STATE OF CONNECTICUT
DEPARTMENT OF TRANSPORTATION

m e m o r a n d u m

subject: New Bridge Design Standard Practice

date: September 27, 2006

to: Arthur W. Gruhn
Bureau Chief
Bureau of Engineering and
Highway Operations

from: Julie F. Georges
Principal Eng.-Bridge Design
Bureau of Engineering and
Highway Operations

Described below is a proposed new Bridge Design Standard Practice which addresses the following concern:

Hot-Mix Asphalt (HMA) overlays of bridge decks – Concern has been expressed regarding the permeability of HMA overlays placed on bridge decks and the effect of milling on bridge deck membranes.

Proposed new practice:

Increase the HMA overlay on all new bridge decks to 3″. The first lift shall be Superpave #4 (1″thick) and the second lift shall be Superpave .5 (2″ thick). This would be provided only for bridges not yet in Final Design.

The pavement structure for those bridges currently in design would remain 2.5″ The first lift shall be Superpave #4 (1″thick) and the second lift shall be Superpave .375 (1.5″ thick).

The Bridge Design Manual would be revised accordingly.

The recommendations of Research and Materials are attached.

APPROVED BY: ______________________ DATE: 10-2-06
Arthur W. Gruhn, Bureau Chief

Attachments

cc: Joseph E. Chilstrom-Federal Highway Administration

Julie F. Georges
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FROM THE DESK OF
THOMAS A. HARLEY

NAME	F.Y.I	PLS DO	PLS. SEE ME
OCT 5 - 2006			
BRIDGE			
LOCAL ROADS			
STATE ROADS			
FILE			

If you have any questions, please contact Mr. Edgardo D. Block at (860) 258-0303.

Attachments

Edgardo D. Block/sh/S:\Secretarial\Users\BlockE\BridgeDeckOverlays.doc

cc: Lewis S. Cannon - Mark D. Rolfe
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STATE OF CONNECTICUT

DEPARTMENT OF TRANSPORTATION

Memorandum

COM-09A REV. 2/91 Printed on Recycled or Recovered Paper

subject Role of Pavement Management in the project-review process

date July 28, 2006

to Ms. Julie F. Georges
Principal Engineer, Bridge Design
Bureau of Engineering and
Highway Operations

from Keith R. Lane, P.E.
Director of Research and Materials
Bureau of Engineering and
Highway Operations

This memorandum is intended to address Hot-Mix Asphalt (HMA) overlays of bridge decks in projects that include the installation of the standard membrane system prevalent in Connecticut Department of Transportation bridge projects..

In a December 1, 2004 memorandum, the Pavement Management Unit suggested that a 3″ overlay thickness on bridge decks could provide easier compaction conditions in which to minimize the permeability of overlays placed on bridge decks. The intent was to increase the lift thickness of the top overlay lift of 0.5″ Superpave HMA (0.5″ being the nominal maximum aggregate size, or NMAS, of the mix) from 1.5 inches to 2 inches. As substantiated in NCHRP Report 531, at a lift thickness of four (4) times the NMAS permeability can be reduced and compaction is more easily achieved; further, for a substantial proportion of HMA mixes used in Connecticut, the beneficial effect of this lift-thickness increase can be expected to be substantial, obviously provided that the compactive effort is adequate. The preferred initial lift to be placed directly on the membrane would be Superpave #4 mix at a thickness of one (1) inch.

In a January 4, 2005 meeting, personnel from Bridge Design and the Office of Research and Materials discussed the issue further. At this meeting the thickness of the first lift of pavement (1 inch of Superpave #4 mix) was discussed in terms of its ability to protect the underlying membrane in a subsequent milling operation. Subsequently, Bridge Maintenance commented that it would prefer a thicker overlay (3.5 to 4 inches) over the bridges to provide additional protection in subsequent mill-and-overlay operations. Those issues, also raised in conversations among Bridge Design and Pavement Management engineers, have lead to this document, the purpose of which is to propose viable options for a variety of situations on bridge decks, including limited overlay thicknesses, the need for cross-slope modification through HMA pavement, and varying traffic volumes and conditions. These options should be circulated to representatives of all affected technical areas so that a consensus can be developed.

The key issues identified by this office are presented below, followed by recommendations that address concerns expressed. Other engineering considerations may govern specific aspects of the recommendations presented herein.

(1) Protection of the membrane system (from rupture/puncture during HMA overlay)
This eventuality is less likely with mixes with smaller NMAS's.

