

CONSTRUCTION OF DURABLE LONGITUDINAL JOINTS

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ABSTRACT

The durability of longitudinal joints in asphalt concrete pavements is a major problem at many locations across North America. After a short period of time under traffic, these joints tend to ravel. In some cases the raveling is severe enough to completely erode the mix at the joint leaving a gap between the lanes.

There are a number of factors during construction that directly affect the durability of a longitudinal joint. The first is the compaction of the unsupported edge of the first lane of mix placed. The second is the amount of overlap of mix on the second lane over the top of the first lane. The third factor is related to the raking of the mix at the joint. The final primary factor is the compaction of the mix at the joint when the second lane is placed adjacent to the first lane.

The construction of a longitudinal wedge joint is discussed. The need for the application of a tack coat on the joint, the need to cut back the unsupported edge of the first lane, and the need to pave in echelon in order to construct a hot joint are also discussed. Construction of a durable longitudinal joint is a question of good workmanship by the contractor using proper construction techniques.

1.0 INTRODUCTION

The durability of longitudinal joints in asphalt concrete pavements is a major problem at many locations across North America. Because of maintenance of traffic considerations, most asphalt pavement resurfacing is done one lane at a time. One lane is paved and then the adjacent lane is paved, with a cold joint between the two lanes. After a short period of time under traffic, these joints tend to ravel. Typically, however, the raveling takes place only on one side of the joint. An example of this type of raveling is shown in Figure 1.



Figure 1. Raveling at a longitudinal joint

Sometimes the raveling at the longitudinal joint is severe enough to completely erode the surface course material adjacent to the joint and expose the underlying pavement layer, leaving a gap between lanes. This type of failure is illustrated in Figure 2. Not only is the long term durability of the pavement compromised, the safety of the traveling public is also a major concern.

Longitudinal joints between traffic lanes or between the mainline pavement and the adjacent roadway shoulder can be properly constructed [1]. Care must be taken to accomplish four primary tasks--compaction of the unsupported edges of the first lane paved, overlap of the mix on the second lane over the top of the first lane, raking of the mix off of the first lane, and compaction of the joint between the two lanes [2]. Using the proper construction techniques, the cost of building a durable longitudinal joint is no more expensive than building a poor longitudinal joint.



Figure 2. Severe erosion of mix at a longitudinal joint

2.0 MEASUREMENT OF JOINT DENSITY

The measurement of the density at a longitudinal joint will typically not be equal to the density obtained in the mainline pavement mix even if all of the proper construction procedures are used [3, 4]. This is primarily due to the compaction of the unsupported edge of the first lane placed. In general, the density of the asphalt concrete mix will be less on the first lane side of the joint (lane 1) compared to the second lane side of the same joint (lane 2).

If cores are used to determine the density level obtained at a longitudinal joint, the location of the core becomes very important in the amount of density measured. If a core is cut more than 150 mm away from the center of the joint, on either side of the joint, the density measured in the core should be the same as for the internal mainline pavement. If a core is cut within a distance of 75 to 150 mm away from the center of the joint, the core density will be somewhat less depending on the tenderness of the mix and the transverse movement of the mix during the compaction operation. In this case, the density on the lane 1 side of the joint (unsupported edge) will typically be less than the density on the lane 2 side of the joint, within the distance of 75 to 150 mm from the center of the longitudinal joint.

Figure 3 shows a core cut directly over the center of the longitudinal joint. In this case, a 100 mm or 150 mm diameter core is centered on top of the visible line between the two lanes. It is noted that although

the core is evenly spaced over the joint at the top of the asphalt concrete layer, the volume of mix in the core is not evenly distributed between the two lanes. This is due to the slope of the mix on the lane 1 side of the joint that is caused by the mix moving out from under the edger plate on the side of the screed of the paver on the unsupported edge. Most of the volume of the core cut from the center of the joint comes from the first lane paved. This means that the density of the joint measured from a core cut directly over the center of the joint will normally be less than the density of a joint measured from a core cut with an offset from the center of the joint.



