Practices and Guidelines for Temporary Transverse HMA Tapers

Requested by
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The Caltrans Division of Research and Innovation (DRI) receives and evaluates numerous research problem statements for funding every year. DRI conducts Preliminary Investigations on these problem statements to better scope and prioritize the proposed research in light of existing credible work on the topics nationally and internationally. Online and print sources for Preliminary Investigations include the National Cooperative Highway Research Program (NCHRP) and other Transportation Research Board (TRB) programs, the American Association of State Highway and Transportation Officials (AASHTO), the research and practices of other transportation agencies, and related academic and industry research. The views and conclusions in cited works, while generally peer reviewed or published by authoritative sources, may not be accepted without qualification by all experts in the field.

Executive Summary

Background

During hot mix asphalt (HMA) construction and rehabilitation, partially completed pavements are often opened to traffic between construction periods. This results in transverse dropoffs at the transition between pavements of different elevations. Caltrans follows the common practice of constructing transverse tapers (or wedges) of hot mix asphalt between the different pavement levels.

Practices vary greatly nationwide for temporary transverse HMA tapers on such factors as taper slope; HMA mix design; and requirements based on dropoff height and speed limit. Best practices on creating such tapers are of interest to Caltrans, since tapers that are too abrupt for conditions may result in a rough ride for motorists. We conducted this Preliminary Investigation to scope recommended practices for temporary transverse HMA tapers.

Note that longitudinal pavement dropoffs, such as those between lanes of traffic or between a lane and the shoulder or curb, are beyond the scope of this investigation.

Summary of Findings

We conducted **Interviews with Experts and Practitioners** on the topic of temporary transverse HMA tapers, including representatives from New York State DOT, the National Center for Asphalt Technology (NCAT) and the Federal Highway Administration (FHWA). We also found limited **Guidance Documents** on the design and construction of such tapers. Given the minimal amount of research available on this topic, we conducted an **Online Survey of State Practice**; based on the survey results and individual state specifications found online, we summarized and analyzed statewide practices. Finally, we provided references for a prefabricated ramp as a possible **Alternative Treatment** for transverse dropoffs.

Interviews with Experts and Practitioners

- Discussions with representatives from FHWA and NCAT provided possible reasons explaining why longitudinal dropoffs have been more carefully studied than transverse dropoffs.
- An NCAT representative provided additional perspective on temporary transverse tapers, describing two ways in which the actual construction of tapers varies from how they are typically specified.
- A New York State DOT representative provided a practitioner's perspective on temporary HMA tapers, explaining how such tapers should meet an agency's needs while being specified only as much as necessary.

Guidance Documents

- As a reference, we provided the Caltrans Standard Special Provision 15-670, "Cold Plane Asphalt Concrete Pavement," which provides for a temporary taper slope of 30:1 horizontal to vertical. (Following Caltrans' convention, slopes are expressed as horizontal to vertical in this document, unless otherwise noted.) We also listed five related Caltrans Standard Special Provisions (39-050, 39-100, 39-150, 39-200 and 39-700) as additional references.
- The book *Asphalt Pavements: A Practical Guide to Design, Production and Maintenance for Engineers and Architects* provides detailed, step-by-step guidance on transverse joint construction.
- Research conducted by the Texas Transportation Institute provides general guidance on acceptable permanent taper slopes.

Online Survey of State Practice

- We conducted an online survey of the American Association of State Highway and Transportation Officials (AASHTO) Subcommittee on Construction and the AASHTO Subcommittee on Safety Management to review state practices, specifications and research efforts on temporary transverse HMA tapers. The responses from 18 states were compiled along with specifications found online for another three.
- One-third of the 18 responding states do not specify their temporary transverse HMA tapers.
- Among the states that do specify temporary transverse HMA tapers:
    - Five provide for different slopes based on traffic speed.
    - Four provide for different slopes depending on how long the tapers will be in place.
    - One provides for different slopes for leading and trailing transitions.
    - Four states include specification language on the taper mix.
- We compiled a table of taper slopes for all states included in the survey or the Internet search. California's specified slope of 30:1, used for temporary HMA tapers during cold planing, is slightly steeper than the median value.

Alternative Treatment

- One manufacturer produced a possible alternative to temporary HMA tapers: a prefabricated, reusable polymer ramp that is temporarily screwed into place on the roadway.

Gaps in Findings

The lack of research on temporary transverse HMA tapers is apparent. With little documented justification behind the wide spectrum of state practices, it is unclear which, if any, represents a best practice.

In addition, our investigation did not reveal the scope of the possible safety issues related to vehicle impacts caused by abrupt temporary HMA tapers, such as personal injury, vehicle accidents, pavement damage and possible related legal issues.

Finally, we did not find significant resources on international practices on temporary transverse HMA tapers. The Canadian provinces were included in the online survey; however, their representatives did not participate.

Next Steps

Caltrans might consider the following related to temporary transverse HMA tapers:

- The **Interviews with Experts and Practitioners** section of this Preliminary Investigation identifies construction methods for HMA tapers that do not match their ideal specifications. To assess whether Caltrans' specified 30:1 taper slope is sufficient, Caltrans may want to analyze current taper construction methods: Are they built at a 30:1 slope? How blunt or truncated are the leading edges of the current tapers?
- A leading transition (or an increase in elevation) may need a taper with a more gradual slope than a trailing transition (or a decrease in elevation). The hazards of a leading edge and the need for a sufficiently gradual slope may be of particular concern for motorcycles. The practice of having a different taper requirement for a leading edge compared with a trailing edge, as specified by Connecticut DOT, may be worth investigating further.

- Caltrans does not specify different taper slopes based on speed limits or exposure period. Caltrans may wish to examine more carefully the specifications of those states that do in the **Online Survey of State Practice** section of this Preliminary Investigation to see if specifying such different slopes based on these types of distinctions would make sense in California.
- Similarly, many of the other state practices listed in the **Online Survey of State Practice** section may suggest specification changes for Caltrans.
- The **Gaps in Findings** section of this report points to a lack of research on temporary transverse HMA tapers and suggests the possibility of studies in a number of areas, such as the effect of differently sloped tapers on different kinds of vehicles traveling at different speeds, or how well current tapers hold up in the short term and the long term.
- The use of an alternative treatment, such as a prefabricated ramp, may be worth investigating further or testing on a trial basis.

