Rut-Resistant Asphalt Concrete Overlays in Wisconsin

ASHWANI K. SHARMA AND LYNN L. LARSON

Premature rutting on asphalt pavements has been experienced throughout the nation, and Wisconsin is no exception. The Wisconsin Department of Transportation (WisDOT) in the 1980s vigorously addressed the rutting problem, developed specifications, constructed several special pavements, and undertook a major research project to study four of these special pavements. The WisDOT specifications for rut-resistant asphalt pavements require high-quality aggregates, high target density, controlled air voids, high fractured particles, high voids in the mineral aggregate, good quality control, and sufficient field compaction. Preliminary results on these special pavements indicate minimal rutting, some premature reflective cracking, but generally good overall performance. Those in WisDOT are committed to construct quality rut-resistant asphalt concrete pavements and are confident that the current specification for heavily traveled roadways will solve the rutting problem.

Premature rutting on heavily traveled asphalt concrete overlays has been documented to be a problem in Wisconsin. Before 1982, hot-mix asphalt (HMA) meeting Wisconsin Department of Transportation (WisDOT) standard specifications was used for overlays on heavily traveled pavements. In general, these overlays performed well for a service life of 15 years. But during the 1982 construction season, a special HMA overlay on Interstate 90/94 experienced significant rutting (ruts measuring up to 1.2 in.). Rutting was of such an extent that the overlay had to be removed by milling before the end of the 1983 construction season. WisDOT Materials, Design, and Construction staff met with the Wisconsin Asphalt Paving Association (WAPA) to discuss the rutting problem, review the specifications, and prepare recommendations to minimize the rutting problem. WisDOT considers ruts exceeding 0.4 in. in a service life of 10 years to be generally unacceptable.

A revised specification was adopted for use during the 1984–1987 construction seasons for overlays on heavily traveled pavements. This specification differed from the previous specifications as follows: coarser, narrower gradation bands with lowered passing No. 200 material; higher percent fractured particles; higher Marshall stability; and slightly higher air voids. Premature rutting (ruts measuring up to 0.7 in.) was observed on many of these overlays. A comprehensive rutting study by WisDOT Materials documented the extent and severity of the rutting problem (*1*).

WisDOT personnel, WAPA representatives, and several national asphalt experts met to develop a mixture that would minimize rutting. The 1988 special specification, Rut-Resistant Hot-Mix Asphalt (RRHMA), incorporated the following points: coarser, narrower gradation bands; higher air voids and voids in the mineral aggregate; higher manufactured sand content; plasticity index based on passing No. 200 material; 75-blow compaction for Marshall design; and 97 percent of Marshall density for pavement compaction. The revisions were used on six major overlay projects during the 1988 construction season. Four of these projects are being studied (*2*). After 1 year of monitoring, these pavements have exhibited negligible levels of rutting.

In the continuing effort to improve the overall performance of RRHMA, WisDOT made the following changes for the 1989 construction season: expanded gradation bands, higher air voids and slightly lower voids in the mineral aggregate, reduced Marshall stability, tensile strength ratio (TSR) requirement, and 92 percent of maximum specific gravity (MSG) for pavement compaction.

SPECIFICATIONS

In search of durable, nonrutting, quality HMA pavement, WisDOT has incorporated changes to achieve these goals. Changes in aggregate specifications over the years are shown in Table 1.

WisDOT has increased the fractured particle requirements to provide for greater aggregate interlock and increased internal strength. The plasticity index is determined on passing No. 200 material instead of passing No. 40 material to reduce clay fines and their associated problems. The wear and soundness limits were changed to increase the overall quality of the aggregates. The natural sand content has been limited to the percentages shown to avoid oversanding the mixtures, yet the limits still provide for adequate mixture workability.

Tables 2 and 3 summarize the WisDOT HMA Specification and Special Provisions, which are used for overlays on heavily traveled pavements. The gradations of aggregates for HMA have gradually been coarsened. The material passing the No. 200 sieve has been significantly reduced to provide more space for asphalt in the mixture. The dust-to-asphalt ratio (No. 200 AC) was first introduced in 1989 to provide adequate asphalt film thickness.

