Technical Paper

ISSN 1997-1400 Int. J. Pavement Res. and Technol. 1(4):121-128

Binder Flushing in Low Traffic Volume Superpave Mixes

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Abstract: This paper analyzes early flushing or "bleeding" that occurred in several sections of Superpave pavement designed for low traffic volume roads in Nebraska. The objective of this study was to develop a better understanding of the causes of flushing and to examine the relationship between flushing and the material specifications for low traffic volume Superpave mixes. Records indicate that construction of the flushed sections proceeded within specifications. Moreover, all QA/QC material test results were within acceptable ranges. A review of mix design parameters for all flushed sections was conducted to verify compliance with Superpave specifications. Comparison of specified parameters between flushed and non-flushed sections with identical mix designs were also conducted. Field samples from flushed and non-flushed sections were obtained and analyzed for mix design verification and binder characterization. Additional testing on recovered asphalt binders was conducted to assess binder contribution to flushing. Results indicated that recovered binder properties did not meet Superpave specifications. This research shows the compatibility of asphalt binder dominates the asphalt-aggregate interaction. Flushing in the affected pavement sections resulted from excessive binder content, variations in binder properties due to poor material quality control, and lack of a requirement to test for separation problems during construction.

Key words: *Asphalt binder; Flushing; Low volume roads; Superpave mixes.*

Introduction

Binder flushing has been observed in specific pavement sections constructed with low traffic volume Superpave Level 2 (SP-2) mixes in Nebraska. These sections are located on low volume roads which were constructed between 1999 and 2000. Flushing was initially observed during the years of 2000 to 2002 at levels ranging from medium to severe. Flushing usually started with a few spots of binder appearing on the pavement surface. Flushing spots increased in size during hot summer days until multiple spots merged to form a distressed area of significant size. The size of the flushed areas continued to increase all summer long. All pavement sections studied had scattered flushed areas, up to 200 feet long, with one or both of the wheel paths flushed. None of the affected sections were flushed over 100% of their surface. No significant rutting was reported in any of the flushed sections. Quality assurance (QA) data compiled by the Nebraska Department of Roads (NDOR) and quality control (QC) data from the pavement contractors showed compliance with the then current Superpave specifications for SP-2 mixes. Pavement surface conditions were generally good with no indication of any other significant defects. Cores taken from the flushed areas showed no signs of moisture-related distresses.

Mix bleeding or binder flushing is a migration of the binder to the surface of a flexible pavement, with or without fines. Krishnan and Rao indicate that migration can happen by means of two mechanisms [1, 2]. The first mechanism is diffusion of binder into air voids when subjected to a temperature exceeding the binder softening point. The second mechanism is movement of the binder due to a pressure gradient developed within the pavement. Development of pressure gradient results from the reduction of air voids under traffic loading. Both mechanisms can occur simultaneously. The contribution of each depends on the temperature-stiffness relationship of the binder, the distribution of air voids in the asphalt mix, and the traffic loads on the pavement. Literatures also suggest binder contamination during the construction process with a solvent such as diesel fuel as possible cause of flushing [3, 4]. Conversations with pavement contractors and state department of transportation personnel plus a review of construction records were unable to identify specific cause(s) of solvent contamination [3].

Literatures relate flushing to the combination of excess binder content and low air voids [5, 6]. O'Connor initiated a study to determine the cause(s) of low quality performance for selected asphalt pavement sections in Colorado [5]. The study evaluated twenty-one projects, some of which performed well, while others performed poorly. Field investigations were conducted to evaluate pavement surface condition with regard to rutting, shoving, bleeding, raveling, and cracking. Among the five distress indicators studied, only rutting and bleeding were found to present significant problems. All flushed sections experienced some degree of rutting with minor severity in some cases [5]. The lack of raveling and cracking was believed to result from the high percentage of soft asphalt used. Several projects were constructed with an air void content of less than 3%, which was equivalent to an over-asphalted mix. Most of these low-void mixes exhibited some bleeding in the wheel path. Bleeding in the wheel path occurred between 2.5% and 3.0% air voids for these pavements. The actual air void content in the wheel paths averaged about one percent lower than the design air void content [5].