Figure 3. Core centered on the longitudinal joint

Measurement of the density of the longitudinal joint using a nuclear density gauge is very problematic. In most cases, the elevation of the compacted mix on each side of the joint is not exactly the same. Typically, the mix on the lane 2 side of the joint is somewhat higher than the mix on the lane 1 side of the joint. This is due to the amount of mix placed on top of the first lane--both the width of the overlap and the height of the overlap. Due to the difference in height, a nuclear gauge generally does not sit flat when placed across the top of the joint. This increases the air gap under one side of the gauge and provides an inaccurate density measurement.

The density of the mix at the longitudinal joint, measured with cores centered on the joint, should be within 1.5 percent of the mainline mat density. If the requirements for the pavement are set at 92.0 percent of the theoretical maximum density, for example, it should be possible, with proper construction techniques, to achieve a minimum of 90.5 percent density at the center of the longitudinal joint. Most specifications for longitudinal joint density, however, set the required density level at 2.0 percent below the required mainline mat density.

3.0 COMPACTION OF THE FIRST LANE

One of the keys to the construction of a durable longitudinal joint is proper compaction of the unsupported edge of the first lane of pavement placed [5]. The mix placed by the paver will have a slope on its outside edge. The amount of slope depends on the type of end or edger plate on the paver screed but typically is approximately 60 degrees. This wedge, which is shown in Figure 3, does not receive the same amount of compaction as the rest of the mix due to its shape and position.

The type of roller used and its position in regard to the unsupported edge of the pavement significantly affects the amount of density that can be obtained. A pneumatic (rubber) tire roller normally can not be used within about 150 mm of the unsupported edge of the lane without pushing the mix sideways due to the high pressure in the rubber tires. This is illustrated in Figure 4. For this reason, a rubber tire roller is not useful in compacting the asphalt concrete mix at the joint on lane 1.

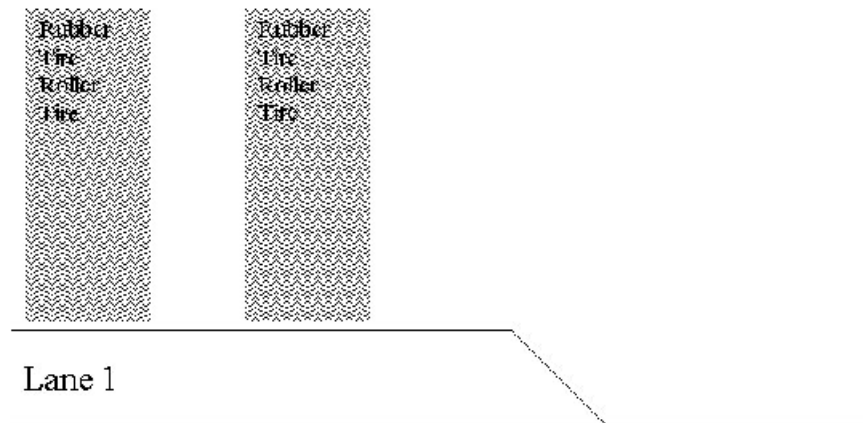


Figure 4. Edge of the rubber tires inside the unsupported edge of pavement

A steel wheel roller, however, can be operated in three different locations in regard to the unsupported edge of the lane. Two of those positions, however, do not provide the proper compactive effort needed to achieve the required amount of density.

As seen in Figures 5 and 6, if the edge of the drum of a steel wheel roller, operated either in the vibratory mode or in the static mode, is inside the unsupported edge of the pavement lane, two things may happen. First, the mix has a tendency to widen out--to move in a transverse direction. This is due to the shear loading on the mix at the edge of the steel drum. The amount of movement is dependent on the properties of the asphalt concrete mixture--a tender mix will shove or move more than will a stiff mixture. In addition, a crack will typically form at the edge of the drum, as shown in Figure 7. This crack is caused by the sideways movement of the mix. Further, the movement of the mix creates a dip at the unsupported edge of the lane, making it much more difficult to match the joint when the second lane is placed. Placing the edge of the roller drum inside the edge of the lane is not good practice.