Marshall parameters were also improved to achieve high-quality mixtures. The compactive effort was increased from 50 to 75 blows per end to provide a laboratory density that more closely duplicated the ultimate pavement condition. The minimum Marshall stability in 1984 was increased to 1,800 lb to help eliminate some of the aggregates that had demonstrated past poor performance. High-stability mixtures do not necessarily reduce rutting. Therefore, the stability value in 1989 was reduced to a minimum of 1,500 lb. Marshall retained

Wisconsin Department of Transportation, Madison, Wis. 53704.

TABLE 1 WisDOT AGGREGATE SPECIFICATIONS FOR HMA

Aggregate Properties	Years				
	1981	1982	1984-1987	1988	1989
Fractured Particles					
a. % by Count one face, min.	45	45	90	90	90
b. % by Count two faces, min.	--	--	--	60	60
Plasticity Index (PI)					
a. passing #40, max.	3	3	3	--	--
b. passing #200, max.	--	--	--	3	3
Wear Loss %, max.	50	50	45	45	45
Soundness Loss %, max.	18	18	12	12	12
Natural Sand, % total aggregate	--	--	5 min.	10 max.	20 max.

TABLE 2 WisDOT HMA SPECIFICATIONS FOR BINDER COURSE

Sieve Size	Percent by Weight Passing				
	1981	1982	1984-87	1988	1989
1 Inch	95-100	100	95-100	100	100
3/4 Inch	-	95-100	-	80-100	80-100
1/2 Inch	65-90	-	65-90	60-85	60-90
3/8 Inch	-	65-90	-	-	50-80
No. 4	40-65	-	40-65	30-50	30-60
No. 8	25-50	30-55	25-50	16-36	16-46
No. 30	-	-	-	17-18	7-24
No. 50	7-25	8-28	7-25	8-13	6-16
No. 200	3-12	3-12	3-12	3-7	3-7
No. 200/AC Ratio	-	-	-	-	0.6-1.2
Marshall Parameters Blows/End	50	50	50	75	75
Stability, lbs, min.	1000	1000-1200	1800	1800	1500
Ret. Stability, %	-	-	-	75	-
Flow, 0.01 in.	18 Max.	18 Max.	16 Max.	8-14	8-16
Air Voids, %	2-6	2-6	2.5-6	3-5	4-6
VMA, % min.	-	-	-	14	13.5
TSR, % min.	-	-	-	-	70
Pavement Target % Marshall Density	93	93	93	97	-
% Maximum Sp. Gr.	-	-	-	-	92

TABLE 3 WisDOT HMA SPECIFICATIONS FOR SURFACE COURSE

Sieve Size	Percent by Weight Passing				
	1981	1982	1984-87	1988	1989
3/4 Inch	100	100	100	100	100
1/2 Inch	95-100	95-100	95-100	93-97	93-97
3/8 Inch	75-100	75-100	75-100	75-95	75-90
No. 4	45-85	45-85	45-75	45-65	45-72
No. 8	30-60	30-60	30-48	25-42	25-54
No. 30	-	-	-	11-22	11-28
No. 50	10-30	10-30	10-25	8-16	8-20
No. 200	5-12	5-12	5-8	3-7	3-7
No. 200/AC Ratio	-	-	-	-	0.6-1.2
Marshall Parameters Blows/End	50	50	50	75	75
Stability,lbs,min.	1200	1200-1600	1800-2000	1800	1500
Ret. Stability,%	-	-	-	75	-
Flow, 0.01 in.	18 Max.	18 Max.	16 Max.	8-14	8-16
Air Voids, %	2-6	2-6	2.5-6	3-5	4-6
VMA, %, min.	-	-	-	15	14.5
TSR, %, min.	-	-	-	-	70
Pavement Target % Marshall Density	95	95	95	97	-
% Maximum Sp. Gr.	-	-	-	-	92

stability had been used to determine aggregate susceptibility to stripping in the presence of water. However, in 1989, the TSR was substituted for this purpose. The Marshall flow limit was confined to a maximum value of 18 until 1988, when it was changed to the range shown in Tables 2 and 3. The minimum mixture air voids have been gradually increased over the years to prevent pavement rutting. The minimum voids in the mineral aggregate (VMA) ensures an adequate reservoir for asphalt cement and is essential for a successful RRHMA.

