

Prevention of Stripping Under Chip Seals

David L. Rettner, Principal Investigator
American Engineering Testing, Inc.

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Research Project
Final Report 2017-35



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16. Abstract (Limit: 250 words) Eighteen chip-sealed roadways in eight cities and counties in Minnesota were evaluated both in the field (for condition surveys and density tests) and in the laboratory (for permeability, stripping, tensile-strength ratio, asphalt film thickness, and mix properties) to evaluate factors associated with stripping in asphalt pavements under chip-seal treatments. Analysis of the test data did not support an earlier MnDOT finding that high air voids were a cause of stripping under chip seals. For those locations that did exhibit stripping, the test data did not support a direct relationship between asphalt pavement density and stripping. In addition, the research did not determine a direct relationship between incidence of stripping and site/supplier data (e.g., bituminous mixture, contractor, geographic location, or year of construction). This observation agreed with observations made by Minnesota city/county engineers. An additional outcome of the research is the large amount of testing data developed, which is documented fully in appendices to the final report.			
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Prepared by:

David Rettner
Derek Tompkins
American Engineering Testing, Inc.

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EXECUTIVE SUMMARY

The Minnesota Department of Transportation (MnDOT) recently conducted a study that identified less dense areas, or high air voids, in underlying asphalt pavements as the main cause of stripping under chip seals (Wood & Cole, 2013). This research project follows the work of MnDOT with extensive testing and analysis of low-volume roads in Minnesota that have experienced stripping under chip seal surface treatments.

The project focus was on 18 chip-sealed roadways in eight cities and counties in Minnesota. The research team evaluated the *in-situ* roads and collected pavement samples for laboratory tests. The research conducted included field studies of pavement distress and density (using ground-penetrating radar and nuclear gauge tests) and laboratory tests for permeability, stripping, tensile strength ratio, asphalt film thickness, and mix properties.

A major outcome of the research is that the research was unable to verify the earlier finding that high air voids were a cause of stripping under chip seals. For those locations that did exhibit stripping, the test data did not support a direct relationship between asphalt pavement density and stripping. In addition, the research did not determine a direct relationship between incidence of stripping and site/supplier data (e.g., bituminous mixture, contractor, geographic location, or year of construction). This observation agreed with observations made by Minnesota city/county engineers.

Other observations from 129 municipal engineers in Minnesota were obtained through an eight-question survey. The survey found that 64 percent of the respondents used chip-seal treatments on a regular basis. Of that fraction, 26 percent reported stripping in chip-sealed pavements as a major issue, 39 percent reported observing stripping but did not perceive it as a major issue, and 35 percent reported that they did not observe stripping in their chip seals. Given the survey and field data results, it is clear that not all roads with chip seals exhibit stripping.

Finally, an additional outcome of the research is the large amount of testing data developed under the project work. This data, which is documented fully in appendices to the final report, will help support and improve future research on stripping in chip seals in Minnesota and chip seal performance in general.

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Preventative maintenance ensures that roadways at all agency levels provide a maximum return on investment. Effective maintenance efforts rely on an understanding of pavement loads (environment and traffic) and proper construction and materials. A critical variable that relies on engineer experience and awareness is timing, or when to initiate maintenance on a given roadway. Unfortunately, the timing of maintenance events, such as chip sealing, can be complicated by unforeseen distresses that reduce the life span for a treatment.

Identifying the factors that contribute to chip seal, or seal coat, performance has been a pavement engineering research concern for many decades, with studies on surface treatments dating back to 1928 (Gransberg & James, 2005). In addition, recent major studies have attempted to isolate factors (such as materials, design, and construction practices) that contribute to better performing chip seals (Gransberg & James, 2005). These major studies provide sound, general advice on the use of chip sealing as preventative maintenance; however, ultimately chip seal performance is a local issue given that (1) the treatment itself is thin and short-lived, (2) small variations in materials or construction, which are known to vary by source/location, can have large effects on performance, and (3) overall performance can depend heavily on the environment.

At the 2014 City Engineers Association of Minnesota, a discussion on asphalt paving mixes included the topic of stripping under chip seals, which was emerging as a major concern for over one-half of city engineers (Garrity, 2014). Stripping is understood to be the loss of asphalt concrete material near the asphalt surface (at the bottom of the chip seal), due to a break-down in the bond between the binder and aggregate in the asphalt. This phenomenon is illustrated in Figure 1 using a sample taken from a Minnesota road during the research. Figure 1b shows how material from the stripped asphalt remains bonded to the chip.



(a)



(b)

Figure 1. (a) Surface and (b) underside of chip seal that has “flaked” with stripped material from underlying asphalt pavement

Surveys conducted in a Minnesota Local Road Research Board (LRRB) and Minnesota Department of Transportation (MnDOT) study found that 40 of 66 local Minnesota agency engineers observed stripping under chip seals (Wood & Cole, 2013). This concern is particularly important in terms of asphalt pavements constructed in the mid- to late-1990s, which have been found to experience premature aging and thus given to stripping. Given Minnesota’s experience with stripping and chip seals, the MnDOT study of chip seals attempted to identify causes of stripping in chip-sealed pavements (Wood & Cole, 2013). The primary hypothesis of this study was that low density (i.e., high air voids) makes asphalt paving mixes more prone to stripping.

Wood and Cole (2013) conducted a study of three locations in Minnesota, from which they collected specimens for air void and permeability analysis in the laboratory. In addition to laboratory testing of 16 field specimens, the authors conducted a laboratory trial of SuperPave mixes common to Minnesota with three levels of air voids (7%, 10%, and 14%). The laboratory trials found that there “was no test that explicitly showed asphalt stripping away from mixtures with higher air voids” (p. B-5). However, on the basis of the 16 field specimens, the authors concluded that less dense areas, or high air voids, were the main cause of stripping in Minnesota chip-sealed pavements.

1.2 RESEARCH SCOPE AND OBJECTIVES

This research project originated from a MnDOT research needs statement that used Wood and Cole (2013) as a starting point for additional investigation of an important issue for local pavement maintenance practices. Thus, the main research objective for this project was to investigate stripping in chip-sealed pavements using testing and analysis of local Minnesota roads.

The research team was provided access to eight municipalities, which provided a total of 18 locations for study. The project scope included the use of these locations for field observation and pavement samples for laboratory examination. The first phase of the project work utilized field surveys, specimen collection, laboratory testing, and analysis to:

1. Verify the finding of Wood and Cole (2013) that high air voids is the primary cause of stripping
2. Investigate why high air voids occurred for locations where observed
3. Identify mix design or construction practices that may have led to observed stripping.

Upon completion of the first phase work, the project objectives were to develop and/or suggest practices to address stripping. Possible practices discussed with LRRB prior to the project work included maintenance techniques to extend the life of chip seals that have failed in stripping; best practices to prevent stripping in Minnesota pavements; and specification, mix design, and construction guidelines for low-volume residential streets if current mix designs are susceptible to failure in stripping

1.3 OVERVIEW OF REPORT

This report documents the full research effort (including data), which included field testing/evaluation and material collection at 18 locations in eight Minnesota municipalities and laboratory testing of collected materials. The report discusses (A) the results of field and laboratory tests and (B) an analysis of collected data. Finally, the report provides recommendations based on testing and analysis.

CHAPTER 2: EVALUATION OF CHIP SEALS IN MINNESOTA

City and county engineers collaborated with the research team to identify 18 locations for the study of chip seal performance, most notably stripping. These locations were used for field testing (i.e., distress condition surveys and density testing) and pavement samples (to be used for further laboratory studies). The following sections describe the locations visited and tests conducted as a part of the project work.

2.1 FIELD LOCATIONS

In the early stages of the project work, during October 2014, members of the research team visited 31 locations in Minnesota as potential sites of stripping in chip seals that could provide data for research. The original 31 sites considered for study are summarized in Table 1. Of the sites considered, 18 were selected for inclusion based on a combination of factors, including the ability to obtain intact cores, the possibility of stripping, and proximity to the Minneapolis-St. Paul metropolitan area to limit travel costs.

The primary 18 sections, located in seven municipalities and one county, consulted for the project work are indicated in the subsections below and shown in Figure 2. Appendix A to this report provides survey condition and core identification information for each location, and Appendix H provides all section information provided to the research team by city/county engineers during the project work.

In addition to the primary sections, additional pavement sections were assessed for the project work. Those additional sections will be noted where applicable (e.g. nuclear gauge testing included extra test locations in six municipalities).

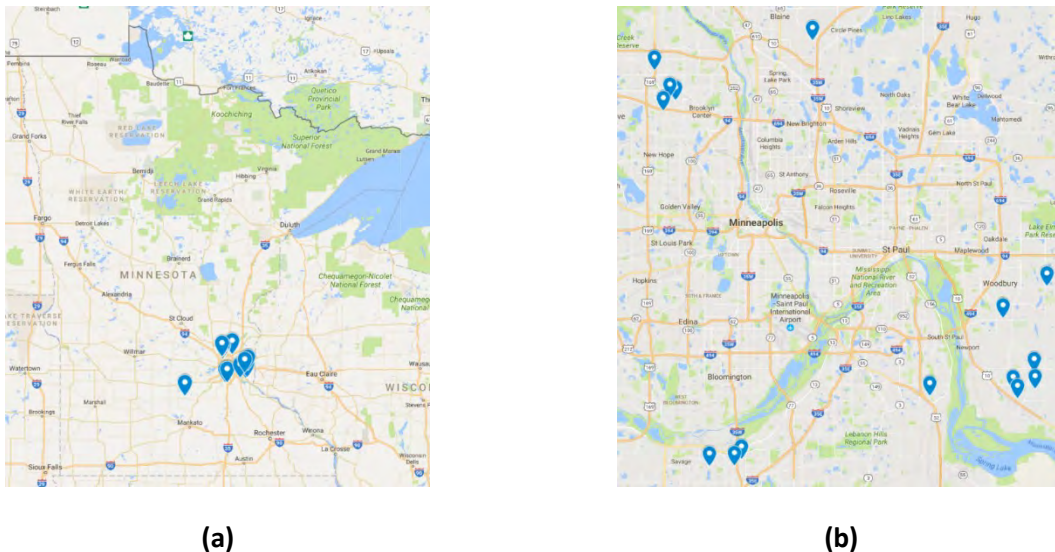


Figure 2. (a) State view and (b) Minneapolis-St. Paul metropolitan area view of locations of pavements surveyed for field and laboratory work

Table 1. Initial sites considered for study under project work

#	City	Street	Condition	Year Constr.	Year Seal Coat	Year last sealed	Last year seal rock	Mix Design	Street Section
1	Woodbury	Lochaven Drive	Stripping in various stages	1989			1/8" Trap Rock	1.5" 2341 Wear; 1.5" Type 2331 Base	8" CL5, 12" Sand
2	Woodbury	Newbury Alcove	Stripping in various stages	1989			1/8" Trap Rock	1.5" 2341 Wear; 1.5" Type 2331 Base	8" CL5, 12" Sand
3	Woodbury	Newbury Alcove	Non-sealed cul-de-sac	1989	n/a	N/A	N/A	1.5" 2341 Wear; 1.5" Type 2331 Base	8" CL5, 12" Sand
4	Woodbury	Torrey Drive	Stripping in various stages	1989			1/8" Trap Rock	1.5" Type 41B Wear; 1.5" Type 31 Base	8" CL5, 12" Sand
5	Woodbury	Bridgewater Parkway	Stripping in various stages	1998			1/8" Trap Rock	1.5" Type 41B Wear; 1.5" Type 31 Base	8" CL5, 12" Sand
6	Woodbury	Salem Drive	Stripping in various stages	1980			Buckshot	2" 2341 Wear	6" CL5, 4" Sand
7	Cottage Grove	Inberg Tr. So.	Stripping in Various stages	reconstructed in 1995	2000?	2007	1/8" Granite	1.5" 2341 Wear; 1.5" 2331 Base	6"-7" reclaimed gravel base
8	Cottage Grove	Islay Ave.	No signs of stripping	1980	2003	2010	1/8" Granite	1.5" 2341 Wear; 1.5" 2331 Base	4" CL 5 gravel base
9	Cottage Grove	Jergen	Stripping in various stages	1991	2003	2010	1/8" Granite	1.5" 2341 Wear; 1.5" 2331 Base	6" CL 5 gravel base
10	Cottage Grove	Jensen	No signs of stripping	1986	2003	2010	1/8" Granite	1.5" 2341 Wear; 1.5" 2331 Base	6" CL 5 gravel base