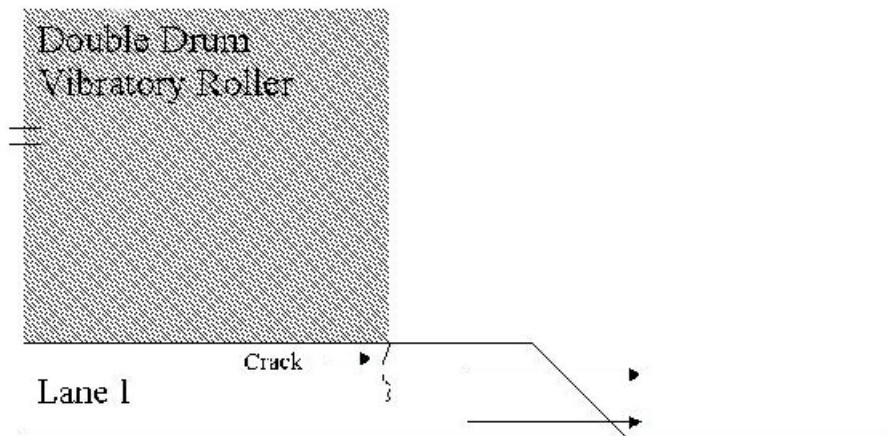


Figure 5. Edge of the roller drum inside the unsupported edge of pavement



Figure 6. Edge of the roller drum inside the unsupported edge of pavement



Figure 7. Crack formed at the edge of the lane due to the position of the edge of the roller drum

The edge of the steel drum can be placed directly over the unsupported edge of the lane. This is shown in Figure 8. In this case, the mix at the unsupported edge will still move sideways or transversely under the force of the roller. Although the mix will widen out, no crack will typically form since the edge of the steel wheel roller drum is right at the edge of the lane. Due to the transverse movement of the mix, however, the opportunity to obtain density at the unsupported edge is not possible.

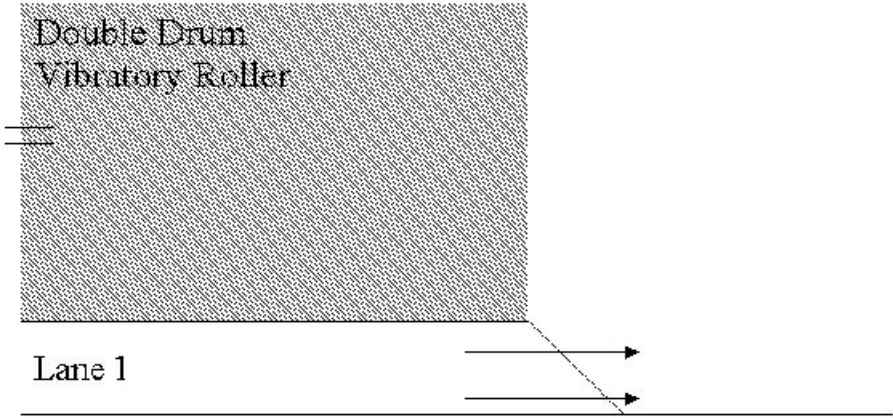


Figure 8. Edge of the roller drum directly on the unsupported edge of pavement

The proper location for the edge of the steel drum is illustrated in Figure 9. The drum is extended over the edge of the lane by approximately 150 mm. In this case, there will be no transverse movement of the mix since there is no shear loading at the edge of the steel drum. Since the mix does not move transversely, no crack is formed. Density is achieved because the edge of the steel drum is compacting air instead of shoving the mix sideways. The proper location of the edge of the steel wheel roller drum over the unsupported edge of lane 1 is shown in Figure 10.

