Longitudinal Joint in Asphalt Pavement

A longitudinal joint occurs in an asphalt pavement when a fresh batch of hot-mix asphalt (HMA) is laid adjacent to an existing lane. It is required to pave the width of a road in multiple lanes because paving the full width of the pavement in a single pass is usually impossible. It is the interface between the two HMA mats. Most often, differences in the temperature and mat plasticity causes an improper bonding of the fresh HMA with the older asphalt lane and this subsequently causes the longitudinal joint to possess a significantly lower density than the rest of the pavement. Over time, a longitudinal crack usually occurs between the asphalt mats, permitting the intrusion of water, increasing roughness, and potentially limiting the life of the pavement.
Based on the conditions under which the mats are laid, the resulting longitudinal joint can be of the following types:

1. Hot Joints: Hot joints are produced when the adjacent lanes are paved in echelon i.e. when two pavers are spaced so that the first lane does not cool significantly before the second lane is laid. If constructed properly, a hot joint appears almost seamless and produces the highest density when compared to the semi-hot and cold joints. The difficulty in obtaining hot joints is that it requires the simultaneous paving of multiple lanes, which is not possible because of today’s constricted work zones especially in case of highways and limited capacity of HMA production to feed more than one paver.

2. Semi Hot Joints: A semi-hot joint or a warm joint is produced when the paver is restricted to proceed for a certain distance before moving back to place the adjacent lane. The HMA in the first lane generally cools down to a temperature of about 120oF to 140oF (49o to 60oC) before the adjacent lane is placed. Semi-hot joint is by far the most commonly used joint type on HMA paving projects. Numerous studies have demonstrated that the semi-hot joint densities are significantly lower than the mat interior densities.

3. A cold joint is produced when the first paved lane has cooled overnight or more before the adjacent lane is placed to match it. A cold joint will also be produced if paving of the first lane is carried too far ahead such that the HMA has cooled well below 120oF (49oC). This would cause a significant density gradient on between the two mats on either side of the joint and result in very low strength in the joint. 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. Also, the low density at this joint enables the seepage of water into the joint which could oxidize the bituminous material. Hence, careful attention needs to be paid to the construction of these joints and this report identifies some of the practices that, if adopted, could significantly reduce the risk of failure of longitudinal joint in the pavement.

Causes for Cracking and Failure of Longitudinal Joint:

As mentioned earlier, substantial difference in densities on either side of the longitudinal joint (density gradient across the joint) is the primary cause of longitudinal joint cracking. The reason for this difference in densities is that when the first lane is paved, one of its edges is unconfined, leading to a lower density after compaction. When the adjoining lane is paved, the edge of the first pass confines the new mix and prevents it from spreading. This results in higher density on the second pass at the center of the road. The unconfined edge of the first pass (in the center), however, is now at a lower elevation, and a minor depression may occur in the middle of the road. This area (from the first pass) also has not been sufficiently compacted and generally displays higher air voids. Therefore, the combination of the depressed area and a high void content allow water to accumulate in this area leading to further deterioration. The other causes of longitudinal cracks are:

1. The height differential due to the poor construction (difficulty in compacting the unconfined edges) or differential settlements after cracking.
2. Residual stress occurring at the wheel path as the HMA mat density increases. When these residual stresses exceed the tensile strength of the HMA, cracking occurs.
3. Temperature and environmental forces: Once the tensile stress under temperature changes or other environmental forces are higher than the existing tensile strength, the construction joint splits apart.
4. Improper overlap of asphalt between the first and second lanes.

All of the above factors would eventually lead to low strength in the joint, which is the ultimate reason for failure. Hence, the solutions required would have to tackle each of the above mentioned causes, and eventually improve the strength of the joint.

Conventional Longitudinal Joint Construction Methods:

1) No Treatment:
In this method, the paver places the hot mix in a lift with vertical edges on both sides. As the lift is rolled, mix particles along the unconfined edge slough off and roll down the face to form a natural angle of repose. No raking or luting is done.