11	Cottage Grove	Hyde	No signs of stripping	1996	2000?	2007	1/8" Granite	1.5" Type 41B Wear; 1.5" Type 31B Base	5-9" reclaimed base
12	Brooklyn Park	Louisiana Ave	Stripping invarious stages	1995	1999, 2006	2014		1.5" Type 41A Wear; 2.5" Type 31B Base	4.5" Class 5 100% crushed Quarry
13	Brooklyn Park	Boone Avenue	Stripping invarious stages	1994	1999, 2006	2014		1.5" Type 41A Wear; 1.5" Type 41 Binder 7" Type 31 Base	6" Class 5 100% Crushed Quarry 16" Select Gran.
14	Brooklyn Park	63rd Avenue	Stripping invarious stages	1993/1994 (wear)	1999, 2006	2014		1.5" Type 41 Wear; 2.5" Type 41 Binder; 3.5" Type 31 Base	6" Class 5 (RAP), 18" Sel Gran/Gran
15	Brooklyn Park	Winnetka	Stripping invarious stages	1995	1999, 2006	2014		1.5" Type 41 Wear; 2.5" Type 31 Base	4.5" Class 5 100% crushed Quarry
16	Brooklyn Park	73rd Avenue	unsure	1998	2000	2007		1.5" Type 41 Wear; 2.5" Type 31 Base	4.5" Class 5 100% crushed Quarry
17	Brooklyn Park	Hampshire	unsure	1999	2000	2007		1.5" Type 41 Wear; 2.5" Type 31 Base	4.5" Class 5 100% crushed Quarry
18	Moundsvie	Program Avenue	moderate to severe stripping in wheelpaths in both wear and non-wear	1994		records still being searched		1.5" Type 41 Wear; 1.5" Type 41 Binder; 2.0" Type 31 Base	
19	Blaine	93rd Avenue	moderate to severe in wheelpaths	1995		2004	FA-2 Granite	3.0" Type 41 Wear	4" Class 5
20	Blaine	93rd Avenue	moderate to severe in wheelpaths	1994		2004	FA-2 Granite	3.0" Type 41 Wear	4" Class 5
21	Burnsville	1990 Street Recon	moderate throughout project locations	8/1990 base, 7/91 wear	2001	2006		Type 41 Wear, Type 31 Base	
22	Burnsville	1991 Street Recon	moderate to severe throughout project locations	8-9/91 Base, 6-7/92 Wear	1999	2008		Type 41 Wear, Type 31 Base	

23	Burnsville	1992 Street Recon	Light (Frontier Lane) to Severe (Harold Drive)	8-9/92 Base, 6-7/93 Wear	1999/2000	None/2010		Type 41 Wear, Type 31 Base	
24	Burnsville	1993 Street Recon	Severe Throughout	8-9/93 Base, 6-7/94 Wear	1999	2010		Type 41 Wear, Type 31 Base	
25	Burnsville	1995 Street Recon	Light to Moderate Scattered	8-9/95 Base, 6-7/96 Wear		2002		Type 41 Wear, Type 31 Base	
26	Burnsville	2005 Street Recon	Light Along Joint (possible joint density problem)	8/31/2005		2011		2" Mill and Overlay; 2" MV3 (B)	
27	Inver Grove Heights	Cahill Avenue/Brooks Blvd	none	2009 (Mill and Overlay)		2011		2" Mill and Overlay; 2" MV3 (B)	previously stripped roadway
28	Sibley County	CSAH 9	Mostly Severe	1996				1.5" 31B Wear, 1.0" 31B Level	Existing Roadway
29	Sibley County	CSAH 9	Moderate to Severe	1997				1.5"31B Wear, 1.0" 31B Level	Existing Roadway
30	Sibley County	CSAH 9	Moderate to Severe	1997				1.5"31B Wear, 1.0" 31B Level	Existing Roadway
31	Osseo	City Wide	Moderate to Severe	1992				Depends on Roadway	

2.1.1 Blaine

Two locations in Blaine, MN, were examined for the project work. Separate ends (west and east) of a stretch of 93rd Avenue were surveyed and cored on December 1, 2014.

2.1.2 Brooklyn Park

Three locations in Brooklyn Park, MN, were examined for the project work. Sections of 73rd Avenue, Louisiana Avenue, and Winnetka Avenue were surveyed and cored on December 2, 2014, and December 3, 2014.

2.1.3 Burnsville

Three locations in Burnsville, MN, were examined for the project work. Sections of 134th Street, Heritage Circle, and Knob Hill were surveyed and cored on November 24, 2014, and November 25, 2014.

2.1.4 Cottage Grove

Four locations in Cottage Grove, MN, were examined for the project work. Sections of Hyde Avenue, Ingberg Trail, Jensen Avenue, and Jergen Avenue were surveyed and cored on November 18, 2014, and November 19, 2014. The cores from Jergen Avenue could not be extracted intact and therefore were not included in the study.

2.1.5 Inver Grove Heights

One location in Inver Grove Heights, MN, was examined for the project work. A section of Brooks Boulevard was surveyed and cored on November 21, 2014.

2.1.6 Osseo

One location in Osseo, MN, was examined for the project work. A section of 8th Avenue was surveyed and cored on December 5, 2014.

2.1.7 Sibley County

Two locations in Sibley County, MN, were examined for the project work. Separate ends (north and south) of a stretch of County State Aid Highway (CSAH) 9 were surveyed and cored on December 4, 2014.

2.1.8 Woodbury

Three locations in Woodbury, MN, were examined for the project work. Sections of Bridgewater Parkway and Newbury Alcove (the cul-de-sac and a straight portion) were surveyed and cored on November 19, 2014, and November 20, 2014. The Newbury Alcove cul-de-sac portion was unsealed and included for a comparison of the chip-sealed and unsealed portions of the road.

2.2 FIELD WORK CONDUCTED

The project research included surveys and extraction of cores from field locations indicated in Section 2.1. A total of 280 cores were collected for testing. The subsections below detail survey and testing procedures and core extraction operation; data and results are presented in Chapter 3.

2.2.1 Condition surveys

Members of the research team noted the general condition of all sections used for the project research. Condition surveys included observations and notes on localized distresses. The process of coring allowed the technician to assess the presence of stripping; this information was recorded with other general information on the pavement condition. In addition, ground penetrating radar (GPR) tests, detailed below, included supporting video surveys that could be used to examine the pavement condition.

2.2.2 Coring for laboratory testing

Coring operations for the project research involved the use of a coring rig mounted to the rear of a truck. The rig is shown in Figure 3. Six-inch diameter cores were obtained by drilling through the asphalt course to the top of the base layer. In addition to providing an intact specimen for testing, it allowed for the measurement of the in-situ pavement thickness.



Figure 3. Truck-mounted rig used to obtain cores on-site

2.2.3 Permeability testing

Field permeability tests using the NCAT Permeameter were investigated for the Cottage Grove, Inver Grove Heights, and Blaine sections. An illustration of one test is shown in Figure 4. Depending on surface roughness, obtaining a good seal was difficult, which complicated both the test and the usefulness of results from the test. Future permeability tests for this project were ruled out, given that the field permeability test has too many variables to confidently measure the permeability of an in-situ pavement with uncertain design.



Figure 4. Configuration of the NCAT Permeameter in attempts at field permeability testing

2.2.4 Evaluation using ground penetrating radar

Field work in support of the project research included ground penetrating radar (GPR) testing of pavement sections. GPR data was continuously collected at residential roadway speeds (20-40 miles per hour) using equipment mounted with 400 MHz and 2 GHz antennas and a SIR-20 control and data acquisition processor. The GPR configuration used for the study met or exceeded the ASTM D4748 and ASTM D6087 standards. Multiple passes were conducted to ensure that sufficient data was collected at 13 locations across five municipalities. The truck-mounted antenna is shown in Figure 5. All GPR data was coupled with precise GPS location data in support of more sophisticated analysis, which is presented in Chapter 3.



Figure 5. Vehicle-mounted GPR used for site evaluation

2.2.5 Nuclear density gauge testing

A nuclear gauge was used to assess the density of pavements on site. Backscatter testing was applied in accordance with ASTM D2950 to quickly assess both properties. Initially, nuclear gauge testing was conducted in six municipalities at 37 separate locations to compare asphalt densities. Of these 37 locations, mix data was available for 29 locations assessed. Extensive nuclear gauge testing was later conducted in these six municipalities to be coupled with the results of GPR testing. More details on these locations are included in the Chapter 3 analysis of test results.

2.3 LABORATORY WORK CONDUCTED

The research team conducted extensive laboratory testing to understand the behavior of chip sealed pavements. The laboratory testing relied upon the collection of a minimum of 12 cores from each of the locations; an example of a collected core is shown in Figure 6.

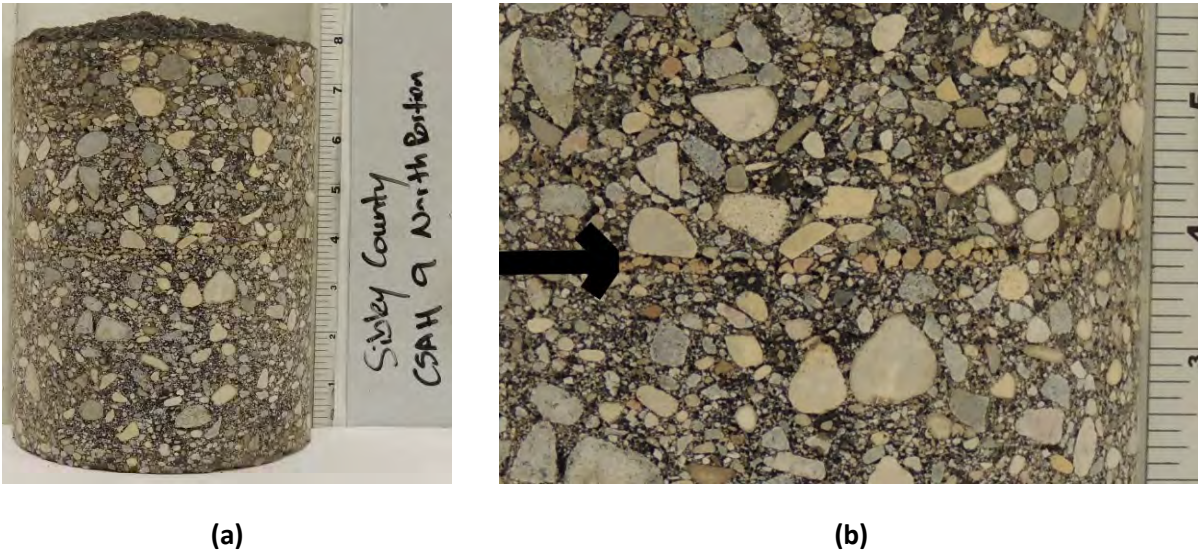


Figure 6. (a) Example of core extracted from pavement for study and (b) close-up of core shows evidence of past chip seal treatments

The subsections below detail the laboratory test procedures applied in this study; data and results from these tests are presented in Chapter 3.

2.3.1 Testing to determine volumetric properties of asphalt samples

Six samples from each of each of the 18 locations were used for volumetric analysis of the underlying asphalt. Specimens were compacted according to AASHTO T 312 for:

- Maximum theoretical specific density (G_{mm}) testing according to AASHTO T 209 and ASTM D 2401 and
- Bulk specific gravity (G_{mb}) testing according to AASHTO T 166.

In preparing cores for G_{mm} testing under AASHTO T 209, the cores were trimmed to remove cut aggregate, and testing was conducted with between 2000 and 2050 grams of material from the center of the core, which is briefly heated to 230°F to dry moisture from the core sample.