Contacts

During the course of this Preliminary Investigation, we spoke to the following individuals:

Federal Highway Administration

Cathy Satterfield
FHWA Office of Safety
Roadway Departure Team
(708) 283-3552, cathy.satterfield@dot.gov

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FHWA Resource Center
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National Center for Asphalt Technology

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New York State DOT

Brian DeWald
Acting Assistant Director for Construction
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Interviews with Experts and Practitioners

We discussed temporary transverse HMA tapers with experts at FHWA and NCAT. The consensus is that while treatment of longitudinal dropoffs is a well-researched topic and remains a high-priority issue, they believed there was little, if any, research on temporary transverse joints. Several reasons were given for the apparent lack of interest in researching this issue:

- Based on how vehicles' tires interact with pavement dropoffs in both the transverse and longitudinal configurations, the amount of wear and damage done by traffic on a longitudinal dropoff is significantly higher than on a transverse dropoff.
- There is also a greater safety issue with longitudinal joints: The loading impact a vehicle experiences from encountering a transverse dropoff will likely be less hazardous than the swerving and loss of control caused by a longitudinal dropoff. Longitudinal dropoffs are particularly hazardous for motorcycles.
- As a temporary feature during construction, any perceived vehicle impact hazards associated with transverse tapers could be addressed with signage or construction speed limits.

Federal Highway Administration

FHWA's longitudinal dropoff treatment program is described in detail on its web page, The Safety Edge (http://safety.fhwa.dot.gov/roadway_dept/pavement/safedge/fhwasa09023/). Three contacts at FHWA were unaware of research or programs at the federal level on transverse dropoffs.

National Center for Asphalt Technology

Mike Heitzman, NCAT's assistant director, provided additional thoughts on temporary transverse tapers:

- Although some states specify a slope or grade for its temporary transverse tapers, in practice they are seldom built to specifications, but instead are built at a steeper, or more abrupt, slope. This is particularly true when a taper will only be used for a very short period, such as overnight. If a taper will be needed for an extended period of time, such as between paving seasons, often a contractor will be asked to fix a taper that does not meet specifications.

- A taper is idealized in specifications as a perfect triangle:

In reality, this is impossible to achieve. The point of the taper is limited by the largest aggregate in the mix. What is created instead is a truncated triangle:

The coarser the aggregate, the more the tip of the taper will be truncated or blunted.

New York State DOT

We spoke to Brian DeWald, New York State DOT's acting assistant director for construction, to get a practitioner's perspective on this topic. As shown in the **Online Survey of State Practice** section of this report, New York has a

detailed specification, with taper slope requirements that vary with speed limit and the exposure time in days that the taper will be used.

DeWald commented further on the impossibility of creating a perfect triangle, noting that to minimize having a blunt nose or truncation at the tip of the triangular taper, contractors in New York will typically use a fine mix, though not a sand mix.

He said that from his perspective, having a taper that performs in a satisfactory manner is the responsibility of the contractor. Since it is only a temporary feature that will not be part of the finished pavement, DeWald did not see the need to overspecify a taper, such as by providing mix requirements, as long as it functions properly.

Guidance Documents

Selected guidance documents may be of interest to Caltrans. As a reference, we included Caltrans' own standard special provisions on HMA tapers. In addition, we included a guide that provides detailed instruction on temporary taper design and installation as well as a research citation on common permanent transition slopes.

Caltrans Standard Special Provisions
http://www.dot.ca.gov/hq/esc/Translab/ope/PavementSpecs_SSPs.html
Caltrans Standard Special Provisions are "used with construction contracts to amend, supplement and incorporate the Caltrans Standard Specifications." Standard Special Provision 15-670, "Cold Plane Asphalt Concrete Pavement" (http://www.dot.ca.gov/hq/esc/oe/specifications/SSPs/2006-SSPs/Sec_10/15/15-670_E_A06-05-09.doc), provides the following language:

> If a drop-off between the existing pavement and the planed area at transverse joints cannot be avoided before opening to traffic, construct a temporary HMA taper. HMA for temporary taper must be:
>
> 1. Placed to the level of the existing pavement and tapered on a slope of 30:1 (Horizontal:Vertical) or flatter to the level of the planed area.
> 2. Compacted by any method that will produce a smooth riding surface.
> 3. Completely removed before placing the permanent surfacing. The removed material must be disposed of outside the highway right of way in conformance with the provisions in Section 7-1.13, "Disposal of Material Outside the Highway Right of Way," of the Standard Specifications.

Standard Special Provisions to Caltrans Standard Specification Section 39, "Hot Mix Asphalt," provide additional language on HMA relevant to the construction and use of temporary HMA tapers. Each provision addresses "Vertical Joints" within the section titled "Construction":

- SSP 39-050, "Hot Mix Asphalt" (http://www.dot.ca.gov/hq/esc/oe/specifications/SSPs/2006-SSPs/Sec_10/22-42/39-050_E_A06-05-09.doc).
- SSP 39-100, "Hot Mix Asphalt Open Graded Friction Course" (http://www.dot.ca.gov/hq/esc/oe/specifications/SSPs/2006-SSPs/Sec_10/22-42/39-100_E_A06-05-09.doc).
- SSP 39-150, "Rubberized Hot Mix Asphalt (Gap Graded)" (http://www.dot.ca.gov/hq/esc/oe/specifications/SSPs/2006-SSPs/Sec_10/22-42/39-150_E_A06-05-09.doc).
- SSP 39-200, "Rubberized Hot Mix Asphalt (Open Graded) or Rubberized Hot Mix Asphalt (Open Graded High Binder)" (http://www.dot.ca.gov/hq/esc/oe/specifications/SSPs/2006-SSPs/Sec_10/22-42/39-200_E_A06-05-09.doc).
- SSP 39-700, "Bonded Wearing Course – Open Graded" (http://www.dot.ca.gov/hq/esc/oe/specifications/SSPs/2006-SSPs/Sec_10/22-42/39-700_E_A07-31-09.doc).

Caltrans' specifications for permanent tapers are available at http://www.dot.ca.gov/hq/esc/Translab/ope/Pavement-Tapers-&-Transitions-Guide.pdf.

Asphalt Pavements: A Practical Guide to Design, Production and Maintenance for Engineers and Architects, 2003.
Citation at http://www.worldcat.org/oclc/53158359
This textbook, available in print and e-book formats, provides guidance on transverse joint construction. The section on transverse joints, pages 256-257, provides step-by-step instructions and considerations for taper construction and removal. This section is excerpted below.

Note that the 1990 National Asphalt Pavement Association publication cited in the text below is **Hot Mix Asphalt Joint Construction, Quality Improvement Series 115**. The citation for that publication is available at http://www.worldcat.org/oclc/41847899.

Transverse joints

A transverse joint can occur at the beginning or end of any point in the paving operation. It is perpendicular to the direction of the mat being placed. Two types of transverse joints are used in the construction of asphalt pavements (Figure 6.11):

- Butt joints are constructed if traffic will not be passing over the end of the pavement before paving is resumed. Butt joints are joints with a vertical face. Butt joints are commonly used in new construction, especially parking lots.