(2) Protection of the bridge deck (from water intrusion during its service life)
This is the main purpose of the membrane. Given that, this consideration places a premium on the minimum possible permeability of the mix.
Three major components which have been identified to affect permeability of a mix and which can be controlled are mix NMAS, gradation and compaction (with "smaller, finer, higher," respectively being more beneficial within a reasonable range)

(3) Minimization of the permeability of the HMA overlay through mix selection and design (for helping minimize water intrusion which could eventually affect the bridge deck).
Smaller NMAS and finer gradation are generally better.

(4) Compaction of the HMA overlay (to provide as impervious a layer as possible for protecting the bridge deck and to minimize rutting due to in-service compaction

in the wheelpaths)
The proper lift thickness for the mixture selected is a variable that can help achieve the highest density for a given compactive effort, all other variables held equal.

(5) Rut resistance (to avoid rutting due to inability of the HMA itself to withstand the traffic loading).
Rut resistance is maximized through increased mix stiffness, which in turn depends on the high-temperature binder properties on the one hand and the aggregate structure on the other. With respect to binders, increasing the PG grading through the use of polymers could provide increased rut resistance. Unfortunately, the aggregate structures that help achieve the stiffest mixes are by and large not those that help achieve the lowest permeability (More quantity of coarse aggregate, increased particle angularity, coarser aggregate in some but not all instances).

(6) Total thickness of HMA overlay over the membrane (dead load on the bridge, design considerations and to avoid excessive dead load)
Increasing the thickness of HMA, once the compactive effort has been maximized and mix permeability has been minimized through material selection and design, would help provide additional protection from water. However, there are practical, technical, and economic considerations that limit the maximum thickness of an overlay on a bridge deck.

(7) Protection of the membrane during HMA overlay removal in future paving projects where the bridge deck is not to be addressed. (Avoid "milling to the membrane" in subsequent paving operations)
Once milling tolerances have been taken into account, which would dictate a minimum first-lift thickness, thicker lifts provide an additional factor of safety.

(8) Need for cross-slope increase on top of the bridge deck through the use of HMA.
The limiting factors here are the lift-thickness to NMAS relationship (which may affect compaction) and the maximum lift thickness technically feasible (also affecting compaction.)

(9) Skid resistance and surface texture. (to provide a skid-resistant surface for traffic as it traverses the bridge, especially in both wet or below-freezing conditions)
Although most mixes considered in the following options meet the requirements for skid resistance except for very specific cases, greater macrotexture can contribute to additional skid resistance. The macrotexture of the mix placed must be adequate for the service conditions; particle angularity, resistance to polishing, aggregate structure, and gradation all play a role in designing an overlay that provides adequate skid resistance.

<u>First (bottom) overlay lift</u>

The first lift should be, in most cases, between 1.0 inch and 1.5 inches, depending on the combination selected.

The concern with a 1.0 inch lift has been stated as necessitating tight control over future milling operations to avoid damaging the bridge deck membrane. Following proper milling procedures, protecting the bottom one-inch overlay which is directly over the membrane should not present a major challenge, but it does require that all personnel pay attention to the operation. A 1.0 inch bottom lift is the recommendation from this office for minimum thickness, subject to the constraints based on other engineering considerations. If the initial overlay thickness is increased by 0.25", then there is an additional, salutary margin of safety for future mill-and-overlay operations. However, if 3" is the overlay thickness limit, this increase reduces the thickness available for the top lift by a corresponding 0.25", raising the specter of increased permeability on the deck, especially if the NMAS of the top lift is 0.5" or larger, where the thickness-to-NMAS ratio would be 3.5 (below 4.0, which may present a problem for coarse (below the restricted zone) mixes. Ideally, a thickness of 3.25 to 3.5 inches would provide the easiest conditions for protecting the membrane during subsequent milling and overlay operations, while providing conditions favorable to impermeability on the top overlay lift. At greater thicknesses, there may be issues of exceeding the maximum lift thickness on the first overlay lift (the #4 Superpave), which could lead to problems in either compaction or mix stability when subjected to significant traffic for a long period of time. In this case Superpave 0.375″ mixes could be used as the first lift without major problems.

Second (top) overlay lift

The major objectives of the surface lift are impermeability, rut resistance, and skid resistance. Experience has shown that the 0.5″ Superpave mixes, placed at the appropriate level for the traffic mix and at proper lift thickness, can perform well in all three respects. 0.375″ Superpave mixes may perform just as well at the appropriate level; the variable introduced would be a change of macrotexture entering the bridge, if the mainline pavement is of higher texture. In cases where the NMAS of the mainline highway surface mix is 0.5″ NMAS, changing the mix at the bridges would also require a separate paving operation.

It would also be possible to use a high-skid-resistant mix as the surface course such as Novachip or another ultra-thin surface course with high-skid-resistance characteristics. This option may be viable for structures on high-speed roadways where the total overlay thickness is the limiting factor but high friction is required. A cost-effectiveness calculation would become part of the decision equation.