Given the results of the G_{mm} and G_{mb} tests, properties such as the percent air voids and the effective specific gravity were calculated. These properties in turn were used to determine the percent voids in mineral aggregate (VMA) and the percent voids filled with asphalt (VFA). Finally, given surface area characteristics for the sieve sizes of the aggregate, the average film thickness (AFT) was calculated.

2.3.2 Hamburg wheel tracker testing

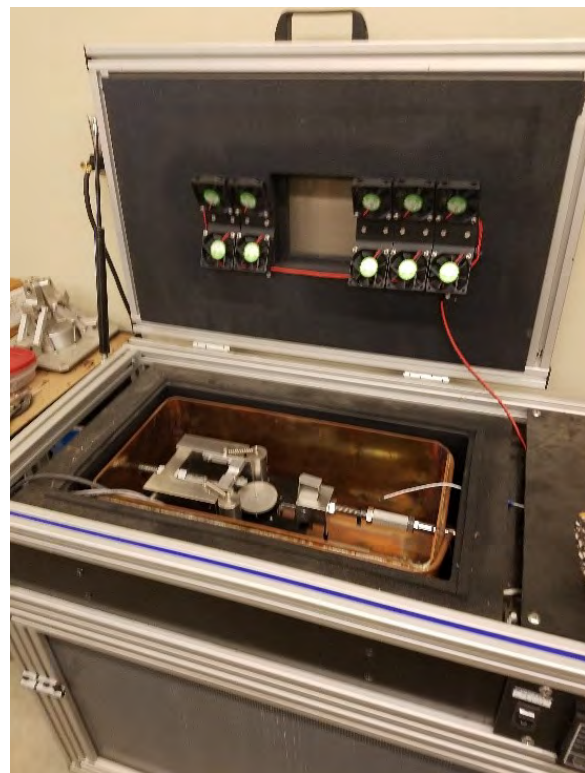
Circular specimens were tested using a Hamburg wheel tracking (HWT) device. AASHTO T 324 procedures were followed for all tests on a total of 18 specimens from 18 locations. The laboratory equipment used for the tests is shown in Figure 7a. The tests were conducted using paired specimens: the first of the pair was compacted with the chip seal, the second of the pair was compacted without the chip seal.

2.3.3 Fracture energy testing

Disk-shaped compact tension (DCT) tests were conducted on specimens to evaluate the fracture energy of asphalt mixes and field specimens. DCT tests were conducted on a total of seven specimens, and all tests were conducted in accordance with ASTM D7313. The laboratory equipment used for the tests is shown in Figure 7b.



(a)



(b)

Figure 7. (a) Hamburg wheel tracker test machine and (b) DCT test machine used for the project research

2.3.4 Permeability testing

Falling head permeability tests were conducted and coefficients of permeability were calculated according to the standard outlined in ASTM PS 129-01. Laboratory permeability tests were conducted on a total of 68 samples from 18 locations. The laboratory equipment used for the tests is shown in Figure 8a.

2.3.5 Tensile strength ratio testing

The tensile strength ratio (TSR) test measures tensile strength loss due to damage under accelerated water conditioning in the laboratory. The modified Lottman tensile strength ratio (TSR) test was conducted according to AASHTO T 283. TSR tests were applied to a total of 18 specimens. The laboratory equipment used for the tests is shown in Figure 8b.



(a)



(b)

Figure 8. (a) Asphalt permeability test and (b) TSR test rig used for the project research

2.4 SURVEY OF MUNICIPAL ENGINEERS

An eight-question survey of Minnesota city and county engineers on their chip sealing practices was performed during Fall 2015. One-hundred twenty nine engineers responded to the survey, which was coordinated online by engineers at the City of Woodbury. The questions are indicated in Table 2. A summary of responses is provided in the results of Chapter 3. Full responses are provided in Appendix K.

Table 2. Questionnaire for survey of Minnesota local engineer chip sealing practices

Item	Question
Q1	Are you currently using chipseals as part of your pavement maintenance program?
Q2	Has your organization used chipseals in the past?
Q3	On roads where chipseals have been used, have you experienced any problems with stripping or delamination of the chipseal with the underlying layer of asphalt? Stripping is defined as a loss in the asphalt/aggregate bond resulting in raveling, a shallow surface pothole, or delamination of the chipseal surface.
Q4	Do you use a polymer modified emulsion with your chipseals?
Q5	When did you start specifying the polymer modified emulsion?
Q6	Have you noticed any difference in the incidence of stripping/delamination on roads with polymer modified emulsion?
Q7	Do you have any pavements which are not chipsealed that are experiencing stripping failures? Stripping is defined as a loss in the asphalt/aggregate bond resulting in raveling, a shallow surface pothole, or delamination of the chipsealed surface.
Q8	Is there anything else you'd like to share about your use or non-use of chipseals?

CHAPTER 3: RESULTS AND DISCUSSION

The results of field testing, laboratory testing, and surveys of municipal engineers are summarized and discussed in this chapter. Additional information on testing or survey data can be found in the appendices to the final report.

3.1 SUMMARY OF FIELD DATA AND SPECIMENS COLLECTED

Given the extent of the data, it is summarized in this chapter rather than being presented in full. The full field data are recorded in Appendix A (Condition surveys and core collection information) and Appendix F (GPR and nuclear density). In addition, while example photographs of core collection are provided in Appendix I, a full record of all core photographs, including cores used for Hamburg Wheel and permeability tests, is hosted online by MnDOT at:

<ftp://ftp2.dot.state.mn.us/pub/outbound/researchservices/Chip%20Seal%20Research/>

Table 3 records locations and nomenclature used to identify field specimens collected and used for laboratory testing.

Table 3. Identification nomenclature for core and field assessments

Core ID Designation	City/County	Road Location
B-93E	Blaine	93 rd Ave, East
B-93W	Blaine	93 rd Ave, West
BP-L	Brooklyn Park	Louisiana Ave
BP-73	Brooklyn Park	73 rd Ave
BP-W	Brooklyn Park	Winnetka Ave
B-134	Burnsville	134 th St
B-H	Burnsville	Heritage Circle Area
B-K	Burnsville	Knob Hill Area
CG-H	Cottage Grove	Hyde Ave
CG-I	Cottage Grove	Ingberg Trail
CG-J	Cottage Grove	Jensen Ave
IGH-B	Inver Grove Heights	Brooks Blvd
O-8	Osseo	8 th Ave
SC-9N	Sibley County	CSAH 9, North
SC-9S	Sibley County	CSAH 9, South
W-B	Woodbury	Bridgewater
W-NA-C	Woodbury	Newbury Alcove, Cul de sac (Unsealed)
W-NA-S	Woodbury	Newbury Alcove, Straight section

3.1.1 Condition of pavement sections

The level of stripping varied from site to site. In the collection of core specimens, field observations were made on the extent of stripping in the vicinity of coring, in addition to general notes on the core itself. A comparison of core condition is shown in Figure 9 using cores collected for the study from a location in Shoreview, MN, that was not included in the final database. Figure 9b shows not only stripping behavior under the chip seal, but also stripping in asphalt lifts. An intact core from a nearby location is shown in Figure 9a to illustrate the extent of stripping through the core depth.



Figure 9. (a) Intact core and (b) core stripped under chip seal and between asphalt lifts, recovered from city of Shoreview, MN

A rough assessment of stripping for all cores on a given site location is recorded in Table 4, based on the extent of condition notes. As a rule, sites with more cores with notes on stripping were considered to have higher levels of stripping than sites with cores with fewer notes. Given its dependency on the observer, this measure is not comprehensive nor objective, and levels of stripping are referred to only in a general sense in the discussion and conclusions. Individual condition surveys and core collection notes are recorded in Appendix A.

Table 4. General observed levels of stripping in field

City/County	Road Location	Observed levels of stripping
Blaine	93 rd Ave, East	Moderate to High
Blaine	93 rd Ave, West	Moderate to High
Brooklyn Park	Louisiana Ave	Moderate
Brooklyn Park	73 rd Ave	Moderate
Brooklyn Park	Winnetka Ave	Moderate
Burnsville	134 th St	Low
Burnsville	Heritage Circle Area	High
Burnsville	Knob Hill Area	Low to Moderate
Cottage Grove	Hyde Ave	Low
Cottage Grove	Ingberg Trail	Moderate
Cottage Grove	Jensen Ave	Low
Inver Grove Heights	Brooks Blvd	Low
Osseo	8 th Ave	Moderate to High
Sibley County	CSAH 9, North	High
Sibley County	CSAH 9, South	High
Woodbury	Bridgewater	Moderate
Woodbury	Newbury Alcove, Cul de sac (Unsealed)	n/a
Woodbury	Newbury Alcove, Straight section	Moderate

3.1.2 Overview of GPR and nuclear gauge testing

The GPR testing included constant GIS information to provide exact locations of measurements. Likewise, the exact location of all nuclear density testing was recorded. This information has been presented in tandem to potentially allow for correlations between nuclear density and GPR dielectric readings. The reporting of this information results in “heat maps” for all sites surveyed. An example of such a map is shown in Figure 10. All maps for all locations are presented in Appendix F. Given the

limitations of the GPR antenna used for the testing, which is a longer-wave antenna, correlating the dielectric with density data does not provide reliable maps of density in the asphalt.



Figure 10. Map of dielectric and density data collected at Newbury Alcove site in Woodbury, MN

However, the nuclear gauge density data can provide useful feedback when viewed alongside other information, such as the results of core testing data from the laboratory. In this study, two rounds of nuclear gauge density testing at a total of 37 locations were conducted in two stages.

Results of the initial testing stage are shown in Table 5. For those initial tests at 9 of the 18 test sites, it was observed that densities did not match the cores, as average field densities were observed to range between 85.3 and 97.2 percent of the maximum core density (i.e. all air voids removed) obtained from volumetric testing. Furthermore, the average densities for some locations were unreasonably low. This raised concerns about compaction on municipal roads.

To address more general concerns about asphalt compaction – rather than issues specific to chip seal treatments – a second round of nuclear gauge testing was conducted on roads with and without chip seals. The results of the second round of tests are shown in Table 6.

The observed densities in the second round of tests were more reasonable. The second round of testing showed that municipal roads had adequate densities in most cases: of the 28 locations in the second round, only two had an average density below 91 percent, and the average maximum density across all locations was 93.3 percent. The second round of testing also indicated that “ordinary” compaction practices in the field produce adequate results. Thus, the cause of stripping is not necessarily related to density if 92 percent field density, as indicated in the MnDOT specification for asphalt compaction, is

considered adequate (MnDOT, 2016). Additional volumetric lab testing is discussed in Section 3.2 to elaborate on density in asphalt under chip sealed pavements.