Objective

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Note: Submitted April 1, 2008; Revised May 12, 2008; Accepted May 30, 2008

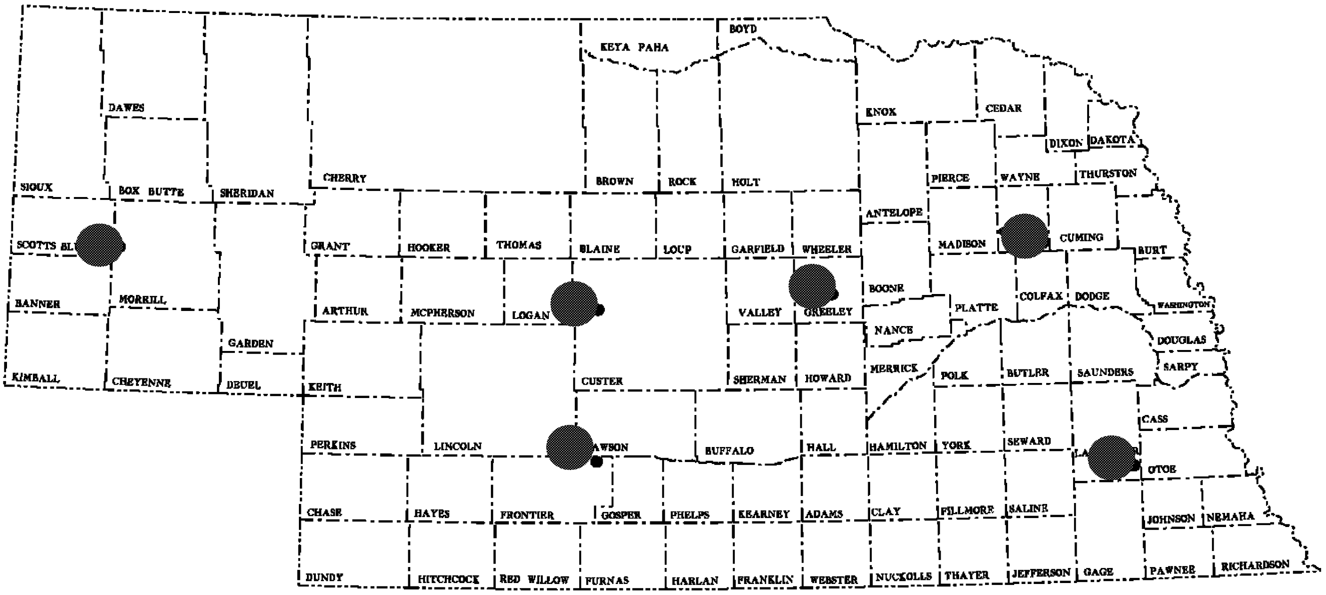

Fig. 1. Map of Nebraska with Locations of Flushed Sections.

Table 1. Specifications for SP-2 Mixes in Nebraska.

Gyratory Level	Earlier (N_{des} 76) (N_{max} 117)	Current (N_{des} 76) (N_{max} 117)
Fine Aggregate Angularity (FAA)	Min. 40	Min. 43
Voids in Mineral Aggregate (VMA)	13-15	Min. 13
Voids Filled with Asphalt (VFA)	65-78	65-78
Use Natural Aggregate	Yes	Yes

N_{des}: Number of gyrations at the design compaction level.

N_{max}: Number of gyrations at the maximum compaction level.

The objective of this study was to analyze data concerning flushing problems for sections of low traffic volume Superpave mixes in Nebraska and to develop a better understanding of possible causes. The results of this study will help pavement design engineers to better understand the nature and performance of Superpave mixes designed specifically for low traffic volume situations.

Superpave Flushing Cases in Nebraska

Fig. 1 is a map of the State of Nebraska with the locations of flushed sections indicated. Distribution of distress indicates that flushing was not regionally specific, which generally excludes environmental factors as a cause. SP-2 is a low traffic volume road mix that encourages the use of naturally occurring aggregate. The NDOR design specifications for SP-2 mixes at the time pavement sections were constructed plus the current specifications are shown in Table 1. The NDOR provided records of thirty-five pavement sections constructed using SP-2 mixes. Eleven sections had been constructed with PG 58-28 binders; five of these PG 58-28 sections were flushed. Twenty-four sections were constructed using PG 64-22 binders, but only one section exhibited low severity flushing within small areas.

Table 2 shows the pavement sections analyzed as part of this study. Flushed sections were reported to have an Average Daily Truck Traffic varying from 190 to 230. The most rapid onset of flushing occurred on Highway 43 within a few weeks after construction was completed (in the summer of calendar year 2000). Because of the severity of flushing, this pavement surface was milled in late 2000. Flushing was observed again on the same section in late summer of 2002, but with much lower severity.

Table 2. SP-2 Pavement Sections Analyzed.

