screed. The paver manufacturers group agreed in September 1996 that, effective December

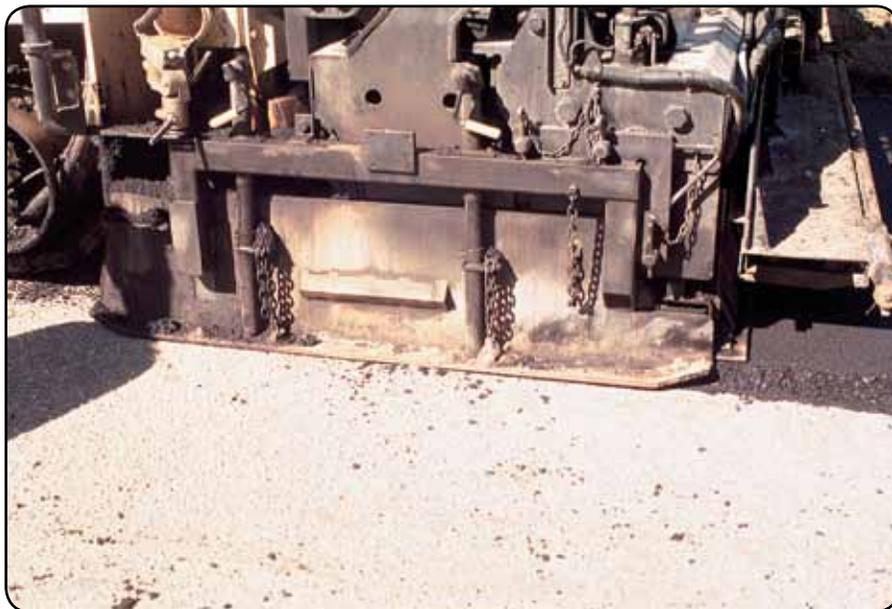


Figure 16



Figure 17



Figure 18

1, 1997, all new pavers will be equipped with end gates that will reach to the back of the screed (Figure 16). As can be seen from Figures 17 and 18, this improves the edge considerably. Extended end gates were common many years ago, but, in an effort to make the end gates easier to raise and lower for accessibility to the mix for hand work, they were soon discontinued except at the front edge of the screed. Further complications resulted from the use of hydraulic strike-offs in front of the screed. Strike-offs extend the width of the screed and are used primarily for pulling turnouts and shoulders. The paver manufacturers group agreed that end gates extending to the rear of the screed would be used on the centerline joint of extendible screeds. On pavers equipped with hydraulic strike-offs, the strike-offs would only be used on the side away from the centerline. The end gates will assure that the mix is at least contained while 25% of the compaction occurs. When utilizing a roller technique where the roller only comes within 6" of the edge of the joint on the first pass, the combination of these two items should improve joint compaction considerably.

JOINT COMPACTORS

In order to insure complete joint density, the paver manufacturers group agreed to continue their work on a screed extension that would

achieve compaction within 92% to 94% of lab density on the outside 12" of the screed area. Various methods were considered and several devices have been tried in the last few years. One technique under discussion forces more mix under the screed at the leading edge. When looking at the above paving principles, this will lead to a thicker mat at the centerline of the joint, making this technique unacceptable. Forcing more mix under the screed at the leading edge assumes that spreading is sufficient to absorb the additional mix. However, precise control could not be achieved.

Figure 19 shows a 12" wide joint compactor developed by Roadtec. This unit is attached to the screed through wedgelock extensions, and the bottom screed plate is detached from the main screed extension. Vertical bars are welded to the screed plate and attached to rubber mounts, isolating the screed plate (shown in red) from the remainder of the screed. A hydraulic vibrator is mounted directly to the screed plate. As shown in **Figure 20**, the rubber isolators are mounted to a tube (shown in white) hinged on the side of the extension, which can pivot up and down vertically at the rear while the leading edge stays fixed to match the leading edge of the paver screed. Weights can be placed on the tube, increasing the down-force onto the rubber mounts. This force, as shown in