Table 5. First round of nuclear gauge density tests for locations with available mix design information

Location	Mix	Year Paved	Maximum density (pcf)	Statistics (% of max density)	
				Standard Deviation	Average
Woodbury - Newbury Alcove	41 Wear	1989	154.8*	2.7%	97.2%
Woodbury - Newbury Alcove (CDS)	41 Wear	1989	155.7*	1.9%	94.3%
Blaine - 93rd Ave East End	41A Wear	1994	154.1*	1.4%	90.5%
Blaine - 93rd Ave West End	41A Wear	1995	153.8*	1.7%	85.3%
Brooklyn Park - Louisiana Ave	41A Wear	1995	152.9*	1.9%	91.5%
Brooklyn Park - Winnetka Ave	41A Wear	1995	153.6*	1.1%	93.7%
Brooklyn Park - 73rd Ave	41A Wear	1998	155.3*	1.6%	90.0%
Woodbury - Bridgewater Pkwy	41B Wear	1998	155.9*	2.3%	90.4%
Inver Grove Heights - Brooks Blvd	MVWE35035B	2009	154.6	1.3%	89.9%

**Obtained from lab-batched mix design and not volumetric testing of field core*

Table 6. Second round of nuclear gauge density tests

Location	Mix	Year Paved	Maximum density (pcf)	Statistics (% of max density)	
				Standard Deviation	Average
Woodbury - Dunmore Rd	LVWE35030B	2005	153.4	1.5%	92.9%
Woodbury - Evergreen Dr	LVWE35035B	2006	152.9	1.6%	96.7%

Cottage Grove - Hedgecroft Ave	LVWE35030B	2007	153.4	2.3%	95.4%
Cottage Grove - 77th Street S	LVWE35030B	2008	153.4	2.1%	92.2%
Woodbury - Paul Rd	MVWE35035B	2008	154.6	1.7%	92.1%
Woodbury - Hillcrest Dr	MVWE35035B	2009	154.2	1.6%	95.2%
Cottage Grove - 63rd Street S	LVWE35030C	2010	154.1	1.2%	96.1%
Woodbury - Crackleberry Tr	SPWEB240B	2010	156	0.9%	92.5%
Cottage Grove - Lock Ridge Ave S	SPWEB240B	2011	155.8	1.4%	88.4%
Inver Grove Heights - Addisen Path	SPWEB240C(R)	2011	156	1.4%	91.5%
Inver Grove Heights - 68th Street SE	SPWEB240C(R)	2012	156	1.6%	91.6%
Inver Grove Heights - Borden Way	SPWEB240C(R)	2012	156	1.0%	91.5%
Cottage Grove - Jeffery Lane S	SPWEB340C	2013	159.3	1.3%	95.9%
Inver Grove Heights - Conroy Way	SPWEB240C(R)	2013	156	1.1%	90.6%
Cottage Grove - Jasmine Ave S	SPWEA330C	2014	152.7	1.5%	94.4%
Inver Grove Heights - Bower Path	SPWEB240C(R)	2014	156	1.2%	94.2%
Woodbury - Somerset Rd	SPWEA330C	2014	155.1	1.5%	96.1%
Osseo - 1.5 St NE	SPWEA240(R)	2015	152.8	0.9%	93.5%
Osseo - 1st Ave	SPWEA240(R)	2015	152.8	1.6%	96.0%
Osseo - 1st St. NE	SPWEA240(R)	2015	152.8	1.1%	91.9%

Osseo - 1st St. SE	SPWEA240(R)	2015	152.8	1.3%	93.0%
Osseo - 3rd Ave. NE	SPWEA240(R)	2015	152.8	1.4%	92.0%
Osseo - 3rd St. NE	SPWEA240(R)	2015	152.8	1.3%	91.3%
Osseo - 4th St. NE	SPWEA240(R)	2015	152.8	1.1%	97.1%
Osseo - 5th Ave. NE	SPWEA240(R)	2015	152.8	0.9%	92.8%
Osseo - 6th Ave. NE	SPWEA240(R)	2015	152.8	1.2%	92.9%
Osseo - 7th St. NE	SPWEA240(R)	2015	152.8	1.1%	92.6%
Osseo - E. Broadway	SPWEA240(R)	2015	152.8	1.2%	92.6%

**Obtained from lab-batched mix design and not volumetric testing of field core*

3.2 SUMMARY OF LABORATORY DATA

As with the field data, laboratory data is summarized in the body of the final report. The following appendices record the laboratory data in full:

- Appendix B, Volumetric testing and summary properties
- Appendix C, Fracture energy testing
- Appendix D, Lab permeability testing
- Appendix E, Hamburg wheel tracking testing
- Appendix G, Tensile strength ratio testing
- Appendix J, Hamburg test photographs

3.2.1 Volumetric testing of asphalt samples

Table 7 summarizes the results of volumetric tests conducted on samples collected from 18 locations considered in the study. Six samples were tested for each location. Chapter 3 details the testing and calculations involved in the development of Table 7. The average air void content across all samples was 5.5 percent, and over 60 percent of tested samples had air void contents between 5 and 8 percent.

Table 7. Summary averages of volumetric testing of asphalt samples from 18 locations

Location	Air Voids (%)	VMA (%)	AFT (microns)	VFA (%)	Extracted asphalt content (%)	Max Density (pcf)
Blaine - 93rd Ave East End	3.0	15.3	9	80.5	5.3	154.1
Blaine - 93rd Ave West End	6.7	17.4	7.3	61.3	4.8	153.8
Brooklyn Park 73rd Ave	8.4	17.7	9.2	52.6	4.2	155.3
Brooklyn Park - Louisiana Ave	4.8	17.2	8.2	72.1	5.5	152.9
Brooklyn Park - Winnetka Ave	2.5	16.0	10.9	84.3	5.8	153.6
Burnsville - 134th St	7.0	18.0	9.1	61.1	4.9	155.9
Burnsville - Heritage Cir Area	7.2	18.4	9.7	60.5	5.0	153.9
Burnsville - Knob Hill Area	8.0	19.3	8.7	58.5	5.1	154.5
Cottage Grove - Hyde Ave S	6.3	16.6	8.9	62.3	4.6	155.2
Cottage Grove - Ingberg Trl S	7.5	18.4	7.1	59.2	4.9	155.9
Cottage Grove - Jensen Ave	7.7	17.6	7	56.4	4.4	156.9
Inver Grove Heights - Brooks Blvd	4.5	15.1	7.9	70.0	4.6	155.1
Osseo 8th Ave SE	7.2	17.9	8.7	59.6	4.8	155.2
Sibley County CSAH 9 North Portion	5.7	17.6	9.7	67.6	5.4	151.0
Sibley County CSAH 9 South Portion	3.9	16.4	8.2	76.3	5.6	150.6
Woodbury - Bridgewater	4.8	16.1	7.3	70.0	4.9	155.9
Woodbury - Newbury Alcove Cul-de-sac	1.4	13.2	11	89.7	5.0	155.7
Woodbury - Newbury Alcove Straight Portion	2.1	13.2	8.5	84.1	4.7	154.8

3.2.2 Summary of Hamburg wheel tracking tests

The results of Hamburg wheel tracking tests (tested samples shown in Figure 11) are used to directly assess the susceptibility of asphalt mixes to moisture and the likelihood of stripping due to moisture damage. These results are presented in Appendix E. The general result of Hamburg testing was that the majority of mixes performed well in stripping resistance; the only clear outlier was the performance of

the Woodbury Newbury Alcove Straight Section sample, which showed signs of stripping after only 521 passes. An additional observation from the data is that mixes from older pavements performed better than those of newer pavements due to higher stiffness values for the aged binders.

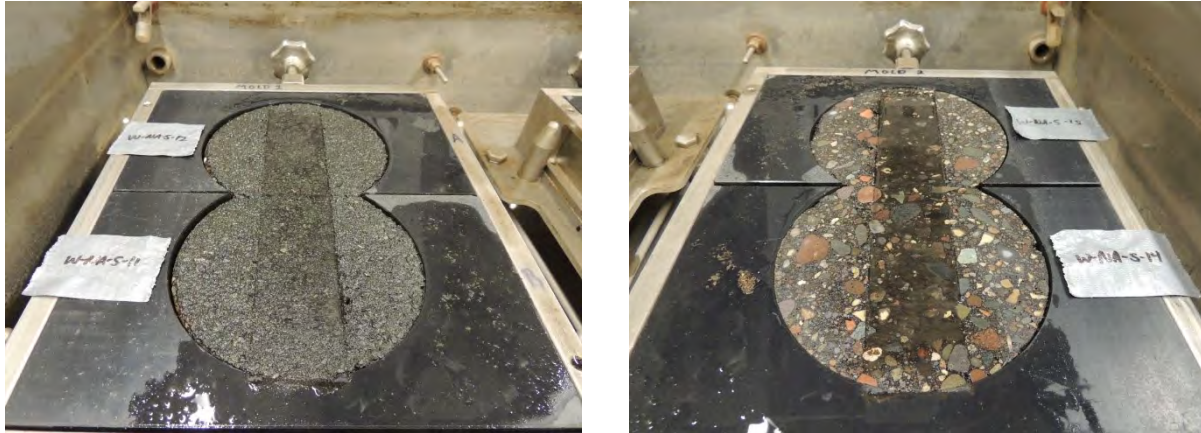


Figure 11. Specimens for stripping study undergoing Hamburg wheel testing

3.2.3 Fracture energy testing

The results of DCT tests are reported in Appendix C. As the tests provided no useful information about stripping behavior in chip-sealed asphalt, DCT testing was discontinued after seven tests.

3.2.4 Laboratory permeability tests

The majority of locations yielded four samples for permeability tests, the exceptions being the west end of 93rd Avenue in Blaine (2 samples) and the cul-de-sac of Newbury Alcove in Woodbury (2 samples). The average permeability results (K and K_{20} , the permeability at 20 deg Celsius) are reported in Table 8. Full data from all 68 samples tested are presented in Appendix D. As noted in Table 8, the specimens collected were relatively impermeable, with the highest measured permeability from a single test no higher than 23.7×10^{-5} cm/sec across all samples.

Table 8. Average calculated coefficients of permeability from laboratory permeability testing according to ASTM PS 129-01

Location	Permeability, K (10⁻⁵ cm/sec)	Permeability, K₂₀ (10⁻⁵ cm/sec)
Blaine - 93rd Ave East End	0.8	0.6
Blaine - 93rd Ave West End	1	0.8
Brooklyn Park 73rd Ave	10.7	7.8
Brooklyn Park - Louisiana Ave	0	0
Brooklyn Park - Winnetka Ave	0	0
Burnsville - 134th St	3.1	2.3
Burnsville - Heritage Cir Area	0.4	0.3
Burnsville - Knob Hill Area	0.4	0.3
Cottage Grove - Hyde Ave S	0.2	0.2
Cottage Grove - Ingberg Trl S	3.5	2.5
Cottage Grove - Jensen Ave	6.9	5
Inver Grove Heights - Brooks Blvd	0	0
Osseo 8th Ave SE	4	2.9
Sibley County CSAH 9 North Portion	0	0
Sibley County CSAH 9 South Portion	0	0
Woodbury - Bridgewater	0.3	0.2
Woodbury - Newbury Alcove Cul de sac (Unsealed)	0	0
Woodbury - Newbury Alcove Straight Portion	0	0

3.2.5 Overview of tensile strength ratio testing

As the results of TSR tests are sometimes used to infer long-term behavior of asphalt in terms of stripping, the results of these tests are relevant to this study. For this project material obtained from the roadway cores was heated and re-compacted at 7% and 11% air voids and TSR tests were performed on

these specimens. Further analysis using the laboratory data aggregated TSR data with condition surveys from field site visits. Results are summarized in Table 9 and Table 10.

Table 9. Summary of tensile strength ratios on mixtures re-compacted at 7% air voids and 11% air voids by location and extent of stripping observed in field

Location	Amount of Stripping Observed	TSR (7% voids)	TSR (11% voids)	Extracted asphalt content (%)
Burnsville - 134th St	Low	0.79	0.7	4.9
Cottage Grove - Hyde Ave S	Low	0.77	0.7	4.6
Cottage Grove - Jensen Ave	Low	0.65	0.51	4.4
Inver Grove Heights - Brooks Blvd	Low	0.76	0.63	4.6
Burnsville - Knob Hill Area	Low to Moderate	0.7	0.65	5.1
Brooklyn Park - 73rd Ave	Moderate	0.7	0.65	4.2
Brooklyn Park - Louisiana Ave	Moderate	0.77	0.74	5.5
Brooklyn Park - Winnetka Ave	Moderate	0.93	0.87	5.8
Cottage Grove - Ingberg Trl S	Moderate	0.73	0.66	4.9
Woodbury - Bridgewater	Moderate	0.91	0.69	4.9
Woodbury - Newbury Alcove Straight Portion	Moderate	0.76	0.65	4.7
Blaine - 93rd Ave East End	Moderate to High	0.76	0.67	5.3
Blaine - 93rd Ave West End	Moderate to High	0.69	0.61	4.8
Osseo - 8th Ave SE	Moderate to High	0.81	0.76	4.8
Burnsville - Heritage Cir Area	High	0.75	0.66	5
Sibley County - CSAH 9 North Portion	High	0.78	0.69	5.4
Sibley County - CSAH 9 South Portion	High	0.84	0.78	5.6

Table 10. Correlating TSR and observed stripping for field sections visited

Amount of Stripping Observed	Count	Average TSR (7% voids)	Average TSR (11% voids)	Average extracted asphalt content (%)
Low	4	0.74	0.64	4.63
Low to Moderate	1	0.77	0.70	4.60
Moderate	6	0.80	0.71	5.00
Moderate to High	3	0.75	0.68	4.97
High	3	0.79	0.71	5.33

3.3 SURVEY RESULTS

As noted in Section 2.4, 129 municipal engineers responded to the survey on local experience with chip seal treatments. Responses are summarized in Table 11, and full responses are provided in Appendix K.