- Tapered joints are used if traffic will be traveling on the pavement before paving is resumed. The taper allows for the transition of traffic to the layer below. The tapered portion is removed when paving resumes, leaving a vertical joint for the new lift to butt up against.

All transverse joints used in asphalt pavement construction are actually a type of butt joint. More specifically however, a butt joint is a joint where traffic will not be allowed to travel over the unsupported edge of the unfinished joint. A taper joint allows traffic to travel over it through the use of a temporary ramp that is formed to protect the vertical edge of the unfinished joint (NAPA 1990). The temporary ramp is the taper in the taper joint. The taper is then removed prior to the resumption of paving, leaving a vertical face or butt joint.

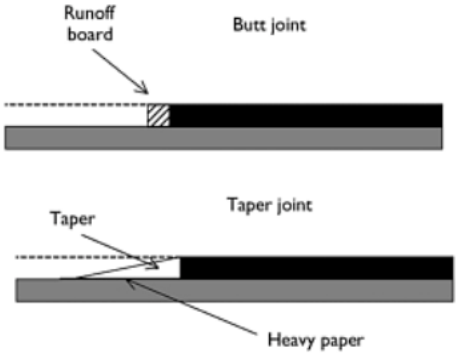


Figure 6.11 Transverse joints.

Transverse joint construction

The paver should be run right up to the point where the transverse joint will be constructed. The head of material in front of the screed should remain as consistent as possible up to the location of the joint. The forces acting on the screed should be constant so that a consistent angle of attack will be maintained for the screed. The goal is to have the same thickness at the joint as has been previously laid; otherwise a surface deviation will occur at the joint. If at all possible, the transverse joint should be located while the head of material is constant or normal. In other words, the transverse joint should not be located where the hopper would empty out at the

end of the day. If this occurs, the head of material in front of the screed will decrease, causing the screed angle of attack to decrease, resulting in a thinner mat at the location of the transverse joint. The thinner mat will translate into a surface deviation or dip in the asphalt pavement at the joint. If the joint is made where the head of material is constant, the paver screed is raised up at the point where the transverse joint will be constructed. All of the mixture in front of the joint will need to be removed, except for the taper, if constructing a tapered joint. A vertical edge is formed by temporarily pushing aside the asphalt mixture in front of the intended location of the joint. Placing a strip of heavy paper, such as kraft paper, down in front of the paver will facilitate the removal of the taper when paving is resumed. The width of the paper is the width of the layer being paved while the length should be about 1 m. The asphalt mixture that was previously removed is then shoveled back on top of the paper and a ramp is formed with a lute (a type of construction rake). When constructing the ramp, the required lift thickness should be continued for about 150 mm past the location of the joint to ensure that the full compacted lift thickness will be attained at the joint (NAPA 1990). What should be left is gradual taper leading down to the layer below. The taper allows traffic to be allowed on the pavement until paving is ready to resume. Taper joints are mostly used on highways and roads and sometimes on parking facilities undergoing rehabilitation. Taper joints are also used when placing the mainline portion of the parking lot prior to the construction of the entrances and approach aprons. This allows vehicles to use the facility during construction. When paving is resumed, the taper is removed mechanically with the assistance of the kraft paper, leaving a vertical or butt joint. An application of a tack coat or rubberized crack filler is applied to the face of the vertical joint to help ensure a tight joint. The paver is brought on the previously placed layer close to the joint. The screed is placed up on starting blocks that have a thickness that is 1.25 times the desired compacted lift thickness. For example, if the compacted design lift thickness is 100 mm, the blocks should be about 125 mm thick. Placing the screed up on these blocks prior to the commencement of paving helps ensure that there will not be a dip at the joint. This procedure should be applied during the construction of any type of transverse joint. During the startup of asphalt paving, when there is no joint to place the lift up against, the starting blocks should be the same thickness as the uncompacted lift thickness being placed. A proper head of asphalt mixture is fed to the screed prior to being moved off the starting blocks. The paver then begins moving and brought up to the correct paver speed (NAPA 1990).

Best Practices of Concrete Pavement Transition Design and Construction, Texas Transportation Institute, 2007.
http://tti.tamu.edu/documents/0-5320-1.pdf
This reference provides guidance on acceptable permanent taper slopes. While it only addresses permanent transition tapers, it may be informative for Caltrans. Page 42 of the PDF provides rate of transition taper on pavement overlays:

The Minnesota DOT has studied transition design practices regarding the rate of transition tapers at the beginning and end of pavement overlays. Although no standard has been adopted, taper rates used throughout the state range from about 1:240 to 1:600. Experience in Minnesota indicates that a transition taper of 1:400 results in an acceptable ride at high speeds. A recent survey of other state DOTs indicated that 1:400 is typical of taper rates used nationwide. In order to provide pavement overlay transitions that provide a smooth ride and are economical, the rate of transition taper on pavement overlays should be determined from the values in Table 2-1.

Table 2-1 Rate of Transition Taper on Pavement Overlays

Design Speed	**Rate of Taper**
50 mph or greater	1:400
35 to 45 mph	1:300
30 mph or less	1:200

Online Survey of State Practice

Based on the lack of existing research in the area of temporary transverse HMA tapers, we conducted a brief online survey of individuals who were likely to have knowledge of state practices, specifications and research efforts on this topic. The distribution list for this survey included representatives from the AASHTO Subcommittee on Construction and the AASHTO Subcommittee on Safety Management. The survey consisted of the following questions:

1. What are your agency's requirements for tapering temporary transverse edges that occur during HMA pavement construction and rehabilitation? If possible, please include limits on wedge slope, mix requirements for the tapered joint, quality control measures and other requirements dependent on edge height, traffic control, speed limit in the construction zone or other factors. (Please note that Caltrans is not seeking input on longitudinal pavement edges at this time.)
2. Please attach or provide a link to your agency's specifications or guidance documents on this topic.
3. Has your agency conducted any research or gathered data in support of its specifications or requirements? If so, please provide details.
4. What is the name, phone number and e-mail address of the appropriate person in your agency to talk to about this topic?

Eighteen state agencies responded to this survey. In addition, we had found online guidelines for three additional states prior to conducting the study. The results from both the survey and the online search are presented here. The full text of the survey responses and online findings is given in the **Survey and Internet Search Results** section on page 11 of this report.

Key Findings

- Of the 18 states that responded to the survey, six (Kansas, Louisiana, New Mexico, North Dakota, Texas and Utah) do not have formal specifications for temporary transverse HMA tapers.
    - North Dakota has a brief plan note on temporary asphalt tapers.
    - In their full survey responses, Texas and Utah provided typical practice in their states.
    - It is noted in the response from Texas: "To my knowledge, we have not conducted research on this issue. It's really never been a problem."