Pavement Sections	Binder Grade	Condition	Year of Construction	Year Flushing Observed	Natural Gravel	Crushed Gravel	Crushed Rock	RAP
HWY-56	PG58-28	Flushed	1999	2002	47.00%	15.00%	22.00%	None
HWY-43	PG58-28	Flushed	2000	2000/2002	42.00%	20.00%	19.00%	None
HWY-23	PG64-22	Slightly Flushed	2002	2002	34.00%	48.00%	18.00%	None
HWY-15	PG58-28	Flushed	2000	2002	41.00%	25.00%	20.00%	15.00%
HWY-26	PG58-28	Flushed	2000	2000/2002	43.00%	50.00%	10.00%	None
HWY-66	PG58-28	Non-Flushed	2000	NA	13.00%	55.00%	15.00%	15.00%
HWY-92	PG58-22	Non-Flushed	1999	NA	46.00%	10.00%	19.00%	15.00%
HWY-75	PG64-22	Non-Flushed	2000	NA	50.00%	13.00%	12.00%	25.00%
HWY-74	PG64-22	Non-Flushed	2000	NA	30.00%	50.00%	20.00%	None

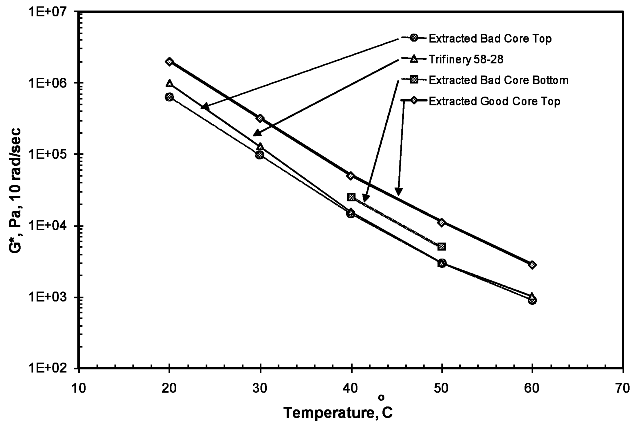

Fig. 2. Comparisons of Extracted Cores and Original Asphalt [7].

During the summer of 2000, an initial study was conducted to determine the cause(s) of flushing on Highway 43. Cores from several pavement sections were obtained and analyzed to determine chemical and physical properties of the binder and to verify design and construction parameters of the flushed mixes [7]. Table 3 and Fig. 2 contain results of testing on the original and extracted binder .The study did not discover any conclusive evidence as to the cause(s) of flushing on Highway 43. The analysis, however, did discover some unusual chemical properties in the extracted binder that were significantly different from those that existed in the original binder. The study found a residual material with lower boiling point in the extracted binder that did not exist in the original binder [7]. Extracted binders were found to be substantially softer than the originals. There were indications that a low compatibility binder had separated, with one of the resulting products consisting of an oily residue which softened the asphalt mix. The original mix design called for 5% asphalt by weight. Flushed cores showed higher asphalt content, with an average value of 6.99% by weight [7]. Non-flushed cores showed an average of 4.92% asphalt content by weight. During this study, it was also discovered that flushing problems with asphalt binders in low traffic volume Superpave asphalt mixes were being experienced in other states.

Methods and Procedures

A study plan was developed that included comparison of flushed sections with selected non-flushed sections, analysis of QA/QC data for both flushed and non-flushed sections and randomly drilled cores in and adjacent to both flushed and non-flushed sections. Several hypotheses concerning the interaction of aggregate from specific sources with various asphalt binders were considered at the beginning of the research program. To examine these hypotheses, specific non-flushed sections were selected by the NDOR for comparisons based on similarity of asphalt sources, principle contractors for both flushed and non-flushed sections, year of construction, and aggregate sources. These comparisons enabled analysis of specific parameters critical to the design and construction of SP-2 mixes. The evaluated sections are listed in Table 2. All severely flushed sections were associated with PG 58-28 binder from various suppliers. Only a single case of PG 64-22 (on Highway 23) exhibited low severity flushing. Visits to each of the flushed sections revealed that the flushing of Highway 23 was insignificant when compared to the other flushed sections.

Table 3. Summary of Thermal Analysis of the Highway-43 Samples.

Sample	Glass Transition Temperature, T_g, ^{0}C	Crystalline Content, mass %
Original PG 58-28	-25.3	2.4
Extracted Good Core Top	-26.3	2.6
Extracted Bad Core Top	-29.4	2.0
Extracted Bad Core Bottom	-27.2	2.3

There was no evidence to suggest that use of natural aggregates contributed to the flushing problem. Many non-flushed sections contained higher percentages of natural gravel than the flushed sections. The same results were found for recycled asphalt pavement (RAP) content. More non-flushed sections than flushed sections contained RAP, and only one flushed section had some RAP content. Possibilities of moisture-related causes were also eliminated. QA/QC data indicated that tensile strength ratio on all flushed sections was above specification requirements. None of the drilled cores in flushed sections showed any moisture-related damage resulting from problems with adhesion between asphalt and aggregate. To examine the possibility of moisture damage due to a failure in cohesion of the asphalt paste, a binder extraction process (ASTM D 1856-95a) was used to check for the presence of water. None of the binder extraction tests (for flushed sections) resulted water in the solvent-asphalt solutions.