Figure 19

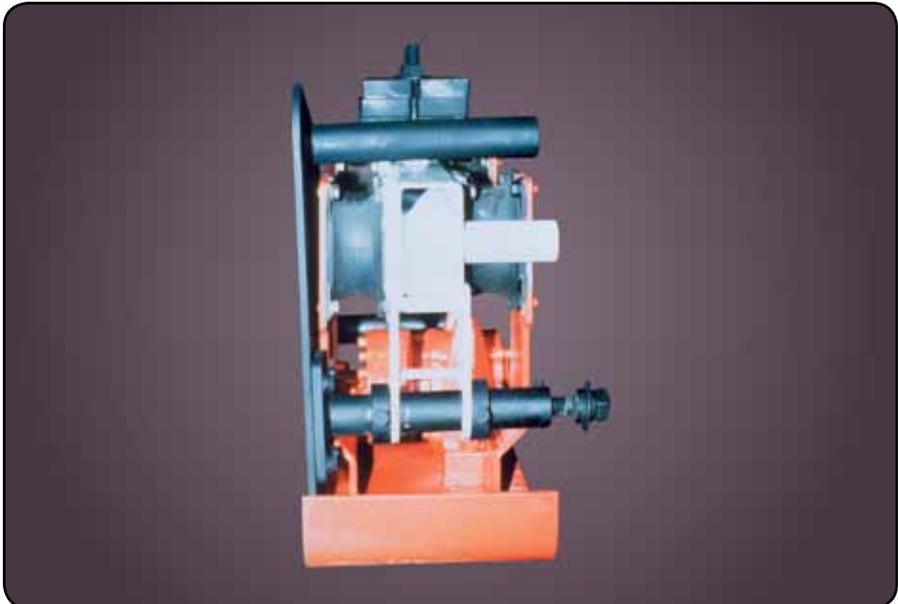


Figure 20

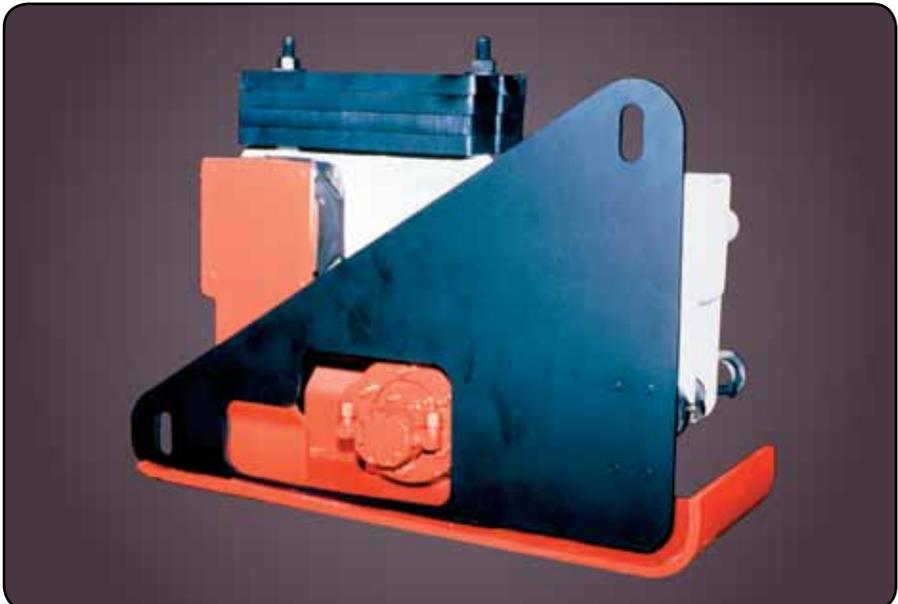


Figure 21

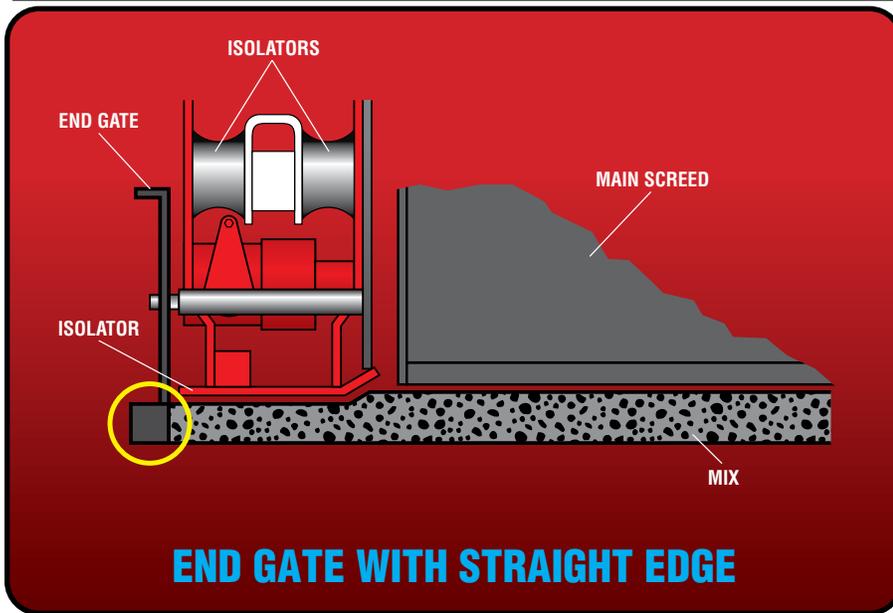


Figure 22

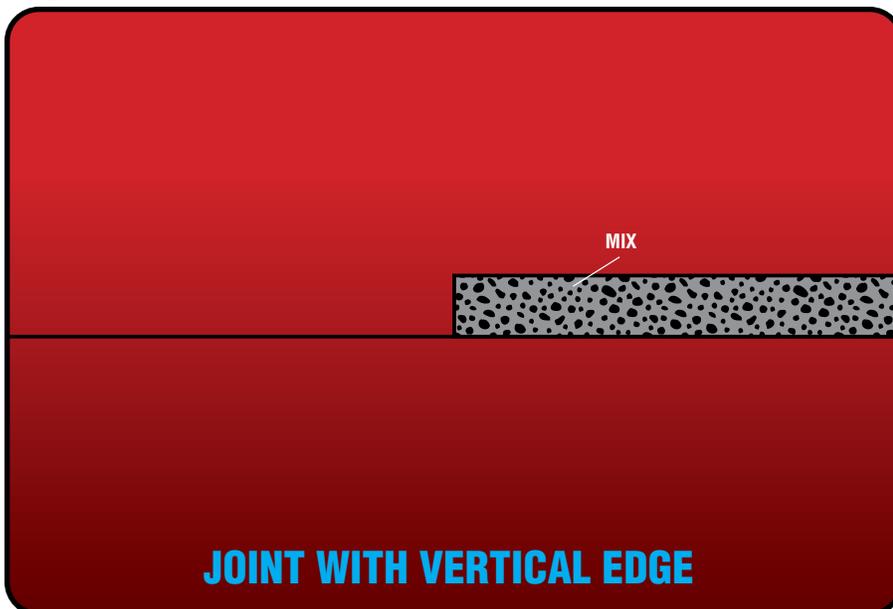


Figure 23

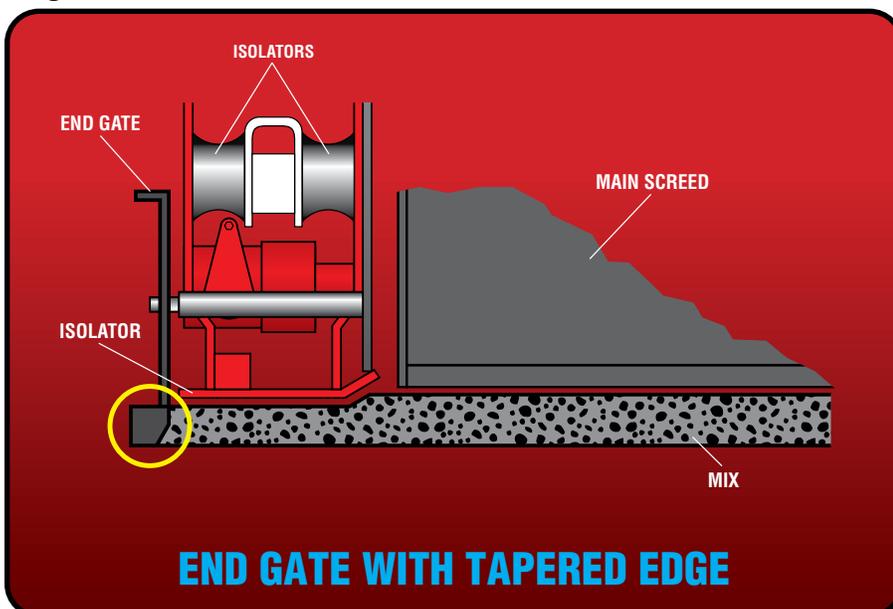


Figure 24

Figure 21, is transferred through the rubber isolators, forcing the vibrating plate further down onto the mix. The end gate is attached through tubes, as shown in Figure 22, to the rigid screed. While positioned vertically against the vibrating plate, it does not hamper the vibrating screed plate's movement. With this device, densities of up to 94% to 95% of lab values have been achieved. The device, together with the extended end gate, allows the construction of a vertical, sharp, tight looking joint (Figure 23) and insures that the mix thickness at the center line is the same as in other portions of the mat, eliminating any depressions or low density areas.