  In addition, three states (Arkansas, Connecticut and Kansas) included specification information for permanent tapers in their survey responses.
- Five states provide for a different taper slope based on the speed of traffic. The speed above which the taper must be more gradual varies by state:
    - Connecticut: 35 mph.
    - Maryland: 40 mph.
    - New York: 45 mph.
    - Arkansas: 55 mph.
    - Missouri states that shorter tapers may be permissible "due to lower speed and traffic volume on the roadway."
- Four states provide for a different taper slope based on total time of exposure:
    - Arkansas: 7 days.
    - New York: 7 days.
    - Oregon: 24 hours.
    - Iowa: end of the day versus the end of season.
- Connecticut provides for different slopes for leading transitions (180:1) and trailing transitions (72:1) on roads with traffic speeds greater than 35 mph.
- Vermont discussed speed limit reductions when using temporary transverse tapers: "Generally a legal 10 mph reduction in speed over normally posted speed limit."

- Four states discussed mix specifications in their survey responses:
    - Connecticut species a Superpave mix: HMA 0.5 or HMA 0.375.
    - Maryland specifies: "Mix will be from an approved mix from the original contract documents."
    - North Dakota calls out a Superpave specification: "All costs associated with labor, materials and equipment for the installation and removal of the asphalt wedges shall be included in the price bid for 'Superpave FAA 45.' "
    - Vermont specifies the mix as "in the same lot as and same mix as adjacent mat." It also calls for the same quality control measures as the adjacent mat.

Below is a summary we compiled of specified transverse taper slopes.

- California's specified slope of 30:1 (see the **Guidance Documents** section of this report) is a middling value but toward the shorter and steeper side among other states.
    - Five states provide for steeper, more abrupt slopes than California at least some of the time.
    - Ten states provide for shallower, flatter slopes than California.

State	**Slope of temporary transverse HMA tapers,** ranked from most to least abrupt
Alaska	From 3.7:1 (15 degrees) to 2.1:1 (25 degrees)
New York	<u>In place 7 days or less</u> Speed limit ≤ 45 mph: 6:1 Speed limit > 45 mph: 10:1 <u>In place more than 7 days</u> Speed limit ≤ 15 mph: 15:1 Speed limit > 45 mph: 30:1
New Jersey	20:1
Illinois	24:1
Vermont	24:1
California	**30:1**
Nebraska	36:1
Arkansas	<u>In place less than 7 days</u> Speed limit ≤ 55 mph: 36:1 Speed limit > 55 mph: 48:1 <u>In place 7 days or more</u> Speed limit ≤ 55 mph: 60:1 Speed limit > 55 mph: 120:1
Oregon	In place under 24 hours: 40:1 In place 24 hours or longer: 160:1
Hawaii	48:1
Connecticut	<u>Roadways 35 mph or less</u> Leading and trailing transitions: 48:1 <u>Roadways greater than 35 mph</u> Leading transitions: 180:1 Trailing transitions: 72:1
Maryland	Speed limit ≤ 40 mph: 48:1 Speed limit > 40 mph: 120:1
Utah	50:1
Michigan	60:1
Iowa	Temporary (end of day): 120:1 Winter shutdown (end of season): 300:1
Missouri	1200:1; can be shortened to 600:1 due to lower speed and traffic volume on the roadway
Kansas	None
Louisiana	None

New Mexico	None
North Dakota	None
South Carolina	None
Texas	None

Survey and Internet Search Results

The full text of each survey response is provided below. For reference, we have included an abbreviated version of each question before the response. Included among these survey results are specifications found online for three additional states (Hawaii, Illinois and Michigan).

Alaska

1. **Agency requirements for temporary transverse HMA tapers:** Our specs are silent on the tapered treatment of transverse paving joints, except to say that they must be saw-cut back or formed against a removable bulkhead on a 15- to 25-degree skew. (See Subsection 401-3.14.)
2. **State specification or guidance documents:** http://www.dot.state.ak.us/stwddes/dcsspecs/assets/pdf/hwyspecs/english/2004sshc.pdf
3. **Supporting research or data:** No.
4. **Contact:** Charles W. Correa, Alaska Department of Transportation, chuck.correa@alaska.gov

Arkansas

1. **Agency requirements for temporary transverse HMA tapers:** On roads under traffic, the mixture shall be spread and finished in full lane widths where practicable. The paver shall alternate between the lanes with such frequency that the adjacent lane shall be laid no later than the next working day after the first lane is laid. A transition area from the new pavement down to the existing pavement will be constructed at the beginning and ending of each day's paving operation. The length of the transition will be based on the thickness of the ACHM course being placed:

Roadway Type	Short Term Temporary (In-place for less than 7 calendar days)	Temporary (In place for over 7 days)	Permanent
Interstates & divided highways with speed limits > 55 mph	4 ft. (1.2 m) length for each 1″ (25 mm) of thickness	10 ft. (3.0 m) length for each 1″ (25 mm) of thickness	100 ft. (30.5 m) length for each 1″ (25 mm) of thickness
Other highways with speed limits ≤ 55 mph	3 ft. (0.9 m) length for each 1″ (25 mm) of thickness	5 ft. (1.5 m) length for each 1″ (25 mm) of thickness	50 ft. (15.2 m) length for each 1″ (25 mm) of thickness

2. **State specification or guidance documents:** http://www.arkansashighways.com/standard_spec/2003/03-400.pdf, page 53 of the PDF.
3. **Supporting research or data:** [No response.]
4. **Contact:** Jerry W. Trotter, Staff Construction Engineer, State Highway and Transportation Department, (501) 569-2570, jerry.trotter@arkansashighways.com

Connecticut

1. **Agency requirements for temporary transverse HMA tapers:** Temporary HMA tapers are included in Section 4.06, Bituminous Concrete of State of Connecticut Department of Transportation Standard Specifications for Roads, Bridges and Incidental Construction, Form 816, as a ConnDOT Owned Special Provision revision dated January 13, 2009. Language is:

   6. Transitions for Roadway Surface: Transitions shall be formed at any point on the roadway where the pavement surface deviates, vertically, from the uniform longitudinal profile as specified on the plans. Whether formed by milling or by bituminous concrete mixture, all transition lengths shall conform to the criteria below unless otherwise specified.

   Permanent Transitions: A permanent transition is defined as any transition that remains as a permanent part of the work. All permanent transitions, leading and trailing ends shall meet the following length requirements:

   a) Roadways greater than 35 MPH = 30 feet per inch of vertical change (thickness).
   b) Roadways 35 MPH or less = 15 feet per inch of vertical change (thickness).
   c) Bridge Overpass and underpass transition length will be 75 feet either:
      (1) Before and after the bridge expansion joint, or
      (2) Before or after the parapet face of the overpass.