The target density for pavements was increased to prevent rutting caused by traffic consolidation. The pavement air voids goal was set at 7 percent at the time of construction. In 1989, maximum mixture specific gravity was substituted for the density target. The contracts provided for reduced payments if the required minimum pavement densities were not achieved.

1988 CONSTRUCTION EXPERIENCE

A total of six projects was constructed in 1988 using RRHMA to overlay the existing portland cement concrete (PCC) pavements (see Table 4). The first four of these projects are being extensively studied as a major research effort. Financing for this study was provided under the auspices of the FHWA Highway Planning and Research Program. This study will continue for 5 years. An initial progress report will be available early in 1990.

The objectives of the aforementioned study follow:

1. To evaluate the performance of new mix design;
2. To relate the performance of new rut-resistant asphalt mix to the performance of previous HMA mixes;
3. To evaluate construction equipment, methods, procedures, and specifications of the new mix; and
4. To evaluate new HMA field-testing procedures.

The properties of the mixtures in the field were monitored daily. Tables 5 and 6 present the VMA and air voids results on field-compacted pavement versus the laboratory values.

Table 7 presents the average percent compaction achieved in the field pavements. Contractors used a wide variety of compaction equipment and rolling patterns as they attempted to achieve the specified compaction. Many problems were

TABLE 4 WisDOT 1988 CONSTRUCTION PROJECTS

	Project Description	District	State Project Number	Construction Year
1.	USH 41, South County Line to North County Line, Fond du Lac County	2	1107-01-70	Summer 1988
2.	I-90/94, Tomah to Lake Delton Road (Camp Douglas to New Lisbon EB Lanes only), Juneau County	4	1016-04-73	Summer 1988
3.	I-94, Hixton to Black River Falls, and Hixton to CTH "F", I-94 EB and WB, Jackson County	5	1021-08-78	Summer 1988
4.	I-94, CTH "T" - STH 128 Section, Hudson - Eau Claire Road, St. Croix County	6	1028-07-71	Summer 1988
5.	I-94, CTH "E" - East County Line, Madison - Waukesha Road, Jefferson County	1	1068-00-71	Summer 1988
6.	I-90, USH 12 - STH 33, Lake Delton - Madison Road, Sauk and Columbia Counties	1	1011-03-81	Summer 1988

TABLE 5 LABORATORY VERSUS PAVEMENT VMA

Project No.	VMA			
	Binder Course		Surface Course	
	Laboratory	Pavement	Laboratory	Pavement
1	13.4	12.9	15.3	14.9
2	13.5	13.7	14.6	13.9
3	13.5	12.4	15.0	13.4
4	14.0	12.5	14.7	13.1
5	15.1	14.0	14.5	15.0
6	14.2	12.6	15.4	14.1

Note - The specification for binder course was 14 percent minimum and for surface course 15 percent minimum.

TABLE 6 LABORATORY VERSUS PAVEMENT AIR VOIDS

Project No.	Air Voids			
	Binder Course		Surface Course	
	Laboratory	Pavement	Laboratory	Pavement
1	3.9	8.8	4.1	8.2
2	4.0	7.0	4.9	8.6
3	4.9	7.0	4.8	8.4
4	5.0	7.2	4.8	8.7
5	5.2	7.6	4.8	8.8
6	4.9	9.0	4.7	7.4

Note - The specifications for air voids for binder course and surface courses required 3-5 percent

TABLE 7 AVERAGE PERCENT COMPACTION IN PAVEMENTS

Project No.	Binder Course	Surface Course
1	94.9	95.1
2	97.5	96.6
3	96.4	96.0
4	97.7	96.9
5	97.8	96.4
6	95.5	96.9

Note - The specifications for binder and surface courses required 97.0 percent minimum compaction.

encountered: pavement shoving under the action of the rollers, aggregate shattering, mixture tenderness, and segregation. Extraordinary efforts and a tremendous number of hours were devoted to overcome these hurdles. With the exception of Project 1, approximately 96 percent compaction was achieved.

