APPENDIX

FHWA/Asphalt Institute Recommendations

The following is the summary of recommendations developed from a joint FHWA/Asphalt Institute project on Longitudinal Joint Best Practices *(March 2014)*.

During Planning and Design

1) Evaluate traffic control requirements to see if echelon paving could be utilized in any facet of a project to minimize the number of traditional cold joints.
2) For mill and fill jobs, evaluate traffic control requirements to require the contractor to mill and fill one lane at a time, eliminating unconfined edges. Care should be taken to thoroughly clean the milled surface, especially at the confined corner.
3) Assess project scope, traffic control and safety requirements for the practicality of evaluating the method of cutting back the joint. This method is routine on airfield projects in the U.S. and is done on roadways in the United Kingdom, with much success.
4) Offset the longitudinal joints horizontally between layers by at least 6 inches, when placing multiple lifts. This does not apply when placing asphalt mix over portland cement concrete (PCC), as it's often preferred to stack the joints directly over the PCC joint.
5) Plan the location of the longitudinal joint in the surface lift to avoid wheel paths, recessed pavement markings, and striping whenever possible.
6) Assure there are well-defined specifications for the placement and quality assurance testing of the longitudinal joints (See Section 5).
7) Use a lift thickness that is at least 4 times the Nominal Maximum Aggregate Size (NMAS) of coarse gradation mixes and 3 times the NMAS for fine gradation mixes. Adequate lift thickness will facilitate compaction for better density.
8) Consider the use of less permeable surface mixes by using:
   - Smallest NMAS mix that is appropriate for the application (will not rut).
   - Using a finer versus coarser gradation.
9) Consider using warm mix asphalt as a compaction aid, especially in late-season paving.
10) Consider the use of the notch wedge joint (versus traditional vertical edge or butt) for lift thicknesses between 1.5 to 3 inches. Several agencies have found that the notch wedge joint provides higher densities on average than the butt joint.
11) Pay for tack as a separate bid item (as opposed to being an incidental requirement) to facilitate getting a sufficient amount of material applied.
12) Include items related to the longitudinal joint as discussion topics for the pre-paving meeting. These include the joint type to be used, planned locations of joints, testing requirements, and locations, construction practices, etc.
13) Planning the lane sequence so as to pave from low to high. This will provide a shingle effect, preventing the overlapped joint material from impeding water flow on the surface. The hot (confined)-side of the joint may be slightly higher than the cold (unconfined)-side.
14) To increase the longevity of the joint after it has been constructed, and perhaps as a remedial action for not meeting a minimum density, evaluate the various "joint

enrichment" approaches. These include applying various surface sealer products at widths 1 to 2 feet or "overbanding" with PG binder at a width of around 4 inches.

During Pavement Lay Down Operations:

1) Follow best practices to avoid mix segregation.
2) Balance plant production, trucking, lay down, and rolling operations to ensure a constantly moving paving operation without stops and starts. Material Transfer Vehicles (MTVs) can help.
3) Use a string line and follow it with a guide attached to the paver in order to produce a straight (or smooth for curves) pass on the first pull.
4) Apply adequate tack coat uniformly to the full width of the paving lane.
5) Ensure the dump person guides the trucks correctly to the paver without bumping or interrupting the constant speed of the paver and not letting the hopper run low.
6) Use paver automation. A critical element to getting joint density is having sufficient depth of material at the longitudinal joint on the hot-side.
    - A joint matcher provides the best opportunity to place the correct depth to match the cold side consistently. The optimal mounting location is a few feet in front of the auger.
    - The use of a ski (versus the joint matcher) is ideal to achieve smoothness but is not ideal to consistently match the joint by providing the optimum depth of asphalt mix.
    - Multiple lifts offer the opportunity to use a ski on intermediate lifts for smoothness and a joint matcher on surface lift for a good joint.
    - Another way of achieving both smoothness and joint density is to use a joint matcher when closing a joint but run a ski on the mat's other side.
7) Coordinate paver and auger speed to allow for a uniform head of material across the entire width of the paver. Maintain paver and auger speed.
8) Extend augers and tunnels to within 12 to 18 inches of the end gate to ensure a continual supply of fresh material flows out to the gate and is not pushed (segregated).
9) Set the end gate properly to firmly seat on the existing pavement surface.
10) Ensure the vibrator screed is turned on all the time, even when the boss or inspector is not around. If paver automation is set correctly, the operator should not need to stand on the screed.
11) When closing a butt or notched wedge joint, overlap by 1 inch, +/- ½ inch. If the joint is milled or cut back, the overlap should be approximately ½ inch.
12) Avoid luting or raking the overlapped material, assuming the proper overlap (previous bullet). If the overlap exceeds 1.5 inches, carefully remove the excess with a flat-end shovel. Do not broadcast excess material across the mat.
13) Place enough material on the hot-side of the joint so that, after rolling, the surface is slightly higher (0.1 inch) than the cold side. This ensures the joint was not starved of material and no bridging of the roller occurred, allowing for good compaction at the hot-side of the joint.