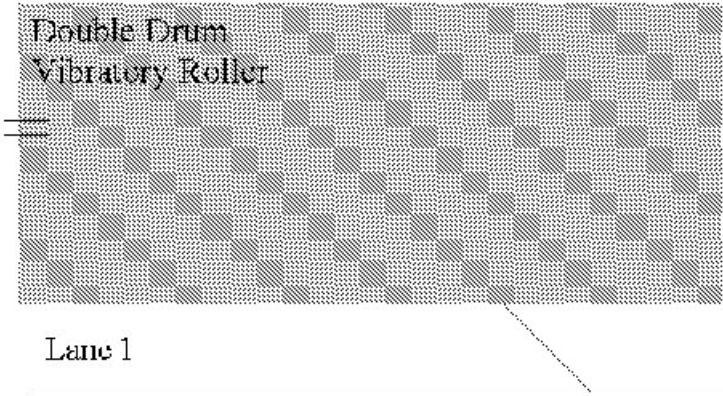


Figure 9. Edge of the roller drum extended over the unsupported edge of pavement



Figure 10. Edge of the roller drum extended over the unsupported edge of pavement

An example of the movement of the unsupported edge of the lane is shown in Figures 11, 12, and 13. In the first figure, Figure 11, the paver operator is placing the mix in a straight line. The unsupported edge of the mix is straight. The angle of the mix at the unsupported edge--the wedge--is also seen in this same figure.

In Figure 12, a double drum vibratory roller is compacting the unsupported edge of the same stretch of pavement. Because the roller operator is not running the roller in a straight line, the edge of the lane is no longer straight. Where the edge of the steel drum is positioned over the unsupported edge of the lane, as where the roller is currently located in the picture, the mix remains in place and does not move transversely. In the foreground of the figure, however, the roller drum was inside the edge of the lane and the mix has moved sideways. The amount of transverse movement is directly related to the location of the edge of the steel roller drum relative to the unsupported edge of the asphalt pavement.

In Figure 13, the paver has moved farther down the roadway. The unevenness of the longitudinal joint is clearly evident. Again, where the edge of the steel drum was placed over the unsupported edge of the lane by approximately 150 mm, no sideways movement of the mix occurred. Where the edge of the drum was either just at the edge of the joint or inside the unsupported edge by some small distance, the mix moved transversely under the shear loading at the edge of the drum. Matching this ragged joint when the second lane is placed next to this lane will be very difficult.



Figure 11. Paver placing unsupported edge of pavement



Figure 12. Transverse movement of the mix at the unsupported edge of pavement



Figure 13. Transverse movement of the mix at the unsupported edge of pavement

In order to construct a durable longitudinal joint, it is necessary to compact the unsupported edge of the first lane correctly. This is accomplished by extending the drum of a steel wheel roller over the unsupported edge of the lane by approximately 150 mm. If this is done, the asphalt concrete mix will not move transversely and a crack will not form in the mix at the edge of the steel drum due to shear loading at the edge of the drum. This lack of movement will allow the second lane to be properly placed and compacted against the edge of lane 1.

4.0 OVERLAP OF MIX FROM LANE 2 TO LANE 1

The second key to the construction of a durable longitudinal joint is related to the amount of overlap of the edger plate on the paver screed over the edge of lane 1 when placing mix for lane 2. Two items need to be considered. The first is related to the thickness of the uncompacted mix from lane 2 over the top of the compacted mix at the edge of lane 1. The second is related to the transverse amount of overlap of the mix from lane 2 over the top of lane 1.

Dense graded asphalt concrete mix typically compacts at a rate of 6 mm per 25 mm. This means to achieve a compacted thickness of 25 mm, the mix usually must be placed from the back of the paver screed at an uncompacted thickness of about 31 mm. Further, to obtain a compacted thickness of 50 mm, the uncompacted mix must be placed to a thickness of approximately 62 mm. When mix from lane 2 is placed over the top of the compacted mix on lane 1, the mix needs to be high by the amount of compaction that will occur.

The amount of overlap of mix from lane 2 onto lane 1 is critical in the construction of a durable longitudinal joint. If an excessive amount of mix is placed over the edge of lane 1, it will have to be removed by raking the joint or it will be crushed by the rollers. If not enough mix is placed over the edge of the first lane, a depression or dip will occur on the lane 2 side of the longitudinal joint. In either case, the joint will not perform properly under traffic. The amount of transverse overlap needed is in the range of 25 to 40 mm for proper longitudinal joint construction.