   In areas where it is impractical to use the above described permanent transition lengths the use of a shorter permanent transition length may be permitted when approved by the Engineer.

   Temporary Transitions: A temporary transition is defined as a transition that does not remain a permanent part of the work. All temporary transitions shall meet the following length requirements:

   a) Roadways greater than 35 MPH:
      (1) Leading Transitions = 15 feet per inch of vertical change (thickness).
      (2) Trailing Transitions = 6 feet per inch of vertical change (thickness).
   b) Roadways 35 MPH or less:
      (1) Leading and Trailing = 4 feet per inch of vertical change (thickness).

   Note: Any temporary transition to be in-place over the winter shutdown period, holidays, or during extended periods of inactivity (more than 7 calendar days) shall conform to the "Permanent Transition" requirements shown above.

   Mix requirement for HMA Transitions:

   Generally HMA 0.5 or HMA 0.375 (see provision for Superpave mix designations) will be used at temporary and permanent transitions. The quality control for mixes will be the same as HMA 0.5 and HMA 0.375 for roadway pavement.

   The Department also publishes an FAQ for guidance in specification administration.

   FAQ section for transitions:

   Pavement Transitions – sometimes referred to as "key cuts"

   Q. What is the difference between a temporary and permanent transition?

   A. Temporary transition – normally formed during paving operation and is located at the end of the day's paving. The temporary transition is placed by the Contractor using a bond breaker (clean sand or paper) and formed by hand or by a paving machine. The next day the Contractor is responsible for saw cutting a sufficient distance back exposing the full depth of the mat, removal and disposal of transition material. Temporary transitions vary in length based on posted speeds and also whether located at the

leading or trailing end of the paving.

Temporary Transition

	Greater than 35 mph			Less than 35 mph	
Lift	Leading	Trailing		Leading	Trailing
1”	15’	6’		4’	4’
1-½”	23’	9’		6’	6’
2”	30’	12’		8’	8’

Permanent transition – required to match the new overlay into the existing road and is done prior to start of overlay. These are normally formed using a milling machine. The length varies and is based on posted speeds. The length is the same for both the leading and trailing end.

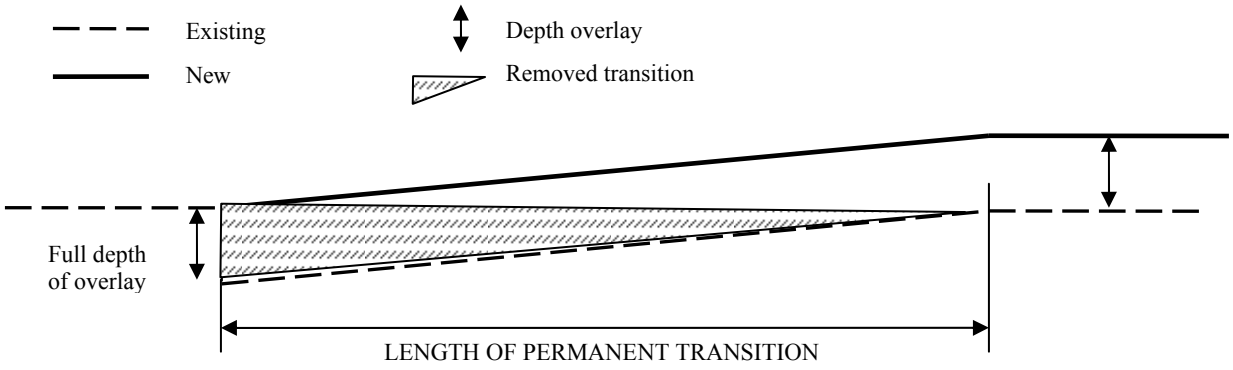
Permanent Transition

	Greater than 35 mph		Less than 35 mph	
Lift	Length		Lift	Length
1”	30’		1”	15’
1-½”	45’		1-½”	23’
2”	60’		2”	30’

For bridges – The transition shall be 75 feet on either side of the structure from the bridge joint or point on the road below the parapet face of the overhead structure.

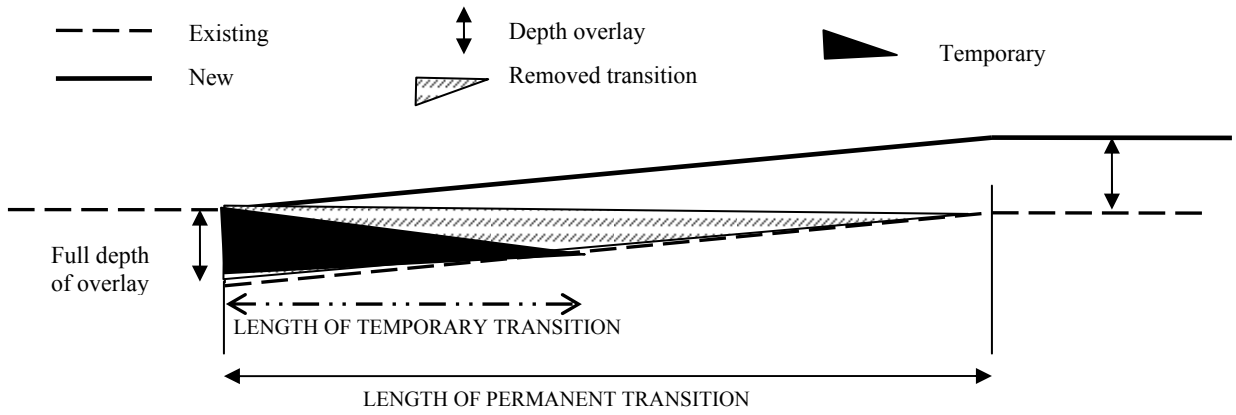
Q. What are the transition lengths for milling operation?

A. Transitions for milling and paving are the same. There are differences in how a transition is formed based on what the paving project involves and are described in methods below. For Method I or II, a temporary transition may need to be placed to ramp traffic from the existing to milled surface. This is formed with HMA and the length is in accordance with chart in A6 for temporary transitions.



Method I
Milling road at full depth – The large miller can form an edge by doing cross cut during milling operation or have small miller perform the cross cut either during milling or prior to paving. The milled edge of existing pavement should still be saw-cut prior to paving to achieve a clean vertical face.

Method II
Overlay existing road – The permanent transition commonly referred to as a touchdown will need to be formed to key the new overlay into the existing pavement without leaving a bump. The length of the permanent transition is set a certain distance (see chart in A6) to allow for the full depth of the overlay. The transition is normally formed with a milling machine that has a drum that is 32 inches or greater in width. Using a Barco miller to form transitions is not preferable because the drum is no more than 12 inches in width and would take too many passes to achieve the correct transition length and achieve a uniform depth.