More than eighty cores were drilled from both flushed and non-flushed sections. Testing included both binder physical properties and asphalt mix design parameters. Overlays were one lift of 5.0cm (2.0inches) for all sections except for Highway 56, which had two lifts, each 5.0cm (2.0inches) in thickness. Cores were obtained to a depth of 15.0cm (6.0inches). The top 5.0cm (2.0inches) of overlay were split into two 2.5cm (1.0inch) layers. Mix parameters were determined for each 2.5cm (1.0inch) layer. Average values were used in the analysis of mix parameters as no significant differences were found between the two 2.5cm (1.0inch) halves. Binder physical properties did not include extracted material from the top 2.5cm (1.0inch) because this layer was subjected to oxidation, contamination, and other causes of aging that prevented an accurate estimation of original binder properties. Binder content was based on the average of the two 2.5cm (1.0inch) halves. For Highway 56 the bottom layer was treated separately from the upper layer and was not separated into two parts. Each of the original layers belonged to a different mix lot, as these overlays were not constructed at the same time. Testing on the cores, QA/QC data and calculations of pavement temperature indicated that flushing occurred primarily in the upper layer. To ensure testing accuracy, all testing was conducted by certified technicians in the NDOR's laboratory facilities.

Results and Discussion

Only a brief summary and examples of the test results are presented in this paper. A complete list of all test results including binder and

Table 4. Testing on Extracted Binders @ 58°C.

			G*/SIN δ, kPa	G*, kPa	δ, Deg
HWY-56 (Flushed Sections)	Core No.	18	1.651	1.645	85.14
		19	1.647	1.642	85.29
		21	1.601	1.596	85.48
		22	0.9387	0.936	86.17
	Un-aged, Original		1.15		
	RTFOT, Original		2.65		
HWY-15 (Flushed Sections)	Core No.	1 (No-Flushing)	2.859	2.842	83.81
		3	1.97	1.965	85.95
		5	1.535	1.532	86.05
		7	1.714	1.71	85.88
		9	0.7933	0.7923	87.07
	Un-aged, Original		1.28	1.278	87.13
	RTFOT, Original		2.886	2.872	84.27
HWY-66 (Non-Flushed Sections)	Core No.	2	6.322	6.238	80.62
		4	6.184	6.101	80.59
	Un-aged, Original		1.18		
	RTFOT, Original		2.98		

Table 5. Testing on Extracted Binders @ 19°C.

			G* SIN δ, kPa	G*, kPa	δ, Deg
HWY-56 (Flushed Sections)	Core No.	18	1039	1187	61.13
		19	1041	1195	60.64
		21	1056	1208	60.90
		22	628.4	706.1	62.86
	PAV, Original		3730		
HWY-15 (Flushed Sections)	Core No.	1 (No-Flushing)	1925	2331	55.68
		3	2774	3342	56.11
		5	1435	1648	60.57
		7	1386	1603	59.86
		9	585.4	642.9	65.58
	PAV, Original		4096	5931	43.68
HWY-66 (Non-Flushed Sections)	Core No.	2	2698	3517	50.1
		4	2773	3633	49.74
	PAV, Original		4056		

mix parameters can be found in the technical report submitted to the NDOR [8].

Analysis of Binder Properties

Table 4 shows the properties of extracted binders from pavement cores. QA/QC data on original binders is shown in Table 5. Flushed sections had been in service for three to four years when cores were extracted. Original binders were PG 58-28 with testing at 58°C for Rolling Thin Film Oven Test (RTFOT) and at 19°C for Pressure Aging Vessel (PAV). Recovered binders from the pavement cores were expected to be stiffer than RTFOT values but softer than PAV values. Results show extracted binders varied in stiffness, but all were softer than RTFOT values and significantly softer than PAV values. In two cases, extracted binders were softer than the original, un-aged binder. Similar results were obtained from the Highway 43 initial flushing study [7].

The chemical analysis on the Highway 43 samples indicated binder-aggregate compatibility problems in the extracted binders. Thermal analysis showed a lower molecular weight material than the original asphalt in the extracted binder. Binder compatibility decreases with age and may lead to phase separation producing a solid, asphaltene-like material dispersed in a relatively fluid medium. The solid material is not extractable with commonly used solvents. Hence, the extracted binder might not include the separated solid phase. An analysis of binder separation would have minimized the possibility of contamination as a cause of softened binders in extracted cores. The NDOR does not require any QA testing for binder separation, and QC testing for binder separation is not a common pavement construction practice in Nebraska.

G*Sinδ @ 19°C and G*/Sinδ @ 58°C values obtained from QA/QC records were based on average test results at the time of construction. It was not possible to refer test data from extracted cores to exact asphalt construction lots because of inadequate record keeping. All QA/QC values showed compliance with the then current specifications for binder grade. Recovered binders from extracted cores showed significant variability in properties, which was not presented in the QA/QC data. Variability of binder parameters within the extracted cores could be attributed to several factors during the construction process, including segregation of mix components. Additional QA/QC measures may be needed to ensure more consistent SP-2 mix quality.