An excessive amount of overlap of the mix from the new lane (lane 2) onto the old lane (lane 1) is shown in Figure 14. In this figure, it appears that the edger plate on the paver screed is about 250 mm over the top of lane 1. With this excessive amount of mix placed on the compacted lane, it is necessary to remove the excess material by hand raking the mix.



Figure 14. Excessive amount of overlap of mix from lane 2 over lane 1

The proper amount of overlap is illustrated in Figure 15. In this case, the amount of overlap is in the range of 25 to 40 mm. Given this amount of overlap, no mix has to be moved off of the top of lane 1. No raking of the mix at the longitudinal joint is needed.



Figure 15. Proper amount of overlap of mix from lane 2 over lane 1

When milling of the existing asphalt concrete pavement surface is done, a vertical face is formed along the edge of the cutting head on the milling machine. This is significantly different than the slope or wedge that is formed by the edger plate on the paver screed. In this case, due to the vertical edge of the adjacent lane of compacted mix, the amount of overlap must be controlled very carefully. To properly construct the longitudinal joint, the amount of overlap of mix from lane 2 over the non-milled surface should be about 10 to 15 mm, maximum.

5.0 RAKING THE LONGITUDINAL JOINT

If the proper amount of mix is placed in the proper place, no raking of the mix at the longitudinal joint is necessary. If an excessive amount of mix is placed over the top of lane 1, raking of the mix is needed, but this typically results in very poor density at the joint. The third key to a durable longitudinal joint is not to rake the joint during construction.

Figure 16 illustrates improper raking of the longitudinal joint. When raking is done, the amount of mix needed at the joint is usually pushed into the hot mix on lane 2 by the person doing the raking. By setting the rake down on the compacted mix of lane 1 and pushing the rake transversely into the mix at the joint, the mix is shoved on top of the hot mix on lane 2. This makes the mix too low on the lane 2 side at the joint and too high on the lane 2 side a short distance away from the joint. Essentially, the mix ends up at the same elevation of each side of the joint. The problem is that the mix on one side of the joint is compacted (lane 1) and the mix on the other side of the joint is not yet compacted (lane 2).



Figure 16. Improper raking of the longitudinal joint

In order for the rollers to be able to compact the mix on the hot side of the longitudinal joint, the asphalt concrete mix must be high--6 mm for each 25 mm of compacted thickness. If the joint is raked flat, the rollers will not be able to compress the mix since it will already be at the same elevation as the compacted mix in lane 1. This will result in very low density at the longitudinal joint on the lane 2 side of the joint.

As seen in Figure 16, the mix being placed is on a milled surface. The amount of overlap of the new mix over the vertical face of the mix on the old adjacent shoulder is about right--15 mm or less. The uncompacted mix is also high--in this case about 12 mm for a 50 mm compacted mix thickness. Thus the paver is placing the right amount of mix in the right place. The raker, however, is ruining the joint by removing the mix adjacent to the joint that needs to be compacted. In this case, the raker is pushing the mix that needs to be compacted at the joint into the interior of lane 2.

Sometimes a raker will attempt to "bump the joint" with the rake. In this case, the mix in the overlap of lane 2 on lane 1 is not pushed over the top of lane 2 but merely humped up at the joint. If the new mix is at the proper height, the extra material right at the joint will have no place to go vertically. This will result in a bump or ridge along the joint. The rollers will then have a tendency to ride on the ridge of extra mix and not be able to properly compact the hot mix adjacent to the ridge.

Proper raking of the mix on the lane 2 side of the joint is not raking the mix at all. Looking back at the illustration shown in Figure 1, it is easy to determine which side of the joint is the lane 1 side and which side of the joint is the lane 2 side. The left side of this joint was paved first--lane 1. The raker placed the rake down on the compacted mix on lane 1. The raker then pushed the overlapped mix across the top of lane 2 and into the interior of lane 2, not leaving the mix on the lane 2 side of the joint high enough to be properly compacted. Essentially the raker made the elevation of the mix on both sides of the joint--both the compacted and the uncompacted side--the same. This did not provide any mix for the rollers to compact. Given the low level of density on the lane 2 side of the joint, the mix raveled with the application of traffic.