2. **State specification or guidance documents:** http://www.ct.gov/dot/lib/dot/documents/dcontractdev/ownedspecs/english/0.128_sec4.06_bit._concrete.doc
3. **Supporting research or data:** The specifications are reviewed every couple of years and revised based on various research done by entities such as NCHRP and Asphalt Institute, internal studies and also by task groups that include Department and industry members. Most recent studies were on the longitudinal wedge joint and use of cores for correlating density results in field to acceptance.
4. **Contact:** Terri Thompson, Office of Construction, Pavement Advisory Team, Connecticut Department of Transportation, (860) 594-3259, terri.thompson@ct.gov

Hawaii

1. **Agency requirements for temporary transverse HMA tapers:**
   SECTION 415 - COLD PLANING OF EXISTING PAVEMENT, 415.03 Construction. (B) Planed Surface and Removed Material. For roadways open to traffic, cold plane each day across full width of traffic lane to avoid longitudinal pavement drop-off between passes. At end of each day's production, construct tapered transitions along longitudinal and transverse pavement drop-offs. Use maximum slopes of 6:1 for longitudinal and 48:1 for transverse tapered transitions. Limit drop-off depths to maximum of 3 inches. Remove transition material before resurfacing.
2. **State specification or guidance documents:** http://hawaii.gov/dot/highways/specifications2005/specifications/specspdf/specspdf-400-499/415_Print.pdf
3. **Supporting research or data:** [Finding based on Internet search.]
4. **Contact:** [Finding based on Internet search.]

Illinois

1. **Agency requirements for temporary transverse HMA tapers:** 24:1. See detailed drawing.
2. **State specification or guidance documents:** http://eplan.dot.il.gov/desenv/011510/78065-139/Plans/011510-78065-139-082-059-11x17.pdf
3. **Supporting research or data:** [Finding based on Internet search.]
4. **Contact:** [Finding based on Internet search.]

Iowa

1. **Agency requirements for temporary transverse HMA tapers:**
   Temporary (end of day) Runouts: 10 ft. in length per inch of lift thickness.
   Winter Shutdown (end of season) Runouts: 25 ft. in length per inch of lift thickness.
   For temporary runouts open to traffic for periods greater than 4 weeks, the Contractor may reduce the

amount of top size aggregate in the transition taper.

Other Requirements:

- Separate transverse construction joints in succeeding courses by at least 6 feet.
- Do not use wood or metal headers to form joint edge during rolling of the fresh mixture.
- Place suitable paper or burlap under the taper to prevent adhesion.
- Remove temporary runouts and winter shutdown runouts before commencing paving.
- Saw header to a straight line at right angles to the centerline to provide a full thickness vertical edge before continuing paving.
- Check resulting transverse construction joint for smoothness with a 10 foot straightedge (and correct as necessary) prior to compaction.

2. **State specification or guidance documents:** The above requirements are contained within Article 2303.03, C, 6 (HMA Construction - Joints and Runouts) of Iowa DOT Standard Specifications – Series 2009. The specification may be found at http://www.iowadot.gov/erl/current/GS/content/2303.pdf, page 10 of the PDF.
3. **Supporting research or data:** No.
4. **Contact:** Jeffrey D. Schmitt, HMA Paving Field Engineer, Office of Construction, Iowa Department of Transportation, (515) 239-1013, jeffrey.schmitt@dot.iowa.gov

Kansas (Response 1)

1. **Agency requirements for temporary transverse HMA tapers:** The only reference to transverse joints in our HMA specs deals with the permanent construction joint, not the temporary transverse edge:

   Transverse Construction Joints. Use a method of making transverse construction joints which shall provide a thorough and continuous bond, provide an acceptable surface texture and meet density requirements. Do not vary the surface elevation more that 3/16 inch in 10 feet, when tested longitudinally across the joint. When required, repair the joints or paving operations will be suspended.
2. **State specification or guidance documents:** (Specification for the permanent joint) http://www.ksdot.org/burconsmain/specprov/2007/DIVISION-600.pdf, page 14 of the PDF.
3. **Supporting research or data:** None.
4. **Contact:** Steven A. Buckley, State Highway Safety Engineer, Bureau of Transportation Safety & Technology, Kansas Department of Transportation, (785) 296-1148, Buckley@ksdot.org

Kansas (Response 2)

1. **Agency requirements for temporary transverse HMA tapers:** Kansas has no requirement for transverse tapers. Standard practice is to pave over a bond breaker and to taper it with the roller. The next day a vertical butt joint is sawed to form a vertical joint to abut to.
2. **State specification or guidance documents:** [No response.]
3. **Supporting research or data:** [No response.]
4. **Contact:** Roy Rissky, Kansas Department of Transportation, royr@ksdot.org

Louisiana

1. **Agency requirements for temporary transverse HMA tapers:** Our specifications are in 507.02 (c) (2) and 502.08 (a), but the temporary transverse joint is not fully addressed, but understood in the State and as directed by the PE.
2. **State specification or guidance documents:** http://www.dotd.louisiana.gov/highways/project_devel/contractspecs/2006_Part_V-Asphaltic_Pavements.pdf
3. **Supporting research or data:** None.

4. **Contact:** Charles Danny Smith, Louisiana Department of Transportation and Development, (225) 379-1568, charles.smith@la.gov, or Brian Buckel, Louisiana Department of Transportation and Development, (225) 379-1503, brian.buckel@la.gov

Maryland

1. **Agency requirements for temporary transverse HMA tapers:** MDOT's specification for temporary transverse tie-ins are that for when HMA paving is applied to roadways with a speed limit of less than or equal to 40 mph, the temporary tie-in must be at least 4 ft in length for each 1 in. of pavement depth. When HMA paving is being applied to the traveled way carrying traffic with a speed of >40 mph, a temporary tie-in must be constructed at least 10 ft in length for each 1 in. of pavement depth. This specification is required in HMA paving operations, as well as in milling and grinding operations during construction and rehabilitation. Mix requirements for the tapered edge are not specified, but will be from an approved mix from the original contract documents.
2. **State specification or guidance documents:** This specification can be found at http://www.marylandroads.com/ohd/part3.pdf, under Section 504, Hot Mix Asphalt Pavement, 504.03.09, Tie-In, page 338 of the PDF.
3. **Supporting research or data:** Maryland's State Highway Administration has rewritten this specification for the July 2008 Standard Specifications for Construction and Materials book along with input from the Maryland Asphalt Association.
4. **Contact:** John T. Shipley, Jr., Maryland State Highway Administration, (410) 802-7481, jshipley@sha.state.md.us

Michigan

1. **Agency requirements for temporary transverse HMA tapers:**

   Section 502.03. Transverse Construction Joint. When constructing a transverse construction joint, stop the paver and lift the screed before the material falls below the auger shaft; remove the paver and roll through the proposed joint location. Cut a transverse vertical joint and remove the excess HMA. Place burlap, canvas or paper as a bond breaker ahead of and against the vertical face. Place HMA against the bond breaker and taper from the new mat down to the existing surface. Extend the temporary taper 5 feet for each inch of mat thickness or as directed by the Engineer. Thoroughly compact and cool the temporary taper before allowing traffic on the new surface. Remove the temporary taper before resuming paving.
2. **State specification or guidance documents:** http://mdotwas1.mdot.state.mi.us/public/specbook/
3. **Supporting research or data:** [Finding based on Internet search.]
4. **Contact:** [Finding based on Internet search.]

