Illinois Extended-Life Hot-Mix Asphalt Pavements

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At the request of the hot-mix asphalt (HMA) industry, the Illinois Department of Transportation (IDOT) initiated efforts to develop contract provisions for the design and construction of "perpetual" HMA pavements. A "perpetual" pavement for this effort is defined by the Asphalt Pavement Alliance as a pavement structure consisting of a rut-resistant, impermeable, and wear-resistant top structural layer, with a rut-resistant and durable intermediate layer, and a fatigue-resistant and durable base layer. IDOT believes a more appropriate term is extended-life HMA pavement.

This paper describes (1) the approach taken by Illinois and its hot mix industry, and (2) the issues involved in developing the contract provisions.

PARTNERSHIP APPROACH

The approach taken was in the form of a partnership of the Illinois Department of Transportation (IDOT), academia, contractors, asphalt suppliers, and national experts. This approach ensured the best information, knowledge, and experiences were available to develop an appropriate specification for Illinois conditions.

The following were represented on the task group:

- IDOT
- Contractors
- Asphalt suppliers
- Aggregate suppliers
- Academia
- Industry association representatives
- National experts

In the planning stages for this effort, it was agreed that a specification could be developed through a series of four meetings spaced 1 to 2 months apart, with various subcommittees working on specific issues between meetings. The first meeting was held June 14, 2000, with the goal of having a draft document by December 31, 2000. This ambitious goal was substantially accomplished.

At the first meeting, the task group determined that the main topics to be addressed could be broken down into the following four distinct areas.

- Pavement substructure,
- Material durability and stripping prevention,

- Fatigue-layer design analysis and bottom-layer mixture design, and
- 20-year pavement surface.

The task group divided itself into subgroups representing these four areas. Issues, questions, and concerns discussed during the general meetings were in many instances assigned to the appropriate subgroup for consideration, with recommendations presented at the next general meeting.

PERPETUAL PAVEMENT DESIGN CONCEPT

The perpetual pavement concept of a three-layered system, renewable surface, middle rut-resistant layer, and lower fatigue resistant layer was explained by representatives of the Asphalt Pavement Alliance. After discussing and fully understanding the concepts, the task group agreed they were reasonable for use in Illinois.

Thickness Issues

The first challenge was to determine appropriate total thickness of the pavement structure and thicknesses for each of the three individual layers. Since 1989, IDOT has been using a mechanistically based pavement-thickness design procedure. It includes limiting the maximum tensile strain at the bottom of the lower lift, as well as limiting the subgrade stress. The IDOT design typically results in design strain levels at or below what pavement design experts are suggesting (i.e., 0.60 microstrain for perpetual pavement). Discussions with the design that procedure authors indicated that the fatigue algorithms used to characterize mixtures used in Illinois were quite conservative. As such, the existing thickness design would already have taken into account any type of mixtures the task group would recommend. To meet the 6-month goal of having a specification, it was decided to use the current design thickness procedure with no change. A long-term goal would be to review the thickness design to recognize a more fatigue-resistant lower layer than currently assured in the design procedure.

Prepared Subgrade

Currently, IDOT’s standard cross section for full-depth hot-mix asphalt (HMA) has the pavement built on top of 12 in. of lime modified soil with added provisions for very weak subgrade soils. The department proposed to replace the 12 in. of lime-modified soil with 12 in. of aggregate subbase. This subbase is used typically in the Chicago area when reconstructing pavements. The gradation is such that a wide range of sized material can be used, but does result in a drainable layer. A review of the reduction in strain at the bottom of the HMA pavement produced a microstrain reduction of 2. Questions were raised as to the benefit of a 2-microstrain reduction compared to the cost of incorporating 12 in. of granular subbase, especially in areas of the state where such aggregate is not readily available. Estimated cost increases ranged from 6 to 14 percent of a typical cross-section cost, depending on the specific project. This issue could not be resolved by the group and was forwarded to IDOT management to resolve.

