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Design, Construction, and Performance of Asphalt Base

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The following five papers were presented at the 54th TRB Annual Meeting.

IOWA'S EXPERIENCE WITH FULL-DEPTH ASPHALT PAVEMENTS

Michael J. Stump, Bituminous Field Engineer, Iowa Department of Transportation

Presentation is an overview of Full Depth Asphalt pavements constructed on county, primary, and interstate highways in Iowa since 1961 when their design was developed as a substitute for untreated crushed stone base pavements. Inspection, equipment, and construction improvements adopted since 1961 are discussed. Performances are mentioned in relation to thickness designs. Changes in mixture requirements because of need for maintenance are discussed.

The observations about Full-Depth asphalt pavements in this presentation are based on pavements constructed of hot mixtures on interstate, primary, and county highways in Iowa. The lower course of each pavement is placed directly on the existing earth subgrade, or an earth subgrade mixed with small amounts of lime, portland cement, gravel, or crushed limsetone. The wearing surfaces of these pavements are usually layers of hot-mix asphalt concrete, but chip seals are also fairly common on county highways. Also included are Full-Depth asphalt pavements constructed in the last three or four years, on the foregoing types of subgrades or subbases, using mixtures produced in drum mixers at lukewarm temperatures varying between approximately 190°F and approximately 225°F.

Although there were Full-Depth asphalt pavements constructed in Iowa prior to 1961, this presentation is limited to the pavements constructed in 1961 and the years following. Strong emphasis was newly placed on this design concept in 1961 as another type of pavement that could replace the designs utilizing untreated crushed stone bases that had been widely used in Iowa prior to this time. In many instances, these crushed stone pavements had performed satisfactorily.

It is not within the scope of this presentation to go very far into the problems that caused the untreated crushed stone base pavements to perform as they did, but it should be explained that many of those bases were constructed with plastic fines exceeding 15 or even 20% of the total content. Responsible agencies and associations made it perfectly clear that in general, crushed limestone bases would not usually give satisfactory performances unless, among other things, the fines were kept below approximately 10%. Serious consideration was given toward changing the specifications accordingly. The matter became somewhat controversial, and as a compromise, the specification for the maximum allowable fines was lowered to 13%. Improvements were specified for construction equipment and aggregate quality, but since 1961, crushed stone bases have tended to be used only on county highways. Gradually, they were used

less each year. During the last two or three years, their construction has been rare.

As far as full-depth asphalt pavements are concerned, enough miles have been constructed in Iowa since 1961 to give significant opportunities for meaningful observations about them. This is especially true for county highways, where approximately 1,300 miles of Full-Depth asphalt pavements have been constructed. On state highways, approximately 250 miles of Full-Depth two-lane pavements, or their equivalent in multiple lanes, have been built. On interstate highways, approximately 30 miles of four-lane Full-Depth asphalt pavements have been constructed.

As far as construction procedures and equipment are concerned, several important improvements have been successfully incorporated since 1961. Large full-width finishing machines have become common since the late 1960's. Storage and surge silos have also become common in the last three or four years.

Iowa adopted an end result density specification for hot mixtures in 1972 that has been successful thus far. With implementation of the end result density specification, increasing use of self-propelled vibratory rollers has occurred. They are used at the contractor's option, and some contractors in Iowa have used them extensively on hot mixtures with satisfactory results. I think their comparative effectiveness in obtaining density has usually been at least equal to other types of rollers, and possibly sometimes somewhat better. However, there were variable results two or three years ago, when they were first being tried. Those variations seemed to be caused by individual rollers not being designed for the layer thicknesses or other features involved, together with insufficient training of the roller operators.

Before Iowa started to allow vibratory rollers to be used on hot mix layers, there was uncertainty about how they might affect the smoothness. Up to now, we have not observed objectionable roughness from them. We certainly have had occasional unsatisfactory roughness, but none that has been associated with vibratory compaction.

As far as pneumatic and standard steel-tired rollers are concerned, it is also the contractor's option to use them if he pleases and obtains satisfactory density and smoothness. They have always and still are being widely used with very successful results.

For the last two years, Iowa's specifications have permitted drum mixers, using conventional hot mix temperatures, for all asphalt-treated base mixtures. Asphalt-treated base mixtures are not suitable for wearing courses in Iowa, and the specifications have not permitted drum mixers for wearing course mixtures, unless special provisions for individual projects were written to allow them. However, it has not been unusual for the County Engineers to have special provisions written to allow the drum mixers for the wearing course mixtures.