Table 6. Average Maximum Seven Days Pavement Temperature, Highway-56.

Year	$d_{(0-50)}$ = 8.3°C	$d_{(0-50)}$ = 5.6°C
1999	57.24	63.43
2000	58.08	64.48
2001	58.45	65.01
2002	59.44	65.01
Mean	58.30	64.48
Standard Deviation	0.91	0.75

The selection of asphalt grade for SP-2 mixes in Nebraska was questioned. All sections with significant flushing used PG 58-28 binders. Only one section with PG 64-22 (Highway 23) showed insignificant flushing. Reports from the NDOR district engineers indicated that flushing primarily occurred during higher summer temperatures. An analysis of pavement temperature for the past four years was conducted for all flushed pavement locations. The objective was not to examine the current performance grade selection system used by the NDOR but rather to determine if exceptional pavement temperature could be a factor. Flushing occurs when pavement temperature is high enough to cause softening of the binder so that it can flow under the effect of traffic loads. Analysis of pavement temperature can help determine the depth of pavement to consider as a source of flushed binder.

Strategic Highway Research Program (SHRP) procedures for Superpave specifications were applied to the temperature analysis [9]. Data on maximum daily air temperature and section longitude and latitude were collected from local sources. All basic assumptions documented in the original SHRP reference were applied. Within the SHRP procedures, the maximum temperature difference between the surface and a 5.0cm (2.0inches) depth during hot summer days was assumed to be between 10 and 20°F. Table 6 presents the average maximum seven day temperature, 20.0 mm below pavement surface, for Highway 56 over the past four years. The table presents two cases; the first case is for a difference of 15°F, $d_{(0-50)}$ = 8.3°C. The second case is for a difference of 10°F, $d_{(0-50)}$ = 5.6°C. In both cases; pavement temperature was higher than optimal for a PG 58 grade mix, with the second case being more critical.

Fig. 3 presents a frequency (in days) of maximum daily temperature based on the assumption of $d_{(0-50)}$ = 5.6°C for Highway 56. Fig. 3 shows that pavement temperature 20.0mm below surface was higher than 58°C for about sixty days in each of the past three years. The data indicate that a PG 64 binder would be a better choice for the Highway 56 location. Similar conclusions were reached for the other flushed sections. The NDOR stopped using PG 58 grade binders in Superpave mixes after the 2001 construction season. While the maximum pavement temperature was higher than design values for all flushed sections, the temperature at a depth of 10.0cm (4.0inches) was not sufficient to soften the binder to the point where it begins to flow. Testing on extracted core materials confirmed this finding.

Effects of Mix Parameters

Air voids in an asphalt mix are necessary to produce specific desired parameters. Approximately 4% air voids in the total compacted mix at optimum asphalt content is generally considered optimal. This air void content must be created in the field during construction by applying sufficient but not excessive compaction effort; it should not be achieved by adding binder until the void space decreases to a specified level. A minimum quantity of dust, defined as material passing the #200 sieve, is required to regulate functions of the binder. Low dust to binder (D/B) ratio results in excessive binder content and can lead to softening of the mix and/or flushing of the binder. Too high of D/B may lead to fatigue cracking. The parameters related to the voids in asphalt mix include binder content, D/B ratio, total voids, and voids filled with asphalt (VFA).

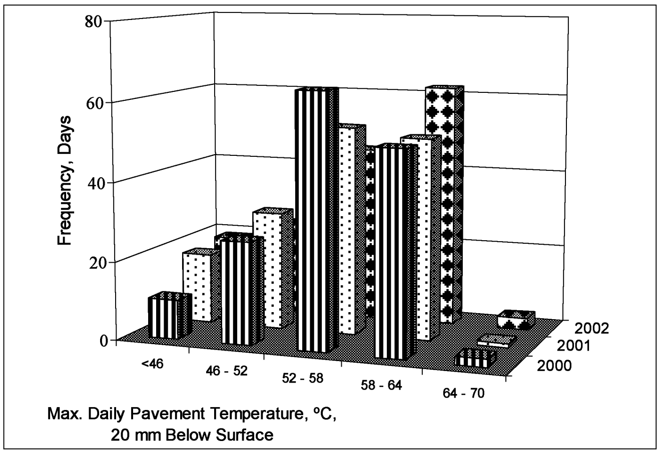

Fig. 3. Frequency of Maximum Daily Pavement Temperature, Highway-56.