Underdrains

Current IDOT design standards require longitudinal underdrains to be placed under the shoulder/pavement joint on both sides of the pavement. The pipe is located low enough to drain the aggregate layer it if exists, or 24 in. below the surface of the pavement when the pavement is built on top of lime-modified soil. The question was raised as to the value of underdrain in the cross section use, especially with clay-type soils in Illinois. After some discussion, it was decided that not enough performance data existed to eliminate the underdrain at this time.

Fatigue-Resistant Layer

Although the pavement thickness design procedure was felt to be conservative in regards to fatigue using existing IDOT mixtures, it was decided to develop a "rich bottom base" to improve the fatigue resistance. Various different mixes were discussed in terms of appropriateness in meeting the characteristics of a highly fatigue-resistant HMA. From a mix design perspective, a very specialized mixture could be designed, but its practicality and resulting cost was questioned. To reduce confusion with additional mix designs, differing aggregate requirements, and varying production criteria during construction, it was deemed most appropriate to modify the mixture used in the middle layer

The selected rich-bottom base used the middle-layer mix design with an asphalt content that provided 2.5 percent air voids at the same gyration level. Adding one-half percent more of asphalt to the 4 percent design wa suggested, but the task group agreed that designing for 2.5 percent voids was more realistic in defining the mixture characteristics desired in the layer. The additional asphalt should also improve moisture damage resistance, provide additional fatigue life, and be easy to place and compact. Also, a higher in-place density requirement of less then 6.0 percent voids for this layer was included. All these characteristics would ensure a durable fatigue-resistant layer. This layer would be constructed in one 4-in. lift.

Intermediate Pavement Layer

After reviewing performance data and the members' review of the mix design requirements, the task group determined that the department's current specified binder mixture and mix design procedure was appropriate for the intermediate pavement layer. The design procedure and ingredient requirements follow the intent of Superpave, and historically Illinois has provided rut-resistant mixtures. The appropriate gyration level would be utilized for the expected traffic over a 20-year period, as recommended by Superpave.

Renewable Surface Layer

To achieve the goal of a 20-year surface life, the use of stone matrix asphalt (SMA) was chosen to resist both rutting and durability problems for the renewable surface layer. The use of IDOT's dense-graded mixtures was discussed, but ultimately not pursued. The task group felt SMA could provide a higher level of long-term durability due to its mixture characteristics.

To determine appropriate thickness of the surface layer, a shear stress analysis of the pavement structures was conducted and the results of rutting and surface cracking studies were reviewed. In most cases, the studies indicate that rutting and cracking occur in the top 4 in. Based on the analysis and studies, the following top layer thicknesses were selected for the SMA:

Traffic	*Total SMA Thickness (Inches)*
Low	2
Medium	4
High	6

For the very high equivalent single-axle load (ESAL) pavements, a 6-in. total thickness of SMA was felt to give a factor of safety to help resist rutting. (Although the specific definitions of low, medium, and high have not been finalized, high may ultimately be defined as 25 million ESALs or greater, based on a 20-year traffic analysis.) For the lower-volume pavements, no need was recognized for the high rut-resistant SMA in the lower part of the surface layer.

However, the task group agreed that the top 6 in. of the pavement would require modified binder to minimize surface cracking. For those pavements with either 2 or 4 in. of SMA, the remaining 4 or 2 in., respectively, would be of the intermediate layer mixture with modified asphalt.

Asphalt Penetration Grade Selection

The use of polymer-modified asphalt cement in both the base layer and intermediate layer was not felt to be cost-effective. It was decided to use modified asphalt in the 6 in. of the surface layer to help resist surface cracking and rutting. The department's current penetration grade selective requirement for full-depth pavements for northern Illinois was felt appropriate for statewide use. It is recognized this is a conservative approach for pavements built in the southern parts of the state. However, the approach would help minimize low-temperature cracking and the polymer would improve durability. For the 6-in. surface layer, "grade bumping" to accommodate slow and standing traffic will use the department's current guidelines.