If raveling occurs at the longitudinal joint, it is most often caused by the raking of the joint and the movement of mix needed at the joint into the interior of the second lane. Raveling typically occurs on the lane 2 side of the longitudinal joint.

6.0 COMPACTING THE LONGITUDINAL JOINT

The final key to constructing a durable longitudinal joint is the location of the rollers during the compaction of the mix at the joint [6]. The rollers can be placed in several different transverse locations. Only one of those locations, however, provides for the efficient compaction of the longitudinal joint.

In the past, it was often common practice to compact the longitudinal joint from the lane 1 or the cold side of the joint. The steel wheel roller, operated in the static mode, was located with most of the drum on lane 1 with only 150 to 300 mm of the width of the drum extending over the joint and over lane 2. Such a compaction operation is illustrated in Figure 17.

This type of compaction operation, however, is very inefficient for a number of reasons. First, most of the weight of the roller is on the previously compacted mix. While the roller is moving over the cold mix, the temperature of the new hot mix in lane 2 is decreasing, thereby reducing the opportunity to obtain the desired level of density in the new asphalt concrete mix. Second, a vibratory roller can not be operated in the vibratory mode on the cold side of the joint--on lane 1. This reduces the amount of compactive effort that can be applied to mix at the joint. In addition, if there is a different cross slope between the two lanes such as when the joint is located at a crown section on the roadway, only a minimum amount of the weight of the roller will actually be in contact with the mix at the joint due to the different slopes between the two lanes. Rolling the mix from the cold side--the lane 1 side--is very inefficient and results in a significantly reduced amount of density in the mix at the joint.

Sometimes a steel wheel roller is placed just inside the longitudinal joint on the hot side of the joint--the lane 2 side. This is done to "pinch the joint" but is not good practice. With a steel wheel roller, if the mix being placed is tender, locating the edge of the steel drum some 150 mm inside the joint will result in the mix being pushed sideways, similar to the problem at the unsupported edge of the pavement on lane 1. Because of the side support from lane 1, however, the mix will simply hump up adjacent to the joint. This will result in a longitudinal ridge being formed along the lane 2 side of the joint. This, in turn, will result in poor compaction of the mix at the joint since the roller on subsequent passes over the joint will ride on the high spot in the mat--the ridge--and not compact the mix next to the ridge at the joint.



Figure 17. Compaction of the longitudinal joint from the cold side

A much better place to position the roller, either a steel wheel roller or a pneumatic tire roller, is a short distance over the top of the joint from the hot side of the joint. For a rubber tire roller, the center of the outside tire of the roller, at the end of the roller with an even number of tires, is placed directly over the top of the longitudinal joint, as shown in Figure 18. Placing the roller in this position permits proper compaction of the mix at the joint as well as compaction of the hot mix on lane 2. This is an efficient way to compact both the mix at the joint and the mix in the mainline pavement.

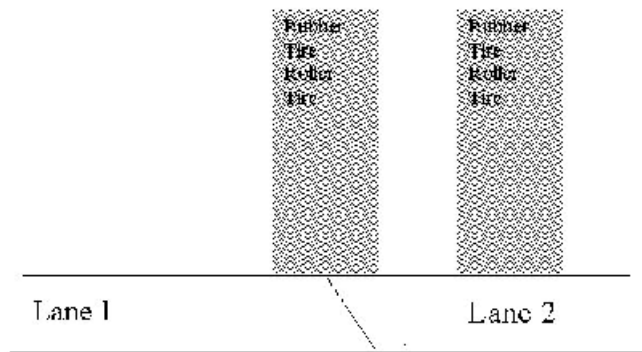


Figure 18. Compaction of the longitudinal joint from the hot side

For a steel wheel roller, the majority of the weight of the drum is placed on the hot mix on lane 2 with only 150 mm or so of the width of the drum extending over the top of the joint and over the top of lane 1. This is shown in Figures 19 and 20. Such a rolling pattern allows the roller to apply most of its weight to the new hot asphalt concrete material while still compacting the mix at the joint. In addition, if there is a different cross slope between the two lanes, rolling from the hot side of the joint--the lane 2 side--will typically achieve a higher amount of compaction at the joint.