For safety reasons many state Departments of Transportation (DOT) require a taper at the joint. The smaller (steeper and narrower) the taper, the more likely it is that sufficient compaction will be achieved. If a taper is to be constructed, then an end gate as shown in Figure 24 can be used, resulting in an edge shaped as illustrated in Figure 25.

When laying the second mat adjacent to the compacted joint, it is essential that the paver operator steer the paver or guide the screed so that the end gate rides directly on top of the existing joint. Utilizing a sonar device or other sensing technique, extendible screeds can be automatically adjusted to insure that precise placement occurs. Due to the high compaction of the vibratory joint compactor, the mix behind the compactor is only approximately 1/8" above the adjacent lane. This allows the roller to pinch the mix in and form an extremely tight joint. It is recommended that tack be sprayed on the vertical edge of the existing lane.

CONCLUSION

It is hoped that through the development of the above device, joints can be mechanically constructed in a way that will make them impervious to water and to have the same density as other portions of the mat. Through a cooperative effort of the paver manufacturers, it is anticipated that the asphalt industry can eliminate premature failure at the longitudinal joint.

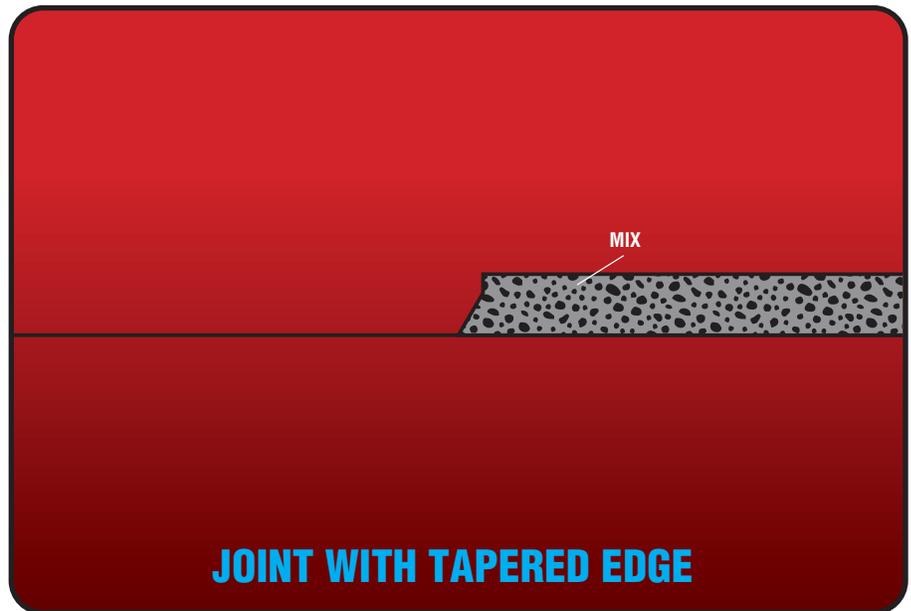


Figure 25

In addition to the authors of this technical bulletin, contributions were made by Jack Farley, Barber Greene Division Caterpillar Paving Products; Jerry Wright, Champion Road Machinery; David Swearingen, Roadtec, Inc. and John Broderick of E.D. Etnyre and Co.