During the construction on each project, asphalt cement samples were required to be sent to the WisDOT Materials Laboratory for acceptance testing and for Penetration Viscosity Number (PVN) index. AC 85–100 grade was required for all projects, and sources for each asphalt cement were documented. The PVN index represents a measure of asphalt temperature susceptibility. The samples showed average results of -0.1 to -1.1, which indicate that adequate structure is provided for heavy traffic.

Samples of baghouse fines from each project were collected and analyzed at the WisDOT Materials Laboratory. At each project it was found to be necessary to reject baghouse fines to control mixture air voids. The laboratory analyses show that the baghouse fines primarily consisted of silt fraction material and therefore would not perform as an asphalt extender.

Plant quality control tests were performed by state personnel to ensure that the specification requirements were being achieved in the field. Marshall test apparatus, extraction equipment, and accessories were available on each project. Three sets of tests were run on mixtures from each 1,500-ton lot for each project.

Five pavement core samples were obtained from each lot to determine the compaction compliance. After density testing in the field, the cores were sent to the WisDOT Materials Laboratory for Marshall testing, extraction, and recovery procedures.

Profile measurements were also taken by using the Rainhart transverse profilograph. These measurements were obtained immediately behind the cold roller, before traffic was allowed on the pavement, and once again before the project was accepted. The results showed that there was virtually no rutting on any of these pavements.

The construction reports on the first four projects were prepared and presented in March 1989 to the WisDOT Council on Applied Research. These reports, along with other pertinent information on all six projects, can be made available on request.

POSTCONSTRUCTION EVALUATIONS

The first four projects will be extensively researched for a period of 5 years or longer to study the long-term performance of RRHMA. The following measurements will be taken:

1. Transverse profile of the roadway, twice a year;
2. Nuclear density and density on the run (DOR), twice a year;
3. Core samples, twice a year for the first year and annually thereafter;
4. Laboratory tests on cores: density, air voids, extraction and recovery, and penetration and viscosity of asphalt;
5. Present serviceability index (PSI), twice a year;
6. Pavement distress index (PDI), once a year; and
7. Weigh-in motion (WIM) study conducted on Project 1 after construction.

After 6 months of service, the pavements showed negligible rutting. One exception to this is Project 2, where asphalt cement content was too high for about one lot of mixture. This section of the highway exhibited 0.25 in. of rutting in the wheelpaths. The average PSI on the four projects was 4.1 on a scale of 0 to 5 (5 being the best). The pavements exhibited premature reflective cracking, and, consequently, some of the cracks have already been sealed. In an attempt to minimize rutting, low asphalt contents were incorporated into the mixtures. This resulted in brittle mixtures that were more susceptible to cracking. Other than cracking, no other major pavement distresses have been noticed at this time.

CONCLUSION

WisDOT is committed to construct quality rut-resistant asphalt concrete pavements capable of carrying ever-increasing and heavier traffic throughout the design life. This commitment involves writing good specifications, incorporating excellent quality aggregates and asphalt cements, conducting a proper mixture design, exercising good quality control and quality assurance, and monitoring and evaluating pavement performance.

The 1988 RRHMA pavements have exhibited negligible amounts of rutting and have brought about positive results but need further improvements. Improvements were incorporated in 1989 RRHMA pavements, and subsequent annual reviews will be conducted to see if further modifications are required. Those at WisDOT believe that the current RRHMA specification for heavily traveled roadways reflects state-of-the-art thinking and are confident that it will solve the rutting problem.

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