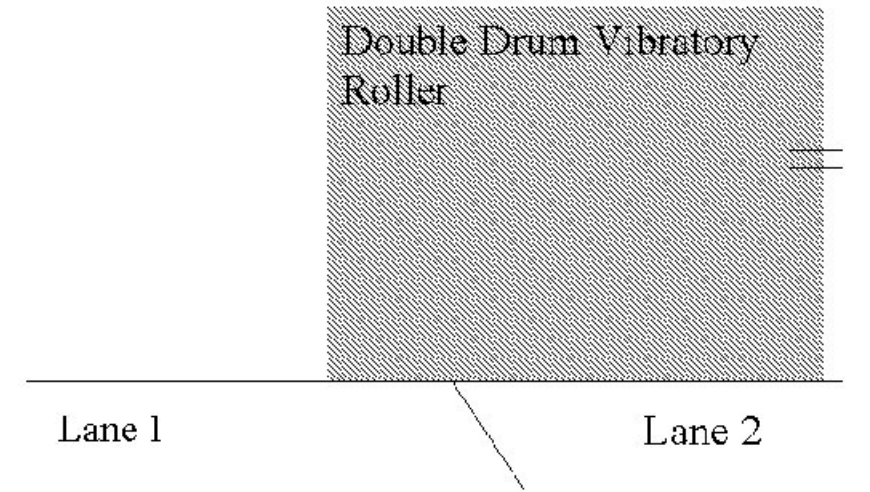


Figure 19. Compaction of the longitudinal joint from the hot side



Figure 20. Compaction of the longitudinal joint from the hot side

When compacting the longitudinal joint between lanes 1 and 2, the rollers can be placed on either the cold side of the joint or the hot side of the joint--on lane 1 or on lane 2. The most efficient location to

place the rollers, either pneumatic tire or steel wheel, is on the hot side of the joint with one tire or a small amount of the width of the drum (150 mm) extending over the top of the joint. This type of rolling pattern will result in higher compactive effort being applied to the mix at the longitudinal joint and thus higher density at the joint. In addition, by rolling from the lane 2 side, the new mix is being compacted at the same time as the mix at the joint, resulting in a more efficient overall compaction operation.

7.0 CONSTRUCTION OF A WEDGE JOINT

Some governmental agencies are starting to construct a wedge joint at the longitudinal joint. This type of joint is shown in Figure 21. The original purpose of the wedge joint was to allow traffic to safely pass over the longitudinal joint from one lane to another while minimizing the difference in the drop off between the lanes. This makes sense from a traffic safety standpoint at the time of construction, but normally does not provide for a very durable longitudinal joint over the long term [7].

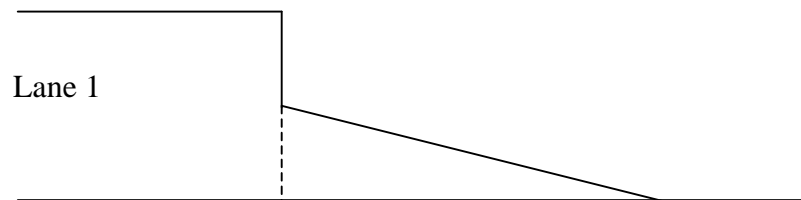


Figure 21. Construction of a longitudinal wedge joint

The wedge joint is typically formed by attaching a piece of metal to the edger plate on the paver screed. This form is used to create both vertical face at the top portion of the unsupported edge and the wedge or slope at the bottom portion of the joint. In most cases, the height of the vertical face is approximately half of the depth of the pavement course. The width of the wedge is typically 300 mm for many projects where a wedge type joint is used.