2) Bumping Unconfined Edges:
This method is similar to the "No Treatment" method except luting is done to bump or manually shape the unconfined edge as the paver moves. The mat is then rolled.

3) Wedge or Tapered Edges:
This technique uses a paver attachment to build a stable edge slope on the unconfined edge of the mat. Slopes of 1:6 and 1:3 vertical to horizontal have been used. Arizona and Michigan DOTs have used 1:6 slopes while New Jersey and Kansas use 1:3. These slopes were selected for traffic safety reasons. Compaction along the sloping unconfined wedge is accomplished by a small roller pulled by the paver.

4) Cutting Back the Joint
Sometimes, the lack of confinement of the mix during the process of compaction results in low-density zones. In order to remove the low-density portion of the mix, the longitudinal edge of the previously placed mix is cut back using a saw for a distance of 25 to 50mm (1 to 2 in). A tack coat is placed on the newly exposed vertical face of the longitudinal joint before paving the adjacent lane. If the wedge is not cut back, proper joint density could be achieved through overlapping, raking, and compacting.

5) Overlapping the Joint
The amount of overlap between the new mat and the previously placed mat is important. The end gate on the paver should extend over the top surface of the adjacent mix a distance of not more than 25 to 37 mm (1 to 1 ½ inches). This amount of overlap provides enough material on top of the joint to allow for proper compaction without having extra mix, which must be pushed back from the joint by a raker. The height of the new mix above the compacted mix should be mm (1/4 in) for each 25 mm (1 in) of compacted mix.

6) Raking the Joint
Excessive raking of the longitudinal joint may cause long-term performance problems. The mix material that is pushed off the longitudinal joint and deposited on the new asphalt mat changes the surface texture of the mat from one side of the lane to the other, and the required density at the joint may become impossible to achieve. Raking of the longitudinal joint can be eliminated with proper overlapping of the new mix on the previously placed mat.

Conventional Longitudinal Joint Compaction Techniques:

1) Rolling from the Hot Side
Running the roller on the hot mat while overlapping the joint by a distance of approximately 150 mm (6 in) over the cold mat is considered the most efficient way of compacting the longitudinal joint. Sometimes the first pass of the roller is completed with the edge of the machine about 150 mm (6 in) inside of the longitudinal joint. The principle behind this method of comp action is that better compaction is obtained when the mix is shoved toward the joint by the roller. No lateral movement will occur under the roller if the mix is stable.

2) Rolling from the Cold Side:
In this old practice, initial rolling of the longitudinal joint starts from the cold side of the joint so that the cold mat supports most of the weight of the roller. In contrast to rolling from the hot side, the majority of the compactive effort is wasted. The mix on the hot side of the joint tends to cool down while the roller is operating on the cold side of the longitudinal joint. As a result, more compactive effort is needed to achieve the required density. It was thought that this method allowed the rollers to "pinch" the joint and obtain a higher degree of density. However, the lane placed first will have an unsupported edge that is always difficult to compact.

3) Echelon Paving:
In this method of paving two pavers run next to each other. The longitudinal joint is constructed similar to the building of a joint against a cold layer. The amount of overlap between the first and second lanes is very important. The recommended maximum distance that the screed and end gate of the trailing paver should extend over the uncompacted mat behind the first paver

edge of the mat on the side of the second paver is required to be approximately 150 mm (6 inch). Once the second paver places the mix against the uncompacted edge of the mix from the first paver, the rollers compacting the second lane start to compact the mix on both sides of the joint.