Missouri

1. **Agency requirements for temporary transverse HMA tapers:** Normally the taper is 1-inch in 100-feet. There have been cases where the designers will shorten the taper to 1-inch in 50-feet due to lower speed and traffic volume on the roadway.
2. **State specification or guidance documents:** http://epg.modot.mo.gov/files/9/98/D-71.pdf
3. **Supporting research or data:** No.
4. **Contact:** John Donahue, Missouri Department of Transportation, (573) 526-4334, John.Donahue@modot.mo.gov

Nebraska

1. **Agency requirements for temporary transverse HMA tapers:**

   Subparagraph l. of Paragraph 5 (Placement Operations) of Subsection 503.04 (Construction Methods) of 503 (Asphaltic Concrete) of the Nebraska Standard Specifications says:

   > When placement is discontinued, a wedge of asphaltic concrete, feathered 3 feet (900 mm) in length for each inch (25 mm) of layer thickness, shall be placed at the end of the lane.

   Paragraph 3.c. of Subsection 510.04 (Construction Methods) of 510 (Cold Milling) of the Nebraska Standard Specifications says:

   > Transitions between milled and unmilled surfaces will be feathered either by milling or with wedges of bituminous material (maximum slope 1 vertical to 12 horizontal).

2. **State specification or guidance documents:**

   http://www.dor.state.ne.us/ref-man/specbook-2007.pdf, page 326 of the PDF for the asphalt wedge specification (page 347 of the PDF for milled and unmilled surfaces).

3. **Supporting research or data:** The 1-inch:3-ft wedge for HMA requirement first appeared in our 1985 specification. I do not know what research went into it. The 1:12 wedge for cold milling first appears in 1997 specification, prior to that wedge had to be placed as directed by the Engineer. I do not know what caused the change, nor do I know why the allowable slopes are different for cold milling and HMA.

4. **Contact:** Andy Dearmont, Assistant Construction Engineer, Nebraska Department of Roads, (402) 479-4451, andy.dearmont@nebraska.gov

New Jersey

1. **Agency requirements for temporary transverse HMA tapers:** HMA placed during the various construction stages shall be transitioned on a minimum 20H:1V slope to meet the adjacent existing grade at the transverse limits of the stage construction areas unless otherwise noted on the stage construction plans.

2. **State specification or guidance documents:**
   http://www.state.nj.us/transportation/eng/CADD/v8/v8TrafficDetails/pdf/100_TCD-1GeneralNotes.pdf, refer to general note 16.

3. **Supporting research or data:** No current research or data on file.

4. **Contact:** Ronald Maruca, Manager, Bureau of Construction Management, New Jersey Department of Transportation, (609) 530-5500, ronald.maruca@dot.state.nj.us

New Mexico

1. **Agency requirements for temporary transverse HMA tapers:** No specific requirements; tapers are as gradual as possible given geometric constraints.

2. **State specification or guidance documents:** None at present.

3. **Supporting research or data:** Not currently.

4. **Contact:** Elias Archuleta, New Mexico Department of Transportation, (505) 827-5100

New York

1. **Agency requirements for temporary transverse HMA tapers:**

   > Bumps and transverse irregularities shall be eliminated to the extent practical. Pavement joints and milling rebates resulting in longitudinal or transverse vertical faces exceeding 1 inch in height that would be exposed to traffic during non-work hours shall be sloped or tapered with temporary patches or shims providing a taper rate in accordance with Table 619-1, Required Taper Rate for Transverse Bumps.

Table 619-1 REQUIRED TAPER RATE FOR TRANSVERSE BUMPS			
Height of Bump (in)	**Associated Exposure Time (Calendar Days)**	**Posted Speed ≤ 45 mph**	**Posted Speed > 45 mph**
1 to 6	≤ 7	6:1	10:1
	> 7	15:1	30:1

2. **State specification or guidance documents:**
   Standard Specification Section 619-3.02, Basic Work Zone Traffic Control
   https://www.nysdot.gov/main/business-center/engineering/specifications/english-spec-repository/section600.pdf, pages 87-88 of the PDF.

   Standard Specification Section 402-3.09, Joints
   https://www.nysdot.gov/main/business-center/engineering/specifications/english-spec-repository/section400.pdf, page 34 of the PDF.
3. **Supporting research or data:** Guidance for signing to address motorcycle safety measures for construction pavement joints was addressed in Engineering Instruction EI 05-013 – Motorcycle Safety Measures on Milled Pavements – Revised Specifications.
   https://www.nysdot.gov/portal/pls/portal/mexis_app.pa_ei_eb_admin_app.show_pdf?id=6572

   Standard Specification Section 401-3.13 B was updated to permit the use of the tapered wedge joint technique in Engineering Instruction EI 98-020 – Revisions to Standard Specification Section 401-3.13 B, Longitudinal Joints
   https://www.nysdot.gov/portal/pls/portal/mexis_app.pa_ei_eb_admin_app.show_pdf?id=1538
4. **Contact:** Thomas Melander, Office of Construction, New York State Department of Transportation, tmelander@ dot.state.ny.us, or Zoeb Zavery, Office of Technical Services, Materials Bureau, New York State Department of Transportation, (518) 485-5277, zzavery@dot.state.ny.us

North Dakota

1. **Agency requirements for temporary transverse HMA tapers:** The tapers are placed under the direction of the project engineer. The NDDOT does not use any specific guidance other than a plan note.
2. **State specification or guidance documents:** 410-PXX, Temporary Asphalt Wedges: The contractor shall place temporary asphalt wedges as directed by the engineer at milled or paving transition locations to allow a smooth transition for the passage of vehicles. All costs associated with labor, materials, and equipment for the installation and removal of the asphalt wedges shall be included in the price bid for "Superpave FAA 45."
3. **Supporting research or data:** No.
4. **Contact:** Greg Kolden, Senior Manager, Construction Services, North Dakota Department of Transportation, (701) 328-3734, gkolden@nd.gov

Oregon

1. **Agency requirements for temporary transverse HMA tapers:**
   00745.62 Transverse Joints.
   (a) Travel Lanes – Construct transverse joints on the travel lane portion of all specified pavement courses, except leveling courses, as follows:

   (1) Temporary End Panel – Maintain pavement depth, line and grade at least 4 feet beyond the selected transverse joint location, and from that point, wedge down on the appropriate slope until the top of the course being laid meets the underlying surface (assuming a pavement course thickness of 2 inches) as follows:

- For wedges that will be under traffic for less than 24 hours, construct an 8 foot long wedge (1V:50H taper rate).
- For wedges that will be under traffic for 24 hours or longer, construct a 25 foot long wedge (1V:160H taper rate).
- Construct, maintain, remove, and dispose of the temporary wedge at no additional cost to the Agency. HMAC for the temporary wedge will be paid for at the pay item price.