Of the engineers surveyed, 64 percent “regularly” used chip seals, 17 percent “sometimes” used chip seals, and 19 percent “never” used chip seals. Of the respondents who use chip seals, 35 percent reported that they do not observe stripping in pavements treated with chip seals. 39 percent reported observing some stripping in chip-sealed pavements, yet did not consider it a major issue. The remaining 26 percent reported stripping as a major issue for their chip-sealed pavements.

Finally, only four percent of respondents reported significant stripping in roads that were not treated with chip seals (unsealed). Twenty-one percent of respondents reported stripping in unsealed roads as a minor issue, and 75 percent did not observe stripping in unsealed roads and did not consider it a significant issue.

Table 11 Questionnaire for survey of Minnesota local engineer chip sealing practices

Item	Question	Answered	Skipped	Responses
Q1	Are you currently using chipseals as part of your pavement maintenance program?	129	0	<p>83 Yes, regularly based on a schedule for most roadways</p> <p>22 Yes, occasionally depending on pavement and traffic conditions</p> <p>24 No</p>
Q2	Has your organization used chipseals in the past?	25	104	<p>9 Yes, but not in the last approximately 5 years</p> <p>6 Yes, but not in the last approximately 10 years</p> <p>3 Yes, but not in the last approximately 20 years</p> <p>7 No</p>
Q3	On roads where chipseals have been used, have you experienced any problems with stripping or delamination of the chipseal with the underlying layer of asphalt? Stripping is defined as a loss in the asphalt/aggregate bond resulting in raveling, a shallow surface pothole, or delamination of the chipseal surface.	112	17	<p>39 No, we have not experienced this issue</p> <p>44 Yes, but this is not a major issue on our roadway network</p> <p>29 Yes, this is a major issue on our roadway network</p>

Q4	Do you use a polymer modified emulsion with your chipseals?	112	17	40 Yes, on all chipsealed roadways 27 Yes, on some chipsealed roadways 14 No 31 Unknown
Q5	When did you start specifying the polymer modified emulsion?	51	78	<i>See Appendix K</i>
Q6	Have you noticed any difference in the incidence of stripping/delamination on roads with polymer modified emulsion?	65	64	10 Yes 24 No 31 Unknown
Q7	Do you have any pavements which are not chipsealed that are experiencing stripping failures? Stripping is defined as a loss in the asphalt/aggregate bond resulting in raveling, a shallow surface pothole, or delamination of the chipsealed surface.	113	16	4 Yes, this is a significant issue 24 Yes, this is a minor issue 85 No, we have not experienced stripping on non-chipsealed surfaces
Q8	Is there anything else you'd like to share about your use or non-use of chipseals?	34	95	<i>See Appendix K</i>

3.4 DISCUSSION AND OBSERVATIONS

3.4.1 Lab and field data

Given the extent of the field and laboratory testing, there is sufficient data to support general observations that would be unsubstantiated in smaller studies. First, based on the condition surveys

from field testing, not all roads with chip seals exhibited stripping. Information provided by city engineers for field sites locations identified less than Moderate levels of stripping in 6 of the 18 primary field sites. Condition information relative to volumetric core data (percent air voids and maximum density) is described in Figure 12.

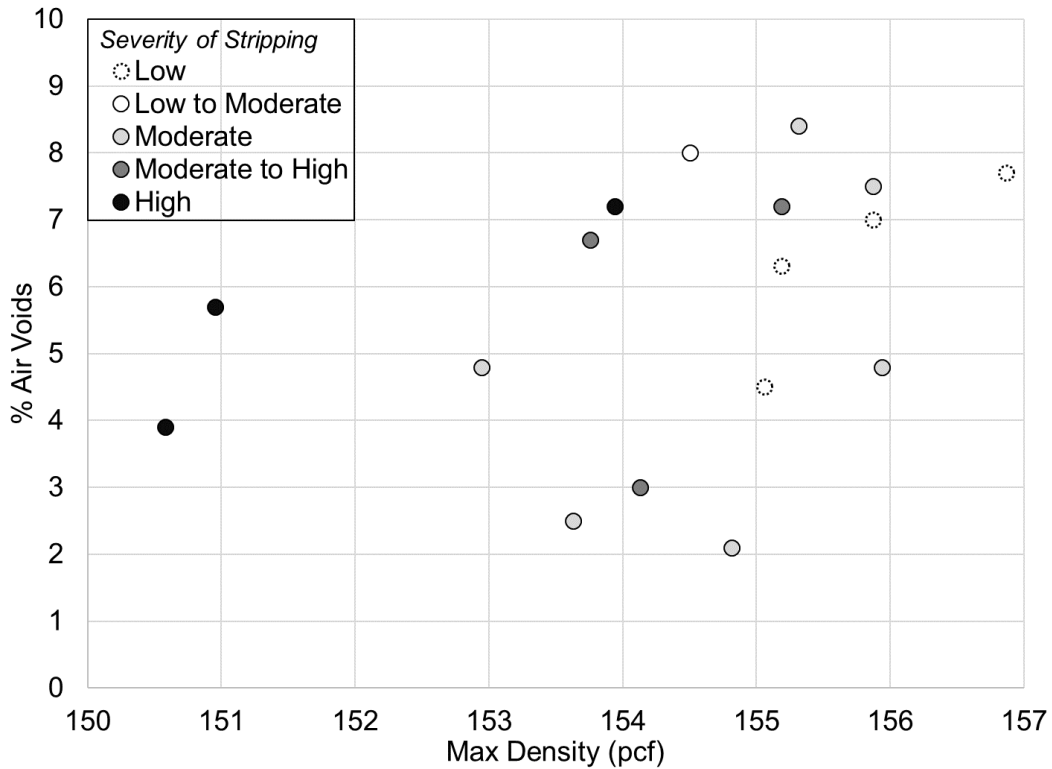


Figure 12. Severity of stripping in chip-sealed pavements in 18 locations with maximum theoretical density and percent air voids

Figure 12 does not describe an observable trend relating the extent of stripping to air void content. As the air void content for all sections examined is 8.5 percent or lower, no sections with excessive air voids were considered in the study. Thus, it is difficult to correlate stripping behavior directly with excessive air voids or air void content in general.

In addition, previous to the MnDOT study published in 2013 (Wood & Cole, 2013), many state and city/county engineers supposed that there may exist a relationship between (A) a specific bituminous mixture, contractor, geographic location, or year of construction and (B) the likelihood and extent of stripping. Table 12 summarizes data addressing this hypothesis. One limitation of the project was the lack of pavement information from municipalities on the sections considered; much of the information provided lacked specific detail on the mix design, for instance. However, based on the data available to this project, a correlation is not apparent between stripping in chip-sealed pavements and a specific mix, contractor, or paving year.

Table 12. Summary of level of stripping and pavement information by section

Location	Amount of Stripping Observed	HMA Design	Year Paved
Burnsville - 134th St	Low	41A Wear	2005
Cottage Grove - Hyde Ave S	Low	LVWE35030B	1996
Cottage Grove - Jensen Ave	Low	SPWEB340C	1986
Inver Grove Heights - Brooks Blvd	Low	MVWE35035B	2009
Burnsville - Knob Hill Area	Low to Moderate	41A Wear	1996
Brooklyn Park - 73rd Ave	Moderate	41A Wear	1998
Brooklyn Park - Louisiana Ave	Moderate	41A Wear	1995
Brooklyn Park - Winnetka Ave	Moderate	41A Wear	1995
Cottage Grove - Ingberg Trl S	Moderate	LVWE35030B	1995
Woodbury - Bridgewater	Moderate	SPWEA240(R)	1998
Woodbury - Newbury Alcove Straight Portion	Moderate	41 Wear	1995
Blaine - 93rd Ave East End	Moderate to High	41A Wear	1994
Blaine - 93rd Ave West End	Moderate to High	41A Wear	1995
Osseo - 8th Ave SE	Moderate to High	SPWEA240(R)	1992
Burnsville - Heritage Cir Area	High	41A Wear	1994
Sibley County - CSAH 9 North Portion	High	SPWEA240(R)	1996
Sibley County - CSAH 9 South Portion	High	SPWEA240(R)	1997

Other questions were proposed to the research team through the course of the study, and these questions were addressed based on limited information available to the study. Those questions include:

- *Is there a relationship between the use of a granular subbase and stripping in chip-sealed pavements?*

No relationship was apparent based on the performance of qualified sections in the study. This can be observed in Table 1.

- *Does the use of polymer-modified emulsions for chip seals lead to stripping?*

A large percentage of municipalities surveyed were unable to identify dates or years for polymer-modified emulsion adoption for their chip seal treatments. Therefore, a relationship between the presence of polymers and stripping could not be determined.

3.4.2 Field behaviors associated with stripping

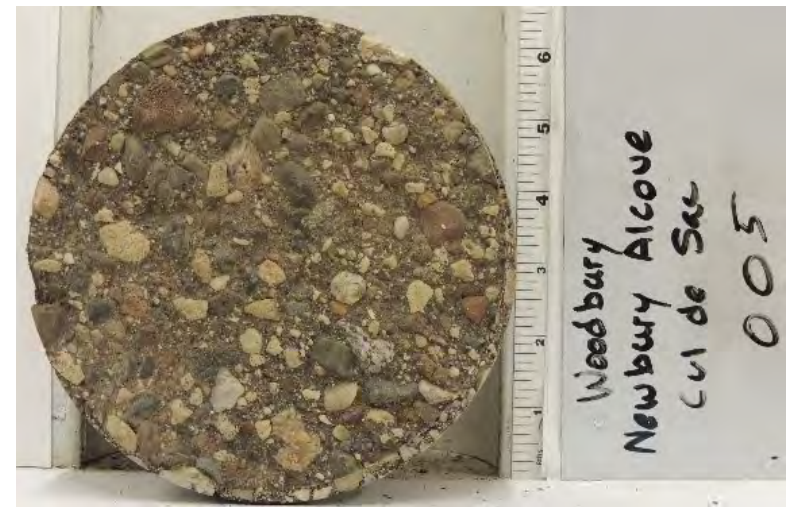
One important outcome of the study was the project survey, which identified important information in the understanding of stripping. First, the stripping behavior observed under chip-sealed pavements is not typically seen on roadways that were unsealed (four percent of engineers reported significant stripping and 21 percent of respondents reported minor stripping in unsealed roads). In this regard, the survey suggests that the presence of the chip seal treatment itself, and not properties of the underlying asphalt, may contribute to stripping.

While not as thorough as the lab and field studies, the project research included surveys of field sections in cities and counties to study how a chip seal may encourage stripping. Municipal engineers have observed that often in roads featuring neighboring chip-sealed and unsealed portions, the chip-sealed roadway will exhibit stripping behaviors, while the unsealed portion experiences only surface raveling. One type of road that was useful for such a survey was a road ending in a cul-de-sac, as these roads are often chip-sealed on their straight portions while the cul-de-sacs are unsealed.