Good Construction practices to ensure a Strong Longitudinal Joint

1) <u>Paving and Compacting the First Lane:</u>
   One of the most important requirements in obtaining a good longitudinal joint is that the paver operator should place the first lane in a uniform, unwavering line. Attention to this detail will simplify the placement of the adjacent lane with a uniform overlap. Another important requirement in obtaining a durable joint is proper compaction of the unsupported edge of the first lane (cold lane). The unsupported edge typically has a slope of approximately 60 degrees. Obviously, the wedge formed by this slope at the edge does not receive as much compaction as the mainline away from the edge. Breakdown compaction with a vibratory or static steel wheel roller can be done with the roller operating in three different locations in respect to the unsupported edge of the first lane. First, rolling can begin with the edge of the roller drum away from the unsupported edge. However, this practice will cause the HMA to shove or move out due to shear loading on the mix at the edge of the steel drum. The extent of this transverse movement will depend upon the stiffness of the HMA mixture. This movement will (a) typically cause a crack to be formed at the edge of the drum, and (b) create a depression at the unsupported edge so that it will be very difficult to match the joint when the adjacent lane is placed. Second, rolling can begin with the edge of the steel drum right on the unsupported edge of the first lane. Although this practice will eliminate cracking at the edge of the roller drum, it would still shove and push out the mix underneath the drum. Therefore, it would not be possible to obtain adequate density at the unsupported edge. Third, rolling can begin with the edge of the steel drum extending over the edge of the first lane by about 6 inches (150 mm). At this position, the edge of the drum does not exert any shear force in the HMA because it is out hanging in the air. Therefore, there is minimal transverse movement of the HMA and reasonable amount of density is obtained at the unsupported edge of the lane. Obviously, this third practice of compacting the unsupported edge will produce the best results and is, therefore, recommended.

2) <u>Raking and Luting:</u>
   Raking or luting at the longitudinal joint can be eliminated if the minimal overlapping as recommended previously is followed. An excessive overlap will require removal of extra material from the cold lane onto the hot lane otherwise the aggregate in the mix remaining on the compacted lane will get crushed resulting in raveling. When that happens, the excessive overlapped material on the cold lane may be “bumped” with a lute onto the hot mat just across the joint. The bump should lie just above the natural slope or the wedge at the edge of the cold lane. Since the HMA on the slope is usually not adequately compacted, there is a good potential that the roller can crowd and compact the bump into the joint.

3) <u>Compacting the Longitudinal Joint:</u>
   Obtaining adequate compaction at the joint is the final key in obtaining a durable longitudinal joint. Most specifications for longitudinal joint density require the density level at no more than 2 percent below the required mainline mat density. By paying attention to construction details

mentioned earlier (Rolling from Hot side) it is possible to obtain a joint density within 1.5 percent of the mainline density. The joint density is best measured by obtaining a 6 inch (150 mm) diameter core centered on top of the visible line between the two lanes. It should be noted that the core would not consist of equal volumes of mix from the cold lane and the hot lane. Due to the presence of natural slope at the unconfined edge of the cold lane, most of the mix in the core will come from the cold lane. This is all right because the density of the cold side is of major concern.

4) Echelon Paving:
As mentioned earlier, best results would be obtained if paving were done in echelon. However this is not possible especially with limited capacity of HMA production to feed more than one paver and because of today's constraints on site, especially in highways, which require at least one lane open to traffic.

5) Tack Coating Longitudinal Joints:
According to some engineers, applying a tack coat on the face of the unconfined edge of the cold lane ensures a better bond (adhesion) and seal of abutting HMA lanes. The tack coat usually consists of asphalt cement, emulsion, or hot poured, rubberized asphalt sealer. Some engineers believe application of thin tack coating material such as asphalt cement and emulsion in case of semi-hot joint is unnecessary since it may not contribute in improving the durability of the longitudinal joint. Recent field research, has demonstrated that the use of hot-poured, rubberized asphalt sealer as a tack coat (about 1/8 inch or 3 mm thick) on the face of the first paved lane produced the most durable longitudinal joints. Therefore, it appears that thick tack coats may be more effective than generally used thin coats of asphalt cement or emulsion.

6) Notched Wedge Joint:
The notched wedge joint is formed by providing a vertical notch and a taper at the edge of the lane paved first (cold lane). A taper of 1:12 (vertical: horizontal) was used. The taper is then overlapped when the adjacent lane (hot lane) is placed.