The restrictions in the specifications for drum mixers did not reflect experiences with deficiencies in their performances. Instead, Iowa has taken a cautious, but hopefully, a progressive attitude toward them. This winter changes in the specifications are being written to permit drum mixers on all of the wearing course mixtures, except Type A asphalt concrete, which is the highest-quality wearing course mixture.

As long as conventional hot mix temperatures have been used with drum mixers, the results have normally been satisfactory. Cooler or lukewarm mixing temperatures have also been tried as experiments with drum mixers in the past three years. Although these results, using lukewarm temperatures have sometimes been uncertain, there is indication that handling techniques may be developing where satisfactory results can be obtained under certain conditions. Objectionable results certainly haven't always occurred when lukewarm temperatures were used, but when they have, it's usually been in the form of lack of uniformity or roughness in the pavement surface.

Automatic screed controls have been important to the construction of full-depth pavements in Iowa. When equipment companies developed economical and reliable automatic screed controls for finishing machines in the middle 1960's, Iowa changed the specifications to require them. The automatic controls have helped significantly toward the construction of smooth riding Full-Depth pavements with a minimum of inspection and engineering costs.

The concept of thick lift construction was one of the most significant developments toward improving construction of Full-Depth pavements in Iowa. Until the late 1960's, Iowa's specifications limited all lift thicknesses to not more than three inches. Furthermore, for primary and interstate projects, the layer placed directly on the subgrade was specified as only two inches.

It was necessary to haul over those thin lower layers as the upper layers were constructed.

Earth subgrades under that initial layer were never perfectly firm. Serious damage to those thin lower layers occurred in places where the underlying subgrade flexed

under haul trucks. Repairs were required for those damaged spots and they were expensive. In order to keep the damage within reasonable limits, contractors sometimes had to lighten loads drastically in the trucks. This tended to be time consuming and expensive.

For the past five years, Iowa has allowed base layers to be as thick as the contractor elects, as long as smoothness and density results are satisfactory. Contractors are still required to keep the subgrades smooth and firm enough during construction to insure that the Full-Depth asphalt pavements will not have varying thicknesses that would be caused by wheel ruts in the subgrade from the paving and hauling equipment. However, once a thicker lower layer has been spread, even on a flexing subgrade, the thick initial lift of asphalt mixture has provided sufficient strength and support for equipment to construct the upper layers without damage to the bottom lift.

Back in the early and mid-1960's when specifications required lower layers of Full-Depth asphalt pavements to be no more than only two or three inches in thickness, Iowa adopted the design practice of using lime or cement stabilization continuously in the subgrades on primary and interstate highway projects. The stabilization was designed, partly, to control the expensive damage that was occurring to the thin lower layers. These continuous lime and cement subgrade treatments were helpful then, but they were very expensive; and they were seldom, if ever, used on county pavements.

Iowa's extensive experience with thick lift construction on the county highway projects, where continuous lime or cement stabilization of subgrades has not usually been designed, indicates that from the standpoint of preventing damage to the base during construction, the stabilization is no longer necessary on the primary and interstate highway projects.

As far as thickness designs for the Full-Depth asphalt pavements in Iowa are concerned, except for possibly the very earliest ones, the AASHO Design Guide has been used for primary and interstate highway projects. For county highway projects, design thicknesses in individual counties have been based on the respective county engineer's opinion, together with a required minimum by the state highway department. The required minimum pavement thickness for county highways has varied throughout the years, normally between five and eight inches, depending on circumstances and time. It has seldom, if ever, been based completely on one of the recognized thickness design procedures for Full-Depth asphalt pavements.

To my knowledge, there has not been an instance where any part of a completed permanent Full-Depth asphalt pavement in Iowa has failed because the design thickness was not adequate. The thickness designs have proven to be sufficient. However, since failures have not occurred because of insufficient thickness, in the many miles that have been constructed, it seems logical to assume that on an overall basis, the thicknesses that have been designed have sometimes been greater than necessary.

The performances of Iowa's Full-Depth asphalt pavements support most of the predictable features about asphalt mixtures that have been reported by asphalt paving technologists through the years. Necessary maintenance has normally been to correct for raveling, cracking, or other types of deterioration in wearing course mixtures.

Wearing course mixtures used on county highways, until the mid to late 1960's, contained a straight 5 3/4% asphalt cement content instead of a laboratory-determined optimum. Air voids as high as 15% were sometimes common in these mixtures. The surface of some of those Full-Depth pavements raveled seriously within the first five years.