Use of Hydrated Lime

Illinois uses liquid additives when it determines a mixture is susceptible to moisture damage (stripping). Based on the Illinois version of AASHTO T-283, there were suggestions to make the existing test procedure more stringent. Ultimately, the task group elected to require the use of hydrated lime for all mixtures used in the extended-life pavement. Along with the mandatory use of lime, the mixtures will still have to pass the department's current tensile strength–ratio requirements. Any future changes to the test procedures would be considered for all mixtures, not just for perpetual pavements.

Mixture Durability Enhancements

The task group agreed on the following items to enhance the durability of the mixtures and so increase the life of the pavement structure.

- Increase minimum lift thickness to 3 to 6 times nominal maximum aggregate size to allow higher in-place density.
- Require positive dust control on HMA plants for better mixture production control.
- Require priming with a polymer material between each lift to promote bonding.

- Require all-virgin aggregate in the bottom layer. This eliminates variability of mixture stiffness due to reclaimed asphalt pavement.
- Require the use of a material-transfer vehicle or a paving machine capable of re-mixing the bituminous mixture for all lifts of all mixtures to reduce the potential for segregation. To eliminate premature pavement fatigue from the vehicle, its use is permitted only on constructed lifts 10 in. or greater in thickness.
- Revise in-place field density testing to promote uniform levels of density across the mat.
- Increase the in-place density requirements for the middle layer to less than 7 percent air voids.

Longitudinal Joint Construction Practices

The task group reviewed the need to improve longitudinal joint durability. It was felt the longitudinal joints would be the portion of the pavement prone to long-term durability problems. The task group discussed procedures such as full-width paving to eliminate longitudinal joints, and cutting of the joint prior to the adjacent lane being paved to improve the density at the joint.

Three recommendations were ultimately made to improve durability of longitudinal joints. First, improve the quality of the material near the joint by requiring mainframe screed extensions and utilizing good paving practices. Second, change the field density–testing procedures to put more emphasis on nuclear tests 2 ft from the joints. Third, require the use of a spray-on polymer-modified tack coat on the vertical face of all lifts that will become longitudinal joints. This tack coat will extend on existing lifts for a width of 6 in. to the side of the existing joint. In combination, all three procedures should improve the life of the longitudinal joints.

Individual Layer Thickness Tolerance

Due to the importance of each of the three layers—the bottom fatigue layer, the intermediate layer, and the surface layer—the concern for construction thickness tolerances of each layer was discussed. The pavement thickness design is already conservative, with the lower fatigue layer given the same fatigue resistant as the intermediate layer, and with modified asphalt binder being required in the upper 6 in., which fully encompasses the shear zone of 3 to 5 in. Therefore it was decided that existing department construction tolerances and total pavement thickness requirements would be used.

Pavement Smoothness Requirements

The department has an ongoing pavement smoothness initiative to improve the smoothness of newly constructed pavements. The department believes that smoother constructed pavements address the public's desire for smoother pavements. Also, pavements built smooth will remain smoother throughout their service life. The task group concurred with including the department's most stringent pavement smoothness specifications for the extended-life HMA pavements.

CONCLUSION

The task group substantially met the goal of having draft documents ready by December 31, 2000. This was accomplished by taking current IDOT pavement and mixture designs, as well as construction practices, and reviewing them for appropriateness when using the three-layered perpetual pavement concept, and then making adjustments where needed. Most of the effort was in improving the durability of mixtures to ensure that they last indefinitely for the bottom and intermediate layers and at least 20 years for the renewable surface layer, with no rutting, surface cracking, or durability issues.

One major item yet unresolved is the need for a 12-in. granular subgrade under the three-layered HMA pavement. An approach being considered is to require the aggregate subbase only for very high levels of traffic.

Two other goals currently being addressed by IDOT and the HMA industry are to develop specifications for SMA mixtures for medium- and low-traffic situations to ensure durability, and specifications for incorporating hydrated lime in HMA mixtures.

Future efforts will include reviewing the thickness-design procedure to account for the different mixtures used in the three layers, as well as maximizing the benefits of such a design.

Currently, the HMA industry in Illinois is pursuing projects where the extended-life HMA pavements specifications can be included.