7) Edge Restraining Device:
The restrained edge compaction technique utilizes an edge compacting device, which provides restraint at the edge of the first lane constructed. The restraining device consists of a hydraulically powered wheel, which rolls alongside the compactors drum simultaneously pinching the unconfined edge of the first lane towards the drum providing lateral resistance. This technique is believed to increase the density of the unconfined edge. The adjacent lane is then abutted against the initial lane edge.

8) Cutting Wheel:
The cutting wheel technique involves cutting 1½-2 inches (38-51 mm) of the unconfined, low-density edge of the first lane after compaction, while the mix is still plastic. A 10-inch (254-mm) diameter cutting wheel mounted on an intermediate roller is generally used for the purpose. The cutting wheel can also be mounted on a motor grader. This process obtains a reasonably vertical face at the edge, which is then tack coated before the placement of the abutting HMA.

9) Joint Maker:
This is an automated joint construction technique developed in the early 1990s. It consists of a device, which is attached to the side of the screed at the corner during construction. The device

forces extra material at the joint through an extrusion process prior to the screed. It is claimed that proper use of the joint maker ensures high density and better interlocking of aggregates at the joint.

Sources Referred to:

1) www.**asphalt**magazine.com/singlenews.asp?item_ID=993&comm=0&list_code_int=MAG01-
2) http://www.ksdot.org/idmws/DocContent.dll?Library=PublicDocs^dt00mx38&ID=003686991&Page=1
3) http://training.ce.washington.edu/WSDOT/Modules/07_construction/longitudinal_joints.htm
4) http://www.eng.auburn.edu/center/ncat/reports/rep96-3.pdf
5) http://www.airporttech.tc.faa.gov/naptf/att07/2007/Papers/P07042%20Kandhal&Mallick.pdf

Specifications Regarding Longitudinal joints:

401-3.14 JOINTS. Minimize the number of joints. Ensure that all joints have the same texture and smoothness as other sections of the course. Remove to full depth improperly formed joints resulting in surface irregularities. Replace with new material, and thoroughly compact.

Precut all pavement removal to a neat line with a power saw or by other approved method. Form transverse joints by saw-cutting back on the previous run to expose the full depth of the course or use a removable bulkhead. Skew transverse joints between 15-25 degrees. Offset the longitudinal joints in one layer from the joint in the layer immediately below by at least 6 inches. Align the joints of the top layer at the centerline or lane lines. Where preformed marking tape striping is required, offset the longitudinal joint in the top layer not more than 6 inches from the edge of the stripe. Core the longitudinal joint at the rate of 3 cores per lot. Maintain the joint densities above 91% of maximum specific gravity. Change the method of joint construction, if necessary, to meet density requirements. The joint densities will not be included in the price adjustment calculations, but must be included in your Quality Control plan.

Source:
http://fhwapap04.fhwa.dot.gov/nhswp/agency/Utah/Standard%20Specifications%20and%20Supplements/Division%2002%20-%20Site%20Construction/02741-HotMixAsphalt.pdf#search=longitudinal joint asphalt density

Density Requirements

a. The target for in-place density including longitudinal joint density is 93.5 percent of Maximum Specific Gravity for projects where the design overlay thickness is greater than 2 inches.

b. The target for in-place density including longitudinal joint density is 92.5 percent of Maximum Specific Gravity for projects where design overlay thickness is less than or equal to 2 inches.

c. Use the average of the Maximum Specific Gravity tests for each lot.

d. Acceptance for in-place density may be based on establishing a rolling pattern for bridge decks, utility work, traffic signals, detours, lane leveling, driveways, etc,

Source:
http://fhwapap04.fhwa.dot.gov/nhswp/agency/Missouri/Standard%20Specifications%20and%20Supplements/D%20-%20Flexible%20Pavements/Sec0403.pdf#search=longitudinal joint asphalt density

403.16.1 Joint Composition. Longitudinal joints shall be formed by the use of an edging plate fixed on both sides of the finishing machine. Care shall be taken to obtain a well bonded and sealed longitudinal joint by placing the hot mixture in a manner ensuring maximum compaction at this point. If directed by the engineer for properly sealing the longitudinal joint, a light coating of bituminous material shall be applied to the exposed edge before the joint is made. The minimum density of all traveled way pavement within 6 inches (150 mm) of a longitudinal joint, including the pavement on the traveled way side of the shoulder joint, shall not be less than 2.0 percent below the specified density when unconfined. The density of the longitudinal joint when confined will be included in the evaluation of the remainder of the mat. Each side of the joint shall be flush and along true lines.