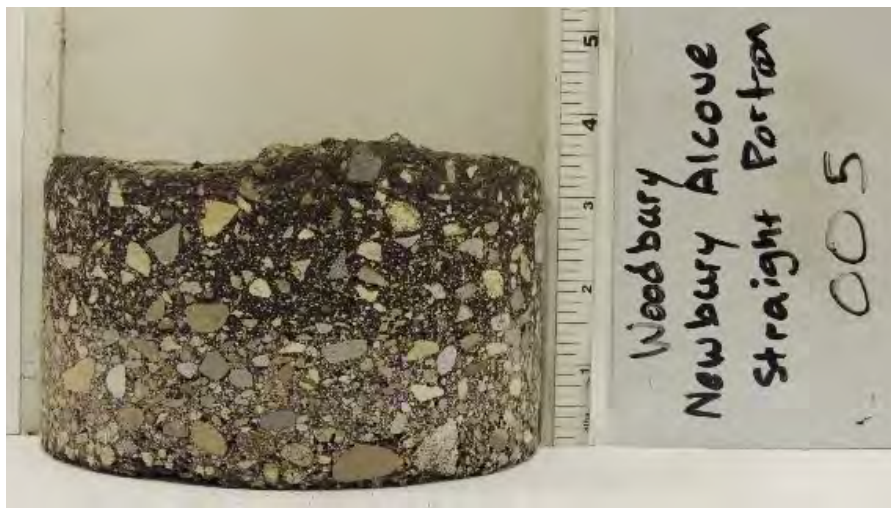
The project included one such road, Newbury Alcove in Woodbury, MN. The relative material lost due to stripping can be seen in comparing Figure 13b and Figure 13d. One confounding factor in this observation, however, is the fact that the Hamburg Wheel test found that the straight portion mix was the only mix susceptible to stripping due to moisture damage.



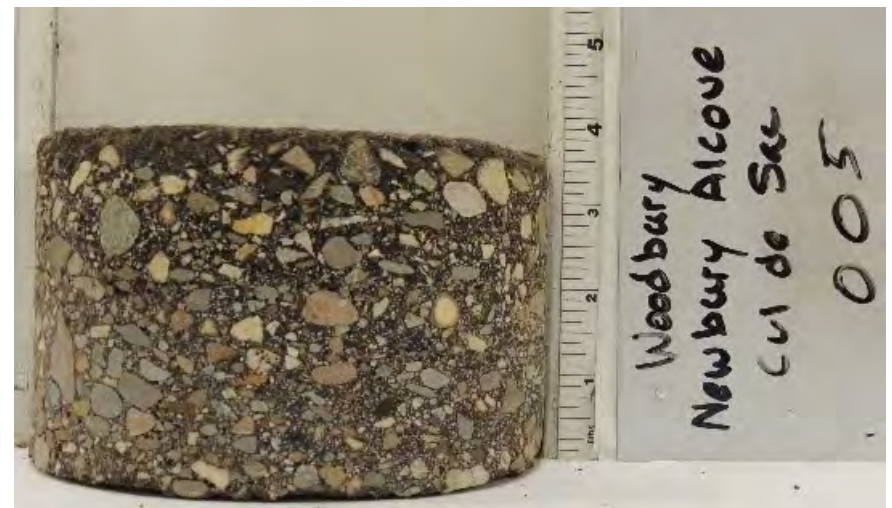
(a)



(c)



(b)



(d)

Figure 13. Comparison of stripping of cores collected from (a-b) straight portion (with chip seal) and (c-d) cul-de-sac (unsealed) of Newbury Alcove in Woodbury, MN

In addition, it has been observed that the presence of the chip seal can exacerbate distresses, as illustrated from a survey of Blue Heron Road in Woodbury, MN, in Figure 14. In other words, a road with sealed and unsealed sections may experience more block cracking in areas with the chip seal (Figure 14b) than in areas without the chip seal (Figure 14a).



Figure 14. Possible contribution of chip seal to advanced cracking in (a) unsealed and (b) chip-sealed pavement on Blue Heron Road in Woodbury, MN

These observations raise questions about how a chip seal may create conditions that (A) contribute to the incidence of stripping and (B) exacerbate other distress in the asphalt pavement. While the project research was extensive, the scope did not include the complex phenomena that govern this problem. It is possible that the chip seal may “trap” moisture/vapor in the asphalt layer immediately beneath the seal. Freeze-thaw cycling may break down the asphalt at an accelerated rate due to the presence of trapped moisture. This is an issue for future research.

CHAPTER 4: CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

The field and laboratory work conducted in this project represents an extensive study of chip-sealed pavement performance in Minnesota. In spite of this effort, many concerns surrounding the behavior chip-sealed pavements remain unresolved.

First, the study was not able to verify the conclusion of earlier MnDOT research that high air voids is the primary cause of stripping (Wood & Cole, 2013). High air voids were not observed in the locations used for the study; furthermore, not all chip-sealed pavements considered in the study exhibited signs of stripping. The latter observation agrees with municipal experience: survey data indicated that 74 percent of city engineers did not identify stripping in chip seals as a major issue.

The study was also unable to identify mix design or construction practices that correlated with the incidence of stripping. That is, based on the results of this study:

- There does not appear to be direct relationship between pavement density and stripping under chip seals.
- There does not appear to be a direct relationship between any specific bituminous mixture, contractor, geographic location, or year of construction and this distress.

The main conclusion of the study is that while stripping under chip seals is a concern, it is not a concern that can be addressed with a simple mix design or paving rule of thumb.

Finally, the distress was observed to be a complex phenomenon that may be caused by the presence of the chip seal as much as it is the composition of the underlying asphalt. Perhaps the matrix of binder and densely packed, angular chip creates too tight of a “seal” on the pavement, thereby trapping moisture and vapor and creating conditions that become damaging under freeze-thaw action. It is hoped that the field and laboratory data collected in this study will be of value to future work that examines this phenomenon in detail.

4.2 RECOMMENDATIONS

Based on field observations and discussions with state, city, and county engineers, the following recommendations and observations are provided on the use of chip-seal treatments and the incidence of stripping under chip seals. As the study was unable to point to an overwhelming cause for the stripping behavior, the recommendations are intended to be a starting point for future discussions and studies of important issues in the use of chip seals.

First, it was observed that stripping behavior under chip seals may be due to trapped moisture and water vapor between the chip seal and the asphalt pavement. This phenomenon would be similar to

stripping behavior observed in conventional overlays of asphalt (Kandhal & Rickards, 2001). Thus, appropriate drainage is important in chip-sealed pavements. The utilization of subsurface drainage will reduce the probability of saturated subbase and base layers, which will reduce the amount of moisture that would be moving through the pavement.

Another factor is to minimize trapped water vapor between the chip seal and the underlying asphalt. If the first lift of pavement is damaged due to insufficient structural capacity to withstand heavy loads (which often occur immediately after the initial lift of bituminous is placed during the construction of a housing development), the pavement may already have significant microscopic sized cracking that allows water vapor to be transmitted from the subgrade soils into the pavement layer and be trapped. Causes of this cracking can include staggered construction of bituminous pavement layers across multiple construction seasons, which subjects the pavement to heavy loads while it is not at full strength.

Many of the cities surveyed during this project have explored the use of thin bituminous overlays, approximately five-eighths inches in thickness, as an alternative to chip seal treatments. In Texas, these fine-mix overlays have shown promise as a surface treatment on oxidized pavement and as a surface treatment to extend the life of roadways exhibiting signs of stripping. Studies have shown these thin overlays can extend the service life by an additional three to five years before a mill-and-overlay is required (Newcomb et al., 2013).

MnDOT has taken steps toward providing guidance on alternatives to chip-seal treatments. Modifications to Sections 2360 and 3139 of the 2016 MnDOT Standard Specifications for Construction account for the use of an overlay, or “thinlay,” using aggregate passing the three-eighths inch sieve as a surface treatment (MnDOT, 2016). As noted, the state of Texas has similar experience and the Texas Department of Transportation has also developed a specification for its fine-mix overlay, detailed in Newcomb et al. (2013). Either of these resources serve as a starting point for municipal efforts in Minnesota.

Finally, one observation of this study was a need for better municipal records on both the paving contractor and the paving materials. While many city and county engineers were able to provide valuable detail on their chip-sealed roads for this study, the results and conclusions were limited by a lack of information (as noted in Section 3.4). More detailed records of the contractor and materials would benefit both future research efforts and municipal efforts to maintain roads.

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APPENDIX A

FIELD CORE IDENTIFICATION AND OBSERVATIONS

CORE ID	DISTANCE FROM CURB (inch)	PHOTO ID	LAT.	LONG.	CORE THICKNESS (in)	Other details	Ravel Level	Lab Notes
B-93E-1	86	2666	45.13897	-93.19541	3.5		Moderate	
B-93E-2	87	2667	45.13894	-93.19551	3.5	Chipped Top	Moderate	
B-93E-3	146	2668	45.13894	-93.19579	3			Perm
B-93E-4	150	2669	45.13894	-93.1958	3			
B-93E-5	89	2670	45.13894	-93.19602	3.25	Chipped Top		Ham - Chip Seal Removed
B-93E-6	89	2671	45.13896	-93.19606	3.25			Perm
B-93E-7	143	2672	45.13895	-93.19621	3.25	Chipped Top		
B-93E-8	143	2673	45.13895	-93.19611	3.25	Chipped Top		
B-93E-9	132	2674	45.13894	-93.1962	3.5			Ham
B-93E-10	132	2675	45.13894	-93.19618	3.5			
B-93E-11	98	2676	45.13892	-93.19595	3.5			Ham - Chip Seal Removed
B-93E-12	98	2677	45.13891	-93.19595	3.75			Ham
B-93E-13	146	2678	45.13897	-93.19575	3.5			Perm
B-93E-14	154	2679	45.13895	-93.19583	3.5	Rounded Top		Perm - Chip Seal Removed
B-93E-15	141	2680	45.13893	-93.1955	2.75	Chipped Top		
B-93E-16	141	2681	45.13896	-93.19571	2.75	Chipped Top		
B-93W-1	159	2682	45.13901	-93.2012	3.5	Chipped Top	Moderate	
B-93W-2	159	2683	45.139	-93.2012	3.5	No Good		
B-93W-3	94	2684	45.13899	-93.20131	3.25			Perm - Chip Seal Removed
B-93W-4	94	2685	45.13902	-93.20133	3.25			Ham
B-93W-5	151	2686	45.13905	-93.20158	4			
B-93W-6	151	2687	45.13906	-93.20157	4		Top 1.5" Moderate Ravel	
B-93W-7	144	2688	45.139	-93.20202	4		Top 1.5" Moderate Ravel	Ham - Chip Seal Removed
B-93W-8	144	2689	45.139	-93.20204	4.25		Top 1.5" Moderate Ravel	Ham - Chip Seal Removed
B-93W-9	94	2690	45.139	-93.20229	3.75	No Good		
B-93W-10	96	2691	45.139	-93.20232	3.25	Chipped Top	Top 2" Moderate Ravel	
B-93W-11	108	2692	45.13901	-93.20217	3.5		Top 2.5" Moderate Ravel	
B-93W-12	108	2693	45.13901	-93.20205	3.5	No Good		
B-93W-13	94	2694	45.139	-93.20171	4		Top 2" Moderate Ravel	
B-93W-14	94	2695	45.13899	-93.20164	4	Chipped Top	Top 2" Moderate Ravel	
B-93W-15	100	2696	45.13899	-93.20151	3.5			Ham
B-93W-16	100	2697	45.13898	-93.20165	3.5			Perm
BP-73-1	147	2717	45.08731	-93.37563	4.5	Core Barrel Marking		
BP-73-2	144	2718	45.08734	-93.37559	4.5			Perm - Chip Seal Removed