Total overlay thickness

A major constraint on bridge overlay thickness is the allowable overlay dead load on the bridge itself. Currently the limit is 2.5 inches. Our recommendations contemplate a total overlay thickness of three (3) inches. Additionally, although a single solution is desirable to address the bridge-overlay issues, the reality is that in order to optimize our investment in the protection of bridge decks a one-size-fits-all approach is unlikely to address all conditions. There will likely continue to be projects where the total overlay thickness over a bridge deck might be limited to a lower amount. In addition, on some bridges superior skid resistance may be identified as warranted. A compendium of other options for protecting the bridge membrane is included as Attachment 1. The major options are indicated as A-H, with some sub-options indicated by number, resulting in combinations such as A1/A2, B1/B2, etc. Options D, E, and F are expected to be the simplest to build, but require more thickness than the current 2.5″ total thickness currently used as the upper limit on dead load for State highway system bridges.

Recommendations

1. Increase the total bridge overlay thickness to a minimum of 3.0 inches.
2. Use 1.0 inch of Superpave #4 mix (minimum) as the bottom lift (Minimum Design Level: Level 2, Maximum Design Level: Lower level of a) Level 3 or b) Design Level of surface lift.) With proper care, this should be sufficient to protect the underlying membrane in subsequent mill-and-pave jobs.
3. Use 2.0 inches of Superpave 0.5″ mix as the top lift.
4. In those instances where the total overlay thickness is constrained to less than 3.0 inches, consider Superpave 0.375″ mix as a feasible alternative to Superpave 0.5″ mix for the top lift, with the following caveat: Investigate the macrotexture of Superpave 0.375″ mix to verify that it does provide sufficient macrotexture for critical areas on high-speed roadways.
5. For other project-specific conditions where these recommendations cannot be met, consider alternatives from Attachment 1.
6. Develop a permeability criterion for acceptance of bridge-deck paving projects, given that this is a critical property of the overlay for protection of the bridge deck. (This is currently under way at the Connecticut Advanced Pavement Laboratory (CAPLab).)
7. Investigate alternative deck-protection systems to those currently in use to see if there are increased cost-benefit ratios to be realized by their implementation (Currently a research problem statement is being developed.)

Option	Description	Total Thickness (in.)	Bottom Layer		Top Layer		Comments
			Type	Thickness (in.)	Type	Thickness (in.)	
A1	Very Thin - High Friction	2.0 - 2.125	SP 0.375	1.5	High-Friction Ultra-thin course (Nova)	0.5 – 0.625"	No problems anticipated; other high-skid-resistant products could be used (ex. Tyregrip, at 0.25-0.375"); cost would be a major consideration.
A2[1] (*)	Thin	2.5	SP #4	1.0	SP 0.5	1.5	Top lift: Difficult compaction conditions for many mixes, especially at higher Superpave design levels; lift thickness different than sections outside deck. **Not recommended.**
A3	Thin	2.5	SP #4	1.0	SP 0.375"	1.5	No problems anticipated; need to verify macrotexture of top lift for skid resistance; need to study effect of texture change versus mix before and after bridge
B1	Thin - High Friction	2.5-2.625	SP #4 **(2 lifts)**	2.0 (2 lifts of 1.0 each)	High-Friction Ultra-thin course (Nova)	0.5 – 0.625	No major problems anticipated; provides for thin first lift; cost would be a major consideration; other high-skid-resistant products could be used
C	Thin - Extra Bottom	2.75	SP #4	1.25	SP 0.375	1.5	No problems anticipated; need to verify macrotexture of top lift for skid resistance; need to study effect of texture change

[1] Existing standard overlay

							versus mix before and after bridge
D	**Standard** (Recommended)	**3.0**	**SP #4**	**1.0**	**SP 0.5**	**2.0**	**No problems anticipated; top lift likely to match lift thickness outside bridge deck (Bridge load check may be required)**
E	**Standard - Extra Bottom**	**3.25**	**SP #4**	**1.25**	**SP 0.5**	**2.0**	**No problems anticipated (Bridge load check may be required)**
F	**Thick**	**3.5**	**SP 0.375**	**1.5**	**SP 0.5**	**2.0**	**No problems anticipated (Bridge load check may be required)**
G	Ultra-thick	4.0	SP 0.375	1.5,2.0	SP 0.5	2.5,2.0	No problems anticipated, except perhaps heat dissipation at installation time from 2" first (bottom) lift. 1.5" first lift would require a 2.5" top lift, and 2" bottom lift would use a 2" top lift. **(Bridge load check may be required)**

(*) Not Recommended

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