Two problems typically occur with the construction of this type of joint. First, it is very difficult to properly compact the wedge section. Because of the narrow width of the wedge, a full size roller can not be used for compaction. Often a very small single drum, static, steel wheel roller is towed behind the paver over the wedge. The amount of compactive effort applied to the mix by this drum, however, is minimal. Depending on the width of the wedge, most of the weight of the roller rides on the adjacent, lower pavement surface and the outside end of the wedge receives little or no compaction. The slope of the roller drum is usually different than the slope of the top of the wedge. This lack of density in the wedge may provide for deterioration of the longitudinal joint, from the bottom up, within a few years.

Second, the vertical face at the top of the wedge joint is difficult to match when the second lane is placed adjacent to lane 1. This was discussed above in regard to paving against an adjacent vertical face. The amount of overlap between the mix placed on lane 2 over the top of the compacted mix on lane 1 must be kept to a maximum of 15 mm.

Improved traffic safety at the time of construction may be offset by increased deterioration of the joint with time and traffic.

8.0 OTHER CONSIDERATIONS

Some individuals believe that it is necessary to apply a tack coat to the unsupported edge of the first lane before mix in lane 2 is placed against that edge [8]. There does not seem to be any definitive evidence that the application of a tack coat provides any benefit in terms of the long term durability of the longitudinal joint. In general, the application of the tack coat is not very uniform because the material is typically placed by hand spray methods. Further, even when placed using an asphalt distributor, the distributor does not always run in a straight line compared to the unsupported edge of lane 1. Thus the tack coat does not always end up evenly applied on the joint.

Paving in echelon is sometimes done with the idea of creating a hot longitudinal joint and eliminating future deterioration at the joint. In this process, one paver is used to place the mix in lane 1. A second paver is used to place the mix in lane 2. The two pavers are usually located within 10 m or so of each other. The ultimate performance of the mix at the longitudinal joint depends primarily on the amount of overlap of mix placed by the second paver over the top of the mix placed by the first or front paver. If that amount of overlap is kept to a minimum--less than 25 mm--an excellent longitudinal joint will be constructed. If the amount of overlap is too much or too little, however, either a ridge or a gap will be formed at the longitudinal joint.

Paving in echelon just for the purpose of creating a hot longitudinal joint is typically not very beneficial or economical. In most cases, the amount of mix produced at the asphalt plant governs the rate of paving. Most asphalt pavers, operated without any type of material transfer device, can place more than 600 tonnes of mix per hour. Splitting the plant mix production to two pavers instead of one simply increases the cost of placing the mix.

Sometimes it is believed that it is beneficial to cut back the unsupported edge of the first lane to eliminate the under compacted mix at the edge of the lane and in the slope or wedge at the side of the joint. This is typically unnecessary. First, this is a very costly operation. Second, the cutting has to be done in a straight line so that the joint can be matched with the second pass of the paver. Third, the amount of overlap of mix on the second lane over the vertical face of the cut joint has to be carefully controlled--15 mm or less in overlap distance, similar to the vertical edge with a milled pavement. There does not seem to be any definitive data which indicates that the cutting back the joint results in a more durable longitudinal joint on a long term basis.

9.0 SUMMARY

If the longitudinal joint is properly constructed, there generally is no need to apply a tack coat to the unsupported edge of the first lane--lane 1. If the longitudinal joint is properly constructed, there is no need to cut back the unsupported edge of the first lane before the second lane is placed adjacent to it. If the longitudinal joint is properly constructed, there is no need to pave in echelon.

Proper construction of the longitudinal joint between pavement lanes consists of four primary steps. First, the unsupported edge of lane 1 must be compacted by placing the drum of a steel wheel roller about 150 mm over the top of the unsupported edge--compacting air at the edge of the drum. Second, the amount of mix placed over the top of lane 1 when the mix in lane 2 is placed should be limited to a distance of 25 to 40 mm. Third, the mix placed at the joint when the second lane is constructed should not be moved with a rake but should remain where placed by the edger plate on the paver screed. Last, the mix at the longitudinal joint should be compacted from the hot side of the joint--the lane 2 side-- with the outside

tire on the rubber tire roller directly over the joint or the drum of a steel wheel roller extending 150 mm over the top of the joint.

Durable longitudinal joints are a workmanship issue. Proper construction techniques will provide for a long life longitudinal joint without raveling or deterioration.

10. REFERENCES

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