CORE ID	DISTANCE FROM CURB (inch)	PHOTO ID	LAT.	LONG.	CORE THICKNESS (in)	Other details	Ravel Level	Lab Notes
BP-73-3	66	2719	45.08723	-93.37544	5	Broke off @ 5 inches	Top 1.5" Moderate Ravel	
BP-73-4	67	2720	45.08728	-93.37553	5	Broke off @ 5 inches, Chipped Top		
BP-73-5	95	2721	45.08724	-93.37529	4.75		Top 2" Moderate Ravel	
BP-73-6	100	2722	45.08724	-93.37528	4.75	Chipped Top	Top 2" Moderate Ravel	
BP-73-7	65	2723	45.08724	-93.33752	5.5			Ham
BP-73-8	72	2724	45.08724	-93.375	5		Top 2" Moderate Ravel	Ham
BP-73-9	73	2725	45.08726	-93.37497	5.25			Ham - Chip Seal Removed
BP-73-10	104	2726	45.08727	-93.37494	5.25	Slight - moderate Ravel	Top 2" Moderate Ravel	
BP-73-11	65	2727	45.08731	-93.37468	5	Chipped Top		Ham - Chip Seal Removed
BP-73-12	62	2728	45.08732	-93.37473	5	No Good		Perm
BP-73-13	114	2729	45.08731	-93.37521	4.5	No Good		
BP-73-14	110	2730	45.0873	-93.37522	4.5	Moderate - Severe Ravel		
BP-73-15	56	2731	45.0873	-93.37529	5	Slight - moderate Ravel	Top 2" Moderate Ravel	Perm
BP-73-16	58	2732	45.08731	-93.3753	5.25	Chipped Top	Top 2" Moderate Ravel	Perm - Chip Seal Removed
BP-L-1	79	2733	45.0689	-93.37054	4.5	Chipped Top		Perm - Chip Seal Removed
BP-L-2	78	2734	45.06887	-93.37055	4.5	Chipped Top		
BP-L-3	98	2735	45.06854	-93.3705	4.5			Perm - Chip Seal Removed
BP-L-4	83	2736	45.06854	-93.37048	4.75			Perm
BP-L-5	124	2737	45.06829	-93.37048	4.5			Ham
BP-L-6	134	2738	45.06827	-93.3705	4.5			Ham - Chip Seal Removed
BP-L-7	135	2739	45.06813	-93.37042	4.75			Ham
BP-L-8	123	2740	45.06812	-93.37042	5			Ham - Chip Seal Removed
BP-L-9	75	2741	45.06804	-93.37046	5	Slight - Moderate Ravel	Top 2" Moderate Ravel	
BP-L-10	78	2742	45.06802	-93.37044	5			Perm
BP-L-11	70	2743	45.06792	-93.37044	6			
BP-L-12	68	2744	45.06796	-93.37045	5.5			
BP-L-13	124	2745	45.06808	-93.37044	4.75		Top 2.5" Moderate Ravel	
BP-L-14	122	2746	45.06811	-93.37045	Broke Off	No Good		
BP-L-15	66	2747	45.06842	-93.37041	5.5		Top 2.5" Moderate Ravel	
BP-L-16	72	2748	45.06842	-93.37044	5.25		Top 2" Moderate Ravel	
BP-W-1	98	2700	45.07529	-93.38113	4.25			
BP-W-2	105	2701	45.07533	-93.38116	4.5			

CORE ID	DISTANCE FROM CURB (inch)	PHOTO ID	LAT.	LONG.	CORE THICKNESS (in)	Other details	Ravel Level	Lab Notes
BP-W-3	55	2702	45.07533	-93.3811	6	No Good Top Raveled		
BP-W-4	144	2703/4	45.07534	-93.38115	5	Crack on Side		
BP-W-5	138	2705	45.07536	-93.38115	6		Moderate	
BP-W-6	88	2706	45.07537	-93.38112	4.75			
BP-W-7	86	2707	45.07543	-93.38112	4.75			Perm
BP-W-8	100	2708	45.07545	-93.38112	broken	No Good		
BP-W-9	89	2709	45.07543	-93.38109	4			
BP-W-10	138	2710	45.07553	-93.3811	4			
BP-W-11	135	2711	45.07554	-93.38111	4.5			Perm - Chip Seal Removed
BP-W-12	76	2712	45.07565	-93.38113	5.25			
BP-W-13	80	2713	45.07565	-93.38112	5			Perm
BP-W-14	98	2714	45.07574	-93.38114	4.5	Chipped Top		
BP-W-15	100	2715	45.07575	-93.38113	4.75			Perm - Chip Seal Removed
BP-W-16	96	2716	45.07579	-93.38116	4.5			
B-134-1	183	2650	44.76126	-93.2654	5.5		Top 1.5" Moderate Ravel	Ham
B-134-2	183	2651	10 feet away		5		Top 1.5" Moderate Ravel	Ham
B-134-3	173	2652	44.76124	-93.26577	5.5	Chipped Top	Top 1.5" Moderate Ravel	Perm - Chip Seal Removed
B-134-4	168	2653	10 feet away		5.25		Top 1" High - Moderate Ravel	
B-134-5	142	2654	44.76131	-93.26618	6.5		Moderate, High @ 2"	
B-134-6	142	2655	10 feet away		6		High Ravel @ 2.5"	
B-134-7	208	2656	44.76111	-93.26701	5.25	Core Barrel Marking on Top	Top 1.5" Moderate Ravel	Perm
B-134-8	208	2657	10 feet away		5.25		Top 1.5" Moderate Ravel	
B-134-9	130	2658	44.76098	-93.26761	6	No Good		
B-134-10	154	2659	10 feet away		6.5		High	
B-134-11	168	2660	44.76082	-93.26806	6		Top 1" Moderate Ravel	Perm - Chip Seal Removed
B-134-12	168	2661	10 feet away		6.75	severe raveling bottom 2/3, Chipped Top		Perm
B-134-13	205	2662	44.76073	-93.26856	6		Top 1.5" Moderate Ravel	

CORE ID	DISTANCE FROM CURB (inch)	PHOTO ID	LAT.	LONG.	CORE THICKNESS (in)	Other details	Ravel Level	Lab Notes
B-134-14	205	2663	10 feet away		6		Top 1.5" Moderate Ravel	
B-134-15	160	2664	44.76096	-93.26978	4.25	Possible Different Construction		Ham
B-134-16	160	2665	10 feet away		4	Possible Different Construction		Ham
B-H-1	Abor Ln 78		44.76486	-93.27869	3	Chipped Top	Moderate - High	
B-H-2	Mayo Dr 110		44.76518	-93.2803	3.5	Lift Line	Moderate	
B-H-3	Northern Dr 138		44.76423	-93.28109	2.5	Lift Line, Chipped Top	Moderate	Perm
B-H-4	Abor Ln 92		44.76486	-93.28234	3.5	Chipped Top	Moderate	
B-H-5	Donegal Dr center of sac		44.76547	-93.28194	3.5	No Good		
B-H-6	Pleasant Dr 115		44.7656	-93.28356	3.25		Top 1.5" High, Moderate Rest	
B-H-7	Grand 100		44.76534	-93.28476	3		Moderate	Perm - Chip Seal Removed
B-H-8	Grand 138		44.76627	-93.28479	2.5	Core Barrel Marking on Top	Moderate	
B-H-9	Grand 100		44.76714	-93.28475	2.75	Rounded Top	Moderate	
B-H-10	Herit Cir S Center of sac	2643	44.76633	-93.27958	4.25/4	A: Cracked B: ok	Moderate	
B-H-11	Herit Cir S 106	2644	44.76658	-93.2803	3		Top 1.5" High, Moderate Rest	
B-H-12	Herit Cir S 126	2645	44.76659	-93.28212	3	Chipped Top	Moderate	Perm
B-H-13	Herit Cir N 64	2646	44.76757	-93.28385	4	No Good		
B-H-14	Herit Cir N 77	2647	44.76756	-93.28137	3.5	No Good		

CORE ID	DISTANCE FROM CURB (inch)	PHOTO ID	LAT.	LONG.	CORE THICKNESS (in)	Other details	Ravel Level	Lab Notes
B-H-15	Herit Cir N 107	2648	44.7675	-93.28015	3		Top 1.5" High, Moderate Rest	
B-H-16	Herit Cir 92	2649	44.76712	-93.27862	3.25		Moderate	
B-H-17	Herit Cir 92	2649	4 feet away from 16		3		Moderate	Perm - Chip Seal Removed
B-K-1	Bryant Ave 110		44.75992	-93.29125	3.5		Top 0.5" High, Moderate Rest	Perm
B-K-2	Bryant Ave 123		44.75891	-93.2913	3.4	Chipped Top	Top 0.5" High, Moderate Rest	Perm - Chip Seal Removed
B-K-3	Bryant Ave 101		44.75788	-93.29139	3.25		Moderate	
B-K-4	Colfax 104		44.75774	-93.29266	3	Chipped Top	Moderate	
B-K-5	Colfax 78		44.75892	-93.29265	3	Chipped Top	High	
B-K-6	Colfax 48		44.75993	-93.2925	3.5		Moderate	Perm
B-K-7	Emerson 112		44.76019	-93.29412	3.5		Moderate	
B-K-8	Emerson 53		44.75954	-93.29377	3.25	Chipped Top	Moderate	
B-K-9	Fremont 77		44.75933	-93.29339	3.5	Chipped Top	Moderate	
B-K-10	Fremont 120		44.75878	-93.29481	3.25	Chipped Top	Moderate	
B-K-11	Knob Hill Ln 109		44.75994	-93.29603	2.75	Chipped Top	Moderate	
B-K-12	Knob Hill Ln 116		44.76014	-93.29677	3.25	Chipped Top	Moderate	Perm - Chip Seal Removed
B-K-13	Knob Hill Ln 112		44.76012	-93.29755	3.5	No Good		
B-K-14	Holly Ln 75		44.75829	-93.29541	3.5		Moderate	
B-K-15	Holly Ln 86		44.75829	-93.29443	3.25	Chipped Top	Moderate	

CORE ID	DISTANCE FROM CURB (inch)	PHOTO ID	LAT.	LONG.	CORE THICKNESS (in)	Other details	Ravel Level	Lab Notes
B-K-16	Holly Ln 74		44.75829	-93.29342	4.25	Chipped Top	Moderate	
CG-H-1	101	2536	44.82561	-92.94412	3		Moderate	
CG-H-2	93	2537	44.82587	-92.94413	3.5		Moderate	
CG-H-3	110	2538	44.82605	-92.94406	3		Moderate	Perm
CG-H-4	101	2539	44.82628	-92.9441	2.75		Moderate	
CG-H-5	59	2540	44.82649	-92.94407	3	Chipped Top	Moderate - High	
CG-H-6	120	2541	44.82665	-92.94411	3	Core barrel Markings on Top	Moderate	
CG-H-7	130	2542	44.82668	-92.94409	3	Core barrel Markings on Top	Moderate	
CG-H-8	93	2543	44.82705	-92.94408	3.75	Core barrel Markings on Top	Moderate - High	
CG-H-9	110	2544	44.82715	-92.94412	2.75	Chipped Top	Moderate	Perm - Chip Seal Removed
CG-H-10	72	2545	44.8269	-92.94417	3.25	Lift Line	Moderate	
CG-H-11	95	2546	44.82687	-92.94418	3.25	Rounded Top		
CG-H-12	78	2547	44.82646	-92.9442	3			Perm
CG-H-13	134	2548	44.82619	-92.94416	3	Core barrel Markings on Top		Perm - Chip Seal Removed
CG-I-1	160	2521	44.82075	-92.93758	2.75	No Good		
CG-I-2	142	2522	44.82073	-92.93755	2.75		Top 1" High, Moderate Rest	Perm
CG-I-3	82	2523	44.82078	-92.93761	3		Low	Perm - Chip Seal Removed
CG-I-4	84	2524	44.82079	-92.93761	3.25		Low	
CG-I-5	90	2519/2520	44.82086	-92.93775	3.5	Cracked on one side (HAM sample)	Top 0.25" High, Moderate Rest	
CG-I-6	118	2525	44.82101	-92.93814	3.25		Low	
CG-I-7	140	2526	44.82112	-92.93827	3.5		Top 1.5" High, Moderate Rest	
CG-I-8	50	2527	44.82122	-92.93843	4		Top 1.5" High, Moderate Rest	
CG-I-9	112	2528	44.82137	-92.93872	3.5		Top 0.25" High, Moderate Rest	
CG-I-10	88	2529	44.82152	-92.93897	3.5	Core Barrel Markings on Top	Top 0.25" High, Moderate Rest	
CG-I-11	80	2530	44.82128	-92.93864	4.25	No Good		
CG-I-12	55	2531	44.82116	-92.93843	3.75	Almost debonded	Low	