The practice was then changed whereby the optimum asphalt content was determined in the laboratory for each wearing course mixtures used on county highway projects. Follow-up procedures were established at the same time to ensure, that if the mixture characteristics happened to change during construction, appropriate changes would also be made in the asphalt contents. Few county pavements constructed since then that have required early maintenance because the optimum asphalt content wasn't used.

For primary and interstate highway projects, wearing course mixtures have always had a laboratory-designed optimum asphalt content. However, until the late 1960's and early 1970's, many of those wearing courses contained such low voids in the mineral aggregate, that they tended to be brittle and develop irregular cracking after about five to ten years performance. The cracks were not usually patterned in a manner that could be related to the overall pavement structure. They seemed to occur at critical points in the wearing course, such as where slight segregation had occurred or sometimes at the longitudinal joint at the centerline. Raveling also tended to occur at these cracks as well as from the surface in general.

During the last five years, specifications have been changed to control these low VMA percentages in the wearing course mixtures on county, primary, and interstate

highway projects. This has been done, in substance, by not approving any mixture designs submitted by contractors, unless the calculated asphalt film thickness, at the optimum asphalt content, is approximately 6.5 microns, or higher.

Serious deterioration of the wearing courses has been noticeable on a few Full-Depth asphalt pavements, because the specifications for soundness permitted aggregates to be used that did not always give satisfactory performances. Standard specifications for soundness of the aggregates in the lower classes of wearing course mixtures, permit a maximum freeze-thaw loss in water of 10 and permit the freeze-thaw loss in a water alcohol solution to go as high as 45. Aggregates meeting these soundness requirements have performed satisfactorily in underlying layers. However, for wearing courses, it has been observed, especially for the 3/4-inch mixture size designation, that a satisfactory performance without serious surface deterioration is not obtainable unless a lower maximum water-alcohol freeze-thaw loss is specified for the aggregates in the wearing course mixture.

In this light, for the last two years on primary highway projects involving lower class wearing course mixtures, if there was the possibility that an aggregate might be used that would approach the specified maximum water-alcohol freeze-thaw loss of 45, the state has usually written special provisions for the project, prior to the letting, that require the aggregates in the wearing course mixture to comply with a maximum water-alcohol freeze-thaw loss of 25. For county highway projects, this special provision can also be written for wearing course mixtures, but the initiative has to be taken by the County Engineer or the state Materials Engineer in the district.

Finally, as far as the asphalt-treated base mixtures for Full-Depth asphalt pavements are concerned, the specifications permit the use of almost all natural or crushed local aggregates that will give reasonable performances. There has been no indication that the quality of the aggregates in the bases was not high enough. The mixtures are also desne graded and mostly 3/4 inch in size.

Until the early 1970's, for the most part, a straight 4% asphalt cement content was used in asphalt-treated base mixtures on all Full-Depth asphalt paving projects. To my knowledge, there has been only one or at the very most, possibly two, pavements where it was thought that failures occurred because the 4% asphalt content was too low. However, the asphalt content in the base is considered to be related to the control of spacing between transverse cracks. Not all projects have had transverse cracking, but in general, transverse cracking has occurred on several. The spacings between these cracks have varied among the pavements. On some, the cracks have been very closely spaced, and some of the engineers have been concerned, because it was thought that these cracks could develop into a serious maintenance problem. It was realized that several factors contributed to the cracks, but it was also reasoned that a higher asphalt content in the base mixtures would have a strong influence in controlling the spacing.

In addition to this, Iowa has been very much aware of the thinking for several years among asphalt paving technologists, that asphalt contents for the base mixtures should be determined in the laboratory, using the same criteria that is used for wearing course mixtures. Because of this thinking, and because of the aforementioned failures and variations in the transverse cracking characteristics of the asphalt bases, about three years ago, Iowa adopted the practice of using laboratory tests to designate asphalt contents in the base mixtures of Full-Depth pavements.

So far, these tests have been used to designate asphalt contents that, as near as possible, will give more uniform characteristics to the base course mixtures. These asphalt content percentages for the bases have been somewhat less than test results indicate would be the optimum for wearing course mixtures. The reason for not using the the optimum has mainly been the associated cost increase.

DESIGN AND PERFORMANCE OF ASPHALT CONCRETE BASES IN THE STATE OF WASHINGTON

R. V. LeClerc, Materials Engineer, and J. P. Walter, Bituminous Testing Engineer, Washington State Highway Commission

Asphalt concrete bases have been used in the state of Washington since about 1960. We are generally pleased with the roadway performance of pavement structures using asphalt concrete bases, but it does vary. Although we plan to continue the design and use of asphalt concrete bases, we also plan a concentrated