Table 7 presents average values of material parameters obtained from records of the original mix designs, QA/QC testing, and testing on flushed and non-flushed cores. Flushed sections had high binder contents. In some cases, actual binder content was significantly higher than the original design content. In the case of Highway 56, mix design was based on 5.0% binder content but flushed cores showed an average of 5.9%. In the case of Highway 43, the mix design was based on 5.0% binder content but flushed cores showed an average of 5.7%, with some values as high as 7.0%. For some pavement sections (Highway 15 and 26), the original pavement design specifications called for slightly higher (5.7%) binder content. Mix designs of non-flushed pavement sections (Highway 66, 92, 74, and 75) were based on a binder content of 4.7% to 5.2%. Cores and QA/QC records of non-flushed sections showed 4.4% to 5.1% binder content.

Table 7 shows that actual D/B ratios for Highway 43 and 26 flushed sections were significantly lower than those on the non-flushed sections for all pavement sections studied. All flushed sections were originally designed with D/B ratios between 0.5 and 0.6. QA/QC records and cores showed a higher ratio of 0.8 for both Highway 56 and 15, but a much lower ratio of 0.3 for Highway 43 and 0.4 for Highway 26. Non-flushed sections had D/B ratios as high as 1.2, but showed no signs of fatigue cracking after three to four years of service. Thus high binder content and low D/B ratio appear to be the principal factors that contributed to flushing on the Highway 26 and 43 pavement sections. These two sections flushed earliest, Highway 43 a few weeks after construction was completed and Highway 26 a few months after construction was completed, had binder contents above 5% and had the lowest D/B ratios.

Table 7. Material Parameters for Flushed and Non-Flushed Sections.

		% Binder	Dust/Binder	Air Voids	VMA	VFA	FAA	%Pass #200
HWY-56	Mix Design	5.0	0.5	3.8	14.5	73.8	40.0	2.5
	QA/QC	5.2	0.9	4.1	15.2	73.3	41.0	4.8
	Flushed Cores	5.9	0.8	3.7	15.3	75.8	40.3	4.7
	Non- Flushed Cores	5.3	0.8	2.9	14.1	79.2	40.6	4.2
HWY-15	Mix Design	5.7	0.6	5.5	17.9	69.2	41.1	3.7
	QA/QC	5.7	0.7	4.1	16.5	75.2	41.0	4.2
	Flushed Cores	5.5	0.8	5.8	16.6	65.4	41.0	4.6
	Non- Flushed Cores	5.6	0.8	3.0	15.21	80.1	40.4	4.8
HWY-43	Mix Design	5.0	0.6	6.0	16.8	64.4	43.5	3.4
	QA/QC	5.1	0.8	3.6	14.4	75.3	42.1	4.0
	Flushed Cores	5.7	0.3	3.9	14.3	72.2	41.5	4.4
HWY-26	Mix Design	5.7	0.5	4.2	15.5	72.7	43.0	2.8
	QA/QC	5.3	0.4	3.7	14.0	75.8	43.2	4.5
HWY-23	Mix Design	5.5	0.5	5.4	15.8	65.8	43.6	2.5
	QA/QC	5.5	0.5	3.6	15.1	70.1	42.6	2.9
HWY-66	Mix Design	4.7	1.1	4.2	14.0	69.9	41.2	5.4
	QA/QC	4.7	1.0	4.0	14.0	71.7	42.6	4.6
	Non-Flushed Cores	4.4	1.2	3.7	14.0	73.7	41.7	5.4
HWY-92	Mix Design	5.0	0.8	6.1	15.0	58.0	42.4	3.9
	QA/QC	4.6	0.9	4.9	14.2	65.6	40.3	3.9
HWY-74	Mix Design	5.2	0.7	4.5	16.2	72.2	40.5	3.7
	QA/QC	4.9	0.7	3.8	14.9	75.5	NA	3.7
HWY-75	Mix Design	5.2	1.2	3.7	14.6	74.3	41.2	5.3
	QA/QC	5.1	1.0	3.9	14.0	72.3	41.0	5.0