Missouri Department of Transportation and the U.S. Army Corps of Engineers Specifications for Longitudinal Joints

Missouri Department of Transportation (MODOT)

MODOT specifies that adjustable plates be attached to both sides of the paver. The outside plate is adjusted at 45 degrees with the surface of the roadbed and slightly compacts the mat. The inside plate is normal to the roadbed and is used for placing the material for the longitudinal joint. The cold mixture edge is required to be set up to a vertical edge by slight compaction with the back of a rake if it slumps. A well-bonded and sealed joint is obtained by maximum compaction. If necessary, a light coating of bituminous material can be applied to the exposed edge before paving the hot- mix asphalt. Irregularities on the cold mat edge must be removed before paving the second lane. The density at the longitudinal joint is specified to be not less than 2% below the specified density on traveled way pavement within 150 mm (6 inches) of a longitudinal joint. This joint includes the pavement on the traveled-way side of the older joint. The pay adjustments for the joint density applies to the full width of the traveled way and is in addition to any other pay adjustments

The U.S. Army Corps of Engineers

The following guide specifications related to the longitudinal joints are based on the Unified Facilities Guide Specifications (UFGS) of the Department of Defense. The hot mix asphalt (HMA) for airfields is covered by UFGS-02749 of March 2002 (13): 27

3.6.2.1 Placing

The longitudinal joint in one course shall offset the longitudinal joint in the course immediately below by at least 300 mm (1 ft). However, the joint in the surface course shall be at the centerline of the pavement.

3.6.2.2 Longitudinal Joints

Longitudinal joints that are irregular, damaged, uncompacted, cold (less than 80 °C or 175 °F at the time of placing the adjacent lane), or otherwise defective, shall be cut back a minimum of 50 mm (2 inches) from the edge with a cutting wheel to expose a clean, sound vertical surface for the full depth of the course. All cutback material shall be removed from the project. All contact surfaces shall be given a light tack coat of asphalt material prior to placing any fresh mixture against the joint. The contractor will be allowed to use an alternate method if it can be demonstrated that density, smoothness, and texture requirements can be met.

3.6.2.3 Mat and Joint Densities

For determining in-place density, one random core (100 or 150 mm diameter) will be taken from the mat (interior of the lane) of each sublot, and one random core will be taken from the joint (immediately over joint) of each sublot. A standard lot will be equal to 2,000 metric tons, and will consist of four equal sublots. After air drying per ASTM D 2726 for laboratory prepared, thoroughly dry specimens, cores obtained from the mat and from the joints will be used for in-place density determination. The average in-place mat and joint densities are expressed as a percentage of the average theoretical maximum density (TMD) for the lot. The average TMD for each lot will be determined as the average TMD of the two random samples per lot. The average in-place mat density and joint density for a lot are determined and compared with Table 3 to calculate a single pay factor per lot based on in-place density, as described below. First, a pay factor for both mat density and joint density are determined from Table 3. The area associated with the joint is then determined and will be considered to be 3 m (10 feet) wide times the length of completed longitudinal construction joint in the lot. This area will not exceed the total lot size. The length of joint to be considered will be that length where a new lane has been placed against an adjacent lane of hot-mix asphalt pavement, either an adjacent freshly paved lane or one paved at any time previously. The area associated with the joint is expressed as a percentage of the total lot area. A weighted pay factor for the joint is determined based on this percentage. The pay factor for mat density and the weighted pay factor for joint density are compared and the lowest selected.
This selected pay factor is the pay factor based on density for the lot.