When the pavement course thickness is different than the above 2 inch example, use the appropriate taper rate to compute the length of the wedge. The wedge length plus the 4 feet or longer panel form the "temporary end panel."

(2) Vertical Face – After the mixture has reached the required density:

- Provide a smooth, vertical face the full depth of the course being laid at the location selected for the joint by sawing, cutting or other approved method.
- Remove the HMAC material from the joint to the end of the panel. If removed before resuming paving beyond the joint, reconstruct the temporary end panel immediately by placing a bond-breaker of paper, dust, or other suitable material against the vertical face and on the surface to be occupied by the temporary end panel. Construct a full-depth panel at least 4 feet long, beginning at the sawed or cut joint, and taper it on a 1V:50H slope to zero thickness.

(3) Excess HMAC – After completing a temporary end panel as specified, dispose of unused, remaining HMAC as directed. Payment will be made for the entire load of HMAC, but will be limited to only one load per joint per panel.

(4) Resume Paving – When permanent paving resumes, remove the temporary end panel and any bond-breakers. Clean the surface of all debris and apply a tack coat to the vertical edge and the surface to be paved.

(5) Joint Requirements – Compact both sides of the joint to the specified density. When tested with a straightedge placed across the joint, the joint surface shall conform to the specified surface tolerances. (This is checked with a 12" straightedge and should not vary by more than a 1/4".)

2. **State specification or guidance documents:** http://www.oregon.gov/ODOT/HWY/SPECS/docs/08book/08_00700.pdf, page 79 of the PDF.
3. **Supporting research or data:** Not that I'm aware of. The 1V:50H taper rate has been in use since 1984; the 1V:160H has been in use by ODOT since 1996.
4. **Contact:** Larry Ilg, Pavement Quality and Materials Engineer, Oregon Department of Transportation, (503) 983.3072, larry.d.ilg@odot.state.or.us

South Carolina

1. **Agency requirements for temporary transverse HMA tapers:** South Carolina does not currently have a spec to address transverse joints. Our maximum lift thickness to be placed while under traffic is 2 inches. If the joint is going to be left in place for more than a day or 2, the contractor will place a "paper" joint and taper it out 4 feet or so, but we don't define this with a spec. The paper joint will be removed prior to tying in to the joint with the next run of asphalt.
2. **State specification or guidance documents:** None.
3. **Supporting research or data:** [No response.]
4. **Contact:** Cliff Selkinghaus, South Carolina DOT, (803) 737-6700, selkinghcb@dot.state.sc.us

Texas

1. **Agency requirements for temporary transverse HMA tapers:** TxDOT does not have any formal requirements, standards or specification regarding temporary transverse edges during HMA operations. We basically just use a paper joint. We usually place construction paper transverse, 2 rolls wide, then place the same mix they are paving with on the taper. This is just to avoid the bump and it is easy for them to remove the next day when they begin to pave.
2. **State specification or guidance documents:** [No response.]
3. **Supporting research or data:** To my knowledge, we have not conducted research on this issue. It's really never been a problem.
4. **Contact:** Tammy Booker Sims, Special Projects Engineer, Maintenance Division, Texas DOT, (512) 416-2476, tsims@dot.state.tx.us

Utah

1. **Agency requirements for temporary transverse HMA tapers:** I have provided a link for that specification in question #2, below. If you need additional help, please contact myself. Additionally, Standard Drawing TC3, http://www.udot.utah.gov/main/uconowner.gf?n=568422811207176855, also provides guidance for vertical drop-offs. Mix requirements would be the same mix design that is being used on the rest of the mat.
2. **State specification or guidance documents:** Standard Specification for Hot Mix Asphalt 02741. http://www.udot.utah.gov/main/uconowner.gf?n=501103205100447286. Part 3.7, Surface Placement, includes information on taper dimensions and vertical edges.

    D. Offset transverse construction joints at least 6 ft longitudinally.

    E. Do not allow construction vehicles, general traffic, or rollers to pass over the uncompacted end or edge of freshly placed mix until the mat temperature drops to a point where damage or differential compaction will not occur.

    F. Taper the end of a course subjected to traffic at approximately 50:1 (horizontal to vertical).
        1. Remove the portion of the pass that contains the tapered end before placing fresh mix.
        2. Tack the contact surfaces before fresh mix is placed against the compacted mix.

3. **Supporting research or data:** There has been no research or data gathering that I'm aware of.
4. **Contact:** George Lukes, Engineer for Materials, Utah Department of Transportation, (801) 965-4707, glukes@utah.gov

Vermont

1. **Agency requirements for temporary transverse HMA tapers:**
   Limits on wedge slope: Temporary wedge is generally 1 inch in 2 feet or as directed by the Engineer.
   Mix requirements for the tapered joint: In the same lot as and same mix as adjacent mat.
   Quality control measures: In the same lot as and same QC as the adjacent mat.
   Other requirements dependent on edge height: Taper as directed by the Engineer.
   Traffic control: Permanent project traffic control in place.
   Speed limit in the construction zone: Generally a legal 10 mph reduction in speed over normally posted speed limit.
   Other factors: Generally removed next day.
2. **State specification or guidance documents:** See Subsection 490.15, Joints, of

http://www.aot.state.vt.us/conadmin/Documents/2006%20Spec%20Book%20for%20Construction/2006Division400.pdf, page 111 of the PDF.

3. **Supporting research or data:** Unknown.
4. **Contact:** Mark Woolaver, Paving Engineer, Vermont Agency of Transportation, (802) 828-1475, mark.woolaver@state.vt.us

Alternative Treatment

A possible alternative to constructing a temporary taper out of HMA is using a prefabricated polymer ramp. Brian DeWald of New York State DOT (see the **Contacts** section of this report) said that the agency had mixed results with this approach.

We found one company that manufactured this type of product.

E Z Road, Inc.
http://www.tempramp.com/End_of_Day_Joints.html
The web site states that the "E Z Road TempRamps are molded from a custom blend of recycled tire rubber and cord" and may be installed repeated times. The recommended hardware installation is 4-, 6-, and 8-inch structural screws.