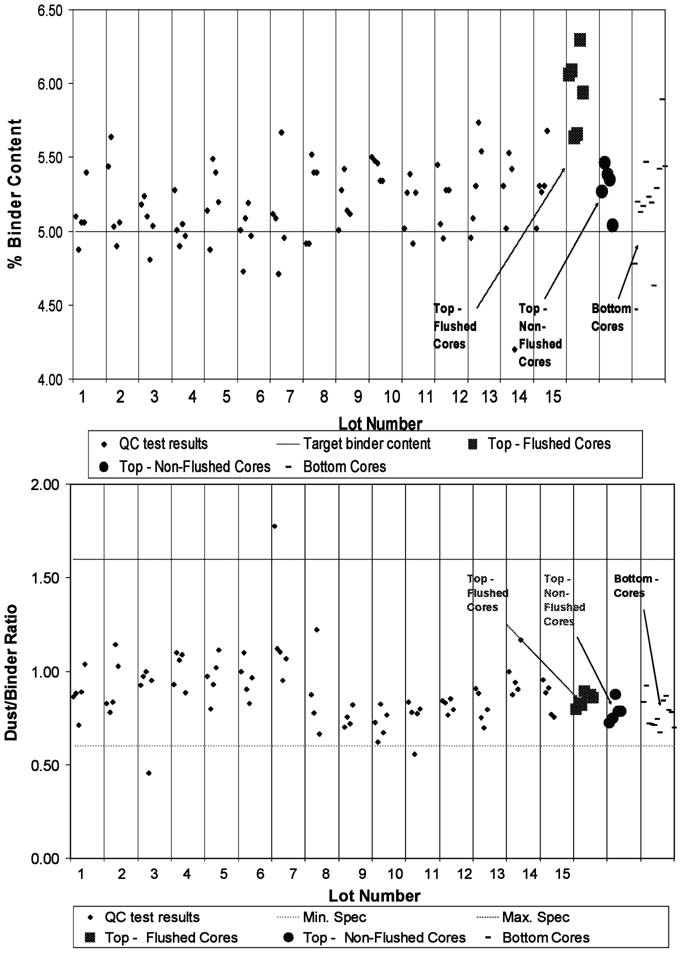

Fig. 4. Comparisons of QA/QC Data with Field Cores for Highway-56.

Theoretically, binder flushes if the voids filled with asphalt (VFA) reaches unity [1, 2]. The VFA value depends on the volume of air voids and the effective binder content of the mix. Most of the extracted cores exhibited higher VFA values than specified by mix design or measured during QA/QC testing (Table 7), but none of the flushed sections had a VFA close to unity. Depending on how the air voids are structured and connected, voids can be very effective in containing the binder. The data in Table 7 show that air voids for both flushed and non-flushed sections are close to 4.0%, so a conclusion regarding the effect of volume of air voids on this flushing problem is not possible. Literatures on the effectiveness of the structure and distribution of air voids in preventing binder flushing support this finding [1, 2].

Conclusions on the causes of the flushing problem cannot be reached without considering the effect of aggregates in the mix. Aggregate contribution to flushing is tied to binder content. Testing showed that the binder content of some flushed sections was low, but the quantity of material passing the #200 sieve was very low for these sections. Design VFA values of pavement sections that flushed were at or near the lower end of the specified range (65 to 78 from Table 1) for the design traffic levels. Flushing occurs when other conditions, including high pavement temperature and/or problems with binder quality, contribute to the problem.

QA/QC Considerations

Results suggest that a primary cause of the flushing problems in specific pavement sections was variation in material properties within the plant produced mix. Binder content was a separate pay item in the contract pay schedule, so pavement contractors had an incentive to use more rather than less binder. Temperatures within pavement sections that flushed were not significantly different from

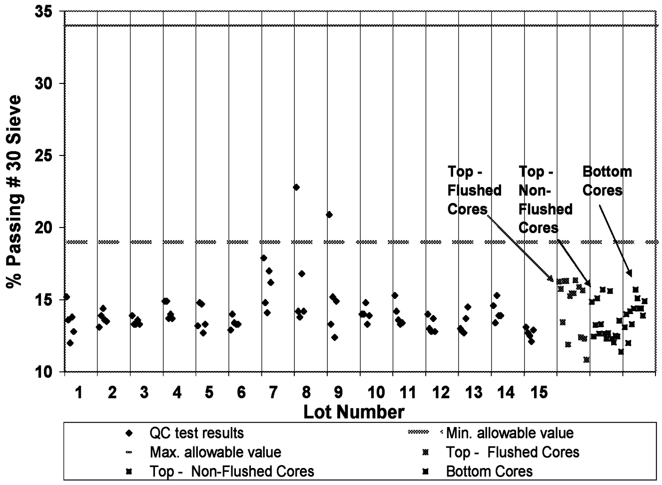

Fig. 5. Highway 56 - Percentage Passing # 30 Sieve versus Lot Number.

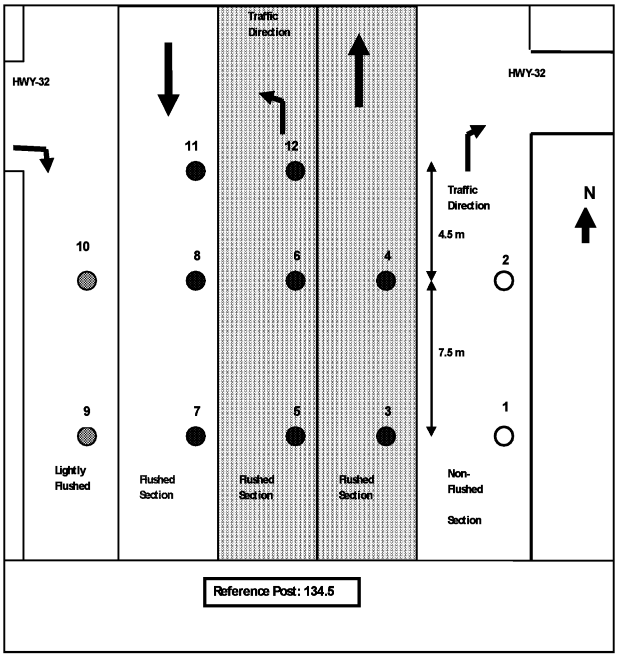

Fig. 6. Effects of Traffic Loads on Flushing Severity.