Treating the Cold Side Joint Face

1) Consider the use of infrared joint heaters, especially in cold weather paving. Studies have shown that heaters can improve joint density by 1-2%. Equipment improvements include longer and more efficient infrared heaters and automation with paver speed to minimize overheating or under-heating.
2) Evaluate the use of joint adhesive (JA), which is a hot-applied rubberized asphalt sealant applied to the open face of longitudinal joints. The use of this material is growing, as agencies believe it seals and improves the durability of the joint. Research also indicates improved performance. Various JA products are available.
3) At a minimum, tack the face of the joint with the same material (emulsion or asphalt cement) being used to tack the mat.
    - If using an emulsion, double tack the joint face.
    - Alternatively, consider using a PG binder to provide greater residual binder.
    - The best material to treat the open face, although the most expensive, is a JA.

During Rolling and Compaction

1) Compact the unconfined edge of the mat with the first pass of vibratory roller drum extended out over the edge of the mat approximately 6 inches.
    - An alternative method is to make the first pass of the vibratory roller 6 inches back from the unconfined edge, and then extend the drum out over the unconfined edge on the second pass. With this method, watch for stress cracks that may develop parallel to, and 6 inches off, the joint. The best method to roll the edge may be mix and lift thickness dependent.
2) Compact the confined edge of joint with the first pass of vibratory roller drum on the hot mat but staying back from the joint 6 to 8 inches on first pass. The second pass should then overlap onto the cold mat 4 to 6 inches. With this method, watch for any stress cracks developing in the mat that are parallel and 6 to 8 inches off the joint.
    - An alternative method is to have the first pass of the vibratory roller on the hot mat overlapping 4 to 6 inches onto the cold mat. A major concern with this method is that if an insufficient depth of asphalt mix is placed (starving the joint), the roller will bridge over and not compact the hot material completely.
3) Encourage the use of rubber tire rollers for intermediate rolling (not finish rolling) of the hot side of the joint to knead the loose material into the joint. The edge of the front outside rubber tire should run just on the inside edge of the joint, and the back outside tire can then straddle over the joint. Rubber tire rollers should not be operated close to the unsupported joint edge due to excessive lateral movement.