the temperature within pavement sections that did not flush. Temperature is seldom the cause of flushing unless other factors contribute to the problem. From binder testing on extracted cores, mix parameters were shown to vary from both QA/QC records and mix design. As shown in Fig. 4, for Highway 56 significant variability existed within both D/B ratio and binder content.

Recovered cores averaged almost 2.0% higher than design binder content and in many cases were significantly softer than the original binder. Softer binders often produce separation problems. However, QA/QC testing for binder separation is not commonly required by the NDOR for asphalt construction projects. Performance graded binders are normally purchased from suppliers with a maximum level of separation certified by the manufacturer.

Fig. 5 illustrates the low content of material passing the #30 sieve versus the lot number for Highway 56. This figure confirms that poor QA/QC procedures and the relaxed nature of low volume road specifications in effect at the time significantly contributed to the flushing problem. Finer materials have higher surface area than coarser materials and adhere to free asphalt particles in the matrix. Lack of significant percentages of fine materials provide more free asphalt, thereby increasing the potential for binder flushing.

Effect of Traffic

Fig. 6 illustrates an example of the effect of traffic on the severity of flushing. The figure shows the intersection of Highway 15 and 32 where several cores were extracted. The extension of Highway 32 eastward is a farm-market unpaved road while Highway 15 is a two-lane asphalt highway. In this location, cores 1 and 2 were drilled in the right-turn lane to the low-volume-road with low or no heavy traffic. Cores 3 and 4 were drilled in the through north-bound lane which experiences slightly heavier traffic. Cores 5, 6, and 12 were drilled in the left-turn lane to Highway 32 with heavy traffic. Cores 7, 8, and 11 were drilled in the south-bound lane with heavy traffic. Cores 9 and 10 were drilled in the right-turn from Highway 32 into Highway 15 with a lower heavy traffic volume than that of a through traffic lane. Binder and D/B parameters were not significantly different between flushed and non-flushed cores at this location. Binder stiffness was softer for low flushing severity than for high flushing severity, indicating that flushing generally increased as traffic volume increased.

Findings and Recommendations

Flushing occurs only under specific combinations of conditions, which are directly related to temperature-stiffness of the binder, air voids distribution, and traffic loading. This research showed the compatibility of asphalt binder dominates the asphalt-aggregate interaction. The study analyzed several instances of binder flushing on low traffic volume Superpave pavements in Nebraska. Flushing occurred despite the fact that an acceptable percentage of air voids was present in all pavements. A significant percentage of the voids in the flushed sections were filled with high asphalt content binder-dust paste. All flushed sections contained excessive binder and insufficient dust. Extracted binder samples from flushed sections varied in physical and chemical properties but all were significantly softer than binders extracted from the non-flushed sections. Material properties of the binders related to compatibility are believed to have caused at least partial separation of the light fractions of the binder within the top pavement layer. High pavement temperature, heavy traffic volume, and significant loading contributed to and accelerated the flushing process on some pavement sections. Flushing in the affected pavement sections resulted from excessive binder content, variations in binder properties, and lack of a requirement to test the binder for separation during the construction process. The fact that asphalt content was a separate pay item within the contract pay schedule explains why the binder content was excessive in many of the flushed sections.

It is also clear that the lack of fines, evidenced by material passing the #30 sieve, contributed to the early distress. This is mainly a QA/QC issue on low volume roads. Additional testing as part of the QA process for low traffic volume Superpave mixes is needed to ensure more consistency during the construction process. That need was demonstrated by the variability of material properties within extracted binders and by the differences in measured parameters between the extracted cores, the mix design, and the values recorded by QA/QC personnel during construction. This paper confirms that early flushing is related to QA/QC problems on low volume roads rather than being a Superpave specification issue. Effort is needed to enhance the specifications for low volume Superpave mixes by including binder separation in QA/QC, sampling and mix acceptance procedures.

Acknowledgements

The authors would like to thank the Nebraska Department of Roads for sponsoring this research. Special acknowledgement is extended to Mr. Mukunda Gopalakrishna in creating some of the tables and graphs required, and to Mr. Udit Molakatalla, Mr. Larry Koves and to Mr. John Dageforde for performing the testing.

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