Specification Approaches and Examples

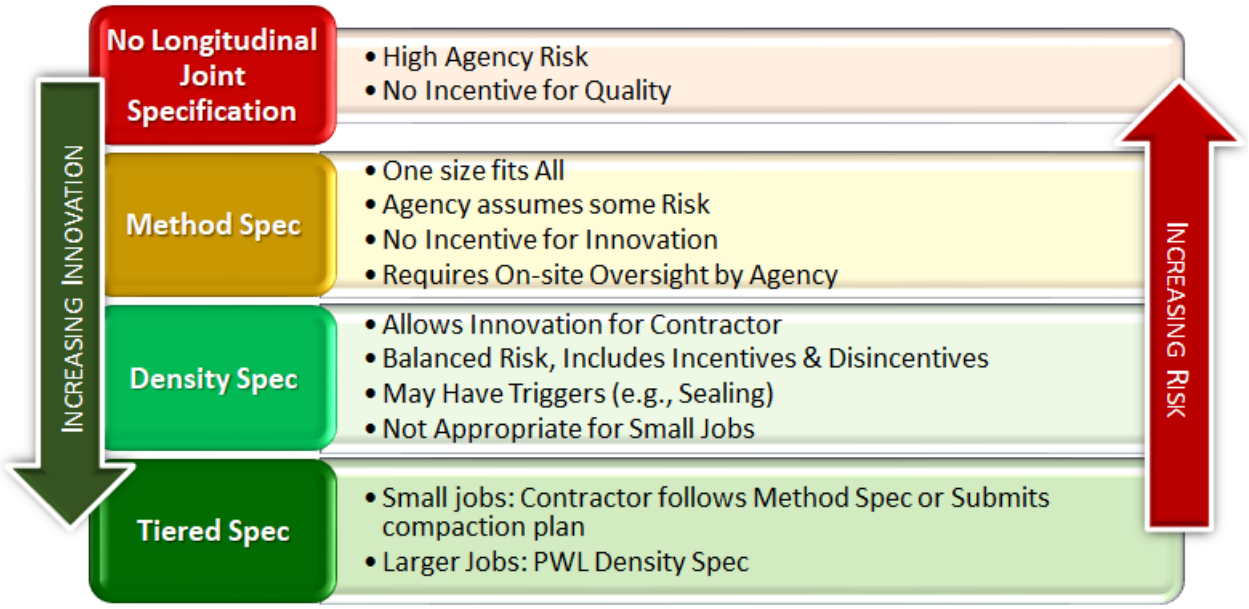

Figure 10. Relationship between Risk and Innovation.

1) States that do not significantly address the quality of longitudinal joints in their specifications have historically found that their joint densities, when taken, are on average 2-5% lower than their mat densities. Multiple research projects have recommended specifying a minimum joint density of 2% lower than the mat density, and/or a minimum of 90% theoretical maximum density (TMD), which is 10% in-place air voids.
2) For the asphalt mat and the joint to be relatively impermeable, in-place air voids need to be less than 7-8%, with most surface mix types used on high-volume roadways. Yet, good joint construction practices typically achieve between 8-10% in-place air voids. This is the reason the area around the longitudinal joint will often deteriorate before the rest of the mat, and why achieving the highest possible in-place joint density is critical.
3) The exact testing location around the longitudinal joint will have a major influence on the relative joint density measurement value. Densities just off the unsupported edge will typically be lower than those just off the confined edge or substantially away from the joint. Densities on either side tend to increase as the distance increases from the joint.
4) Within State agency specifications, there is a wide variation regarding mat density requirements, testing method (cores versus gauges), frequency, analysis (PWL versus average), incentives/disincentives, etc. There is an even greater degree of variation regarding how States address longitudinal joints in their specifications. At the beginning of this project, approximately one-third of States had some type of minimum density requirement at the joint. While there is no single best approach for every agency or application, the following acceptance criteria are suggested as a starting point for States looking to implement a longitudinal joint specification. These assume a large enough project where a statistically based sample size is attainable.

- Cut 6" cores, centered directly over visible joint for butt joints, or centered over wedge for wedge joint. These core locations provide an approximate 50/50 split between the two lots, whose Rice values can then be averaged and used.
- Example: Pay scale for longitudinal joint density:
  - ≥ 92% of TMD: earns a maximum bonus.
  - Between 92% and 90% of TMD: 100% pay and pro-rated bonus.
  - < 90% of TMD: reduced payment, and require the joint be sealed by either overbanding (with a PG binder) or a surface seal product.
- For joint densities less than 92%, knowing the joint is still likely permeable, consider sealing either by overbanding or the use of a surface seal product.

5) A contractor's quality control program should include the following.
   - Construct a complete longitudinal joint as part of the test strip.
   - Determine the optimum rolling pattern for density at the joint.
   - Monitor joint density for each lane and both edges with a density gauge that is calibrated to mat cores. Set the gauge parallel to the joint, with the gauge edge offset 2" from the visible joint. The gauge cannot seat properly if placed directly over the joint. Take the average of 2 (or 4) 1-minute readings, rotating 180 degrees between each.
6) Key steps in implementing a new longitudinal joint specification:
   - Agency and industry work together
   - Training (best practices, possible alternatives)
   - Establish a baseline of existing joint densities (randomly selecting projects to test)
   - Make incremental changes (trying different techniques, products, or specs)
   - If requiring a minimal density for the first time, take incremental steps:
     i) The first year require "report only" (calculate any bonus/penalty without adding/subtracting dollars)
     ii) Gradually increase density requirement to reach 90%, or possibly higher, as it can be shown to be accomplished on a regular basis.
   - Evaluation Plan: Measure densities to compare to baseline densities, monitor joint performance, etc.