CORE ID	DISTANCE FROM CURB (inch)	PHOTO ID	LAT.	LONG.	CORE THICKNESS (in)	Other details	Ravel Level	Lab Notes
CG-I-13	88	2532	44.82107	-92.93822	3	Core Barrel Markings on Top		Perm
CG-I-14	93	2533	44.82092	-92.93806	3.75	Rounded Top	Top 0.5" Moderate, Low Rest	
CG-I-15	134	2534	44.82076	-92.93768	3.75	Rounded Top	Top 1/8" Moderate, Low Rest	
CG-I-16	112	2535	44.82068	-92.93753	3.75	Rounded Top	Low	Perm - Chip Seal Removed
CG-J-1	72	2626	44.82964	-92.91728	3.5		High	
CG-J-2	117	2627	44.82983	-92.91727	3.25		High	
CG-J-3	71	2628	44.83004	-92.91725	5.5		Top 1" High	
CG-J-4	117	2629/30	44.83018	-92.91727	3.25		High	
CG-J-5	116	2631	44.83034	-92.91724	3.75		High Ravel @ 1"	
CG-J-6	82	2632	44.83049	-92.91724	3.75		High Ravel @ 1"	Perm - Chip Seal Removed
CG-J-7	103	2633	44.83088	-92.91724	3.5	Rounded Top, Possible different mix		
CG-J-8	100	2635	44.83104	-92.91723	4		High	Perm
CG-J-9	112	2636	44.83137	-92.91727	4			
CG-J-10	80	2637	44.83143	-92.91724	4.25	Rounded Top	High Ravel @ 1"	
CG-J-11	110	2638	44.8316	-92.91723	3.5	Chipped Top		Perm - Chip Seal Removed
CG-J-12	78	2639	44.83175	-92.91721	3.5			
CG-J-13	98	2640	44.83176	-92.91737	3.5			Perm
CG-J-14	103	2641	44.83159	-92.91733	3.5		High Ravel @ 1-2"	
CG-JE-1	172		44.82842	-92.91596	3.75	8" extremely raveled		
IGH-B-1	75	2610	44.82507	-93.04418	4.25	Chipped Top	Low	
IGH-B-2	126	2611	44.82491	-93.0448	5.25	Rounded Top	Low	
IGH-B-3	60	2612	44.82484	-93.0453	5		Low	
IGH-B-4	107	2613	44.82478	-93.04596	5.5		Low	Perm - Chip Seal Removed
IGH-B-5	59	2614	44.82465	93.04664	4.5		Low	Ham - Chip Seal Removed
IGH-B-6	128	2615	44.82448	-93.04708	4.25	Chipped Top	Low	
IGH-B-7	96	2616	44.82426	-93.04741	5.25	Rounded Top	Low	Perm - Chip Seal Removed
IGH-B-8	70	2617	44.82396	-93.04767	5		Low	
IGH-B-9	118	2618	44.82349	-93.04776	4.5	Rounded Top	Low	Ham
IGH-B-10	58	2619	44.82327	-93.04777	5.5	Chipped & Rounded Top	Low	Ham
IGH-B-11	136	2620	44.82311	-93.04774	5	Chipped & Rounded Top	Low	
IGH-B-12	78	2621	44.82274	-93.04776	5.25	Chipped Top	Low	Perm
IGH-B-13	114	2622	44.82243	-93.04782	5.5	Chipped & Rounded Top	Low	Perm

CORE ID	DISTANCE FROM CURB (inch)	PHOTO ID	LAT.	LONG.	CORE THICKNESS (in)	Other details	Ravel Level	Lab Notes
IGH-B-14	68	2623	44.82227	-93.04788	6		Low	
IGH-B-15	124	2624	44.82211	-93.04791	5	Chipped & Rounded Top	Low	
IGH-B-16	52	2625	44.82198	-93.04798	3.75	Chipped Top	Low	Ham - Chip Seal Removed
O-1	120	2777	45.11086	-93.39199	4.75	Rounded Top		Ham - Chip Seal Removed
O-2	93	2778	45.11093	-93.39205	4.5	No Good		
O-3	56	2780	45.11119	-93.39204	5			
O-4	56	2781	45.11112	-93.39204	5			Perm
O-5	62	2782	45.11136	-93.39204	5.5	Chipped Top		
O-6	67	2783	45.11138	-93.39203	5.5		Top 1.5" Moderate Ravel	
O-7	100	2784	45.11155	-93.39208	4			
O-8	100	2785	45.11157	-93.39205	3.75			
O-9	52	2786	45.11163	-93.39206	5.25			Ham
O-10	53	2787	45.11163	-93.39206	5.25			Perm
O-11	102	2788	45.11175	-93.39207	4			
O-12	104	2789	45.11178	-93.39205	4.25			Perm - Chip Seal Removed
O-13	58	2790	45.11179	-93.39205	5.25			Ham
O-14	54	2791	45.11177	-93.39205	5			Ham - Chip Seal Removed
O-15	116	2792	45.11194	-93.39202	4			
O-16	118	2793	45.11189	-93.39202	4.5			Perm - Chip Seal Removed
SC-9N-1	43	2763	44.65232	-94.09159	8			
SC-9N-2	43	2764	44.65234	-94.09158	6			
SC-9N-3	58	2765	44.6524	-94.09161	8			
SC-9N-4	60	2766	44.65242	-94.09162	8		Moderate Ravel @ 2"	Perm - Chip Seal Removed
SC-9N-5	26	2767	44.6525	-94.09158	8.5			
SC-9N-6	26	2768	44.65254	-94.09159	8.5		Moderate Ravel @ 2"	Perm
SC-9N-7	48	2769	44.65262	-94.09158	8.5	Chip @ top		
SC-9N-8	52	2770	44.65266	-94.0916	9		Moderate Ravel @ 2.5"	
SC-9N-9	33	2771	44.65275	-94.09158	9.5			Perm
SC-9N-10	36	2772	44.65276	-94.09158	9			Perm - Chip Seal Removed
SC-9N-11	90	2773	44.65284	-94.0916	8			
SC-9N-12	87	2774	44.65289	-94.09159	8	Lift Line		
SC-9N-13	22	2775	44.65297	-94.09158	7.5			
SC-9N-14	19	2776	44.65301	-94.09158	7.5	Core Barrel Marking		
SC-9S-1	36	2749	44.6018	-94.0921	9.25		Low	Perm

CORE ID	DISTANCE FROM CURB (inch)	PHOTO ID	LAT.	LONG.	CORE THICKNESS (in)	Other details	Ravel Level	Lab Notes
SC-9S-2	30	2750	44.60182	-94.0921	10		Low	
SC-9S-3	46	2751	44.60195	-94.09214	9	No Good Top Broke Off		
SC-9S-4	85	2752	44.60199	-94.09213	9		Low	
SC-9S-5	23	2753	44.60221	-94.09209	8.5		Low	
SC-9S-6	23	2754	44.60223	-94.09209	10		Low	
SC-9S-7	68	2755	44.60231	-94.09211	8.25	Chipped Top	Low	
SC-9S-8	70	2756	44.60235	-94.09213	9	Chipped Top	Low	Perm - Chip Seal Removed
SC-9S-9	96	2757	44.60242	-94.09214	9.5		Low	
SC-9S-10	98	2758	44.60245	-94.09212	9.25	Chipped Top	Low	
SC-9S-11	23	2759/60	44.60259	-94.09213	6.75		Low	Perm
SC-9S-12	23	2761	44.60257	-94.09209	8.5		Low	Perm - Chip Seal Removed
SC-9S-13	18	2762	44.60265	-94.09211	8		Low	
W-B-1	116	2562	44.92165	-92.90073	3.25	Small crack on top (HAM Sample) Chipped on Top	Low	Ham
W-B-2	122	2563	44.92155	-92.90065	3.5	Chipped on Top	Low	Perm
W-B-3	114	2564	44.92151	-92.90055	3.5		Low	
W-B-4	88	2565	44.92149	-92.90059	3.5		Low	Perm - Chip Seal Removed
W-B-5	104	2566	44.92144	-92.90052	3.5	Chipped on Top	Low	Ham
W-B-6	98	2567	44.92139	-92.90045	3	Chipped & Rounded on Top	Low	
W-B-7	105	2568	44.92136	-92.90038	3.25		Low	Ham - Chip Seal Removed
W-B-8	78	2569	44.92131	-92.90029	3.5		Low	Ham - Chip Seal Removed
W-B-9	92	2570	44.92125	-92.90021	3.75		Low	Perm - Chip Seal Removed
W-B-10	67	2571	44.92127	-92.90017	3.5	Chipped on Top	Low	
W-B-11	85	2572	44.9214	-92.90035	3.75	Chipped on Top	Top 1" moderate Rest Low	
W-B-12	63	2573	44.92145	-92.90044	3.75		Low	
W-B-13	64	2574	44.9215	-92.90048	4		Low	
W-B-14	79	2575	44.92154	-92.90054	4		Low	Perm
W-B-15	74	2576	44.92166	-92.90065	3.75		Low	
W-B-16	70	2577	44.92171	-92.90071	3.5	Chipped & Rounded on Top	Top 1.5" moderate Rest Low	
W-NA-C-1	Middle of Circle	2578	44.89251	-92.95605	3.25		Low	
W-NA-C-2	185	2579	44.8926	-92.95605	3.25	Chipped Top	Low	

CORE ID	DISTANCE FROM CURB (inch)	PHOTO ID	LAT.	LONG.	CORE THICKNESS (in)	Other details	Ravel Level	Lab Notes
W-NA-C-3	360	2580	44.89255	-92.95609	2.5	Chipped Top	Low	
W-NA-C-4	105	2581	44.89252	-92.95612	4		Low	Perm Tested(12/5), No water level movement @ 20 min
W-NA-C-5	158	2582	44.89251	-92.95616	3.5	Core Barrel Moved creating a ring on top	Low	Perm Tested(12/5), No water level movement @ 20 min
W-NA-C-6	173	2583	44.89248	-92.95617	4		Low	
W-NA-C-7	200	2584	44.89248	-92.95621	3.5		Low	
W-NA-C-8	287	2585	44.89246	-92.95616	3		Low	
W-NA-C-9	312	2586	44.89245	-92.95615	3		Low	
W-NA-C-10	208	2587	44.89242	-92.95613	3		Low	
W-NA-C-11	336	2588	44.89242	-92.95609	3		Low	
W-NA-C-12	336	2589	44.89244	-92.95602	4		Low	Hamburg Sample
W-NA-C-13	270	2590	44.89244	-92.95603	3.25		Low	
W-NA-C-14	251	2591	44.89249	-92.95598	4		Low	Hamburg Sample
W-NA-C-15	190	2592	44.89255	-92.95604	3		Low	
W-NA-C-16	120	2593	44.89256	-92.95602	3.5		Low	
W-NA-S-1	92	2594	44.89271	-92.95601	3.5		Low	Chip seal removed by saw, Perm Tested(12/5), No water level movement @ 20 min
W-NA-S-2	94	2595	44.89272	-92.95603	3.25	Rounded Top Edges	Low	
W-NA-S-3	88	2596	44.89277	-92.95604	3.25		Low	
W-NA-S-4	70	2597	44.89287	-92.95602	3	Chipped Top	Low	
W-NA-S-5	62	2598	44.8929	-92.95599	3.25	Chipped Top, Bit Marking on Top	Low	

CORE ID	DISTANCE FROM CURB (inch)	PHOTO ID	LAT.	LONG.	CORE THICKNESS (in)	Other details	Ravel Level	Lab Notes
W-NA-S-6	63	2599	44.89293	-92.95602	3.5	Chipped Top	Low	
W-NA-S-7	86	2600	44.89304	-92.95605	3	Chipped Top	Low	
W-NA-S-8	93	2601	44.89303	-92.95605	3.25	Rounded Top Edges, Bit Markings on Surface	Low	
W-NA-S-9	70	2602	44.89315	-92.95607	4.5	Chipped Top	Low	Chip seal removed by saw, Perm Tested(12/5), No water level movement @ 20 min
W-NA-S-10	147	2603	44.89305	-92.95608	3.5	Rounded Top Edges	Low	Perm Tested(12/5), No water level movement @ 20 min
W-NA-S-11	168	2604	44.89277	-92.95607	4		Low	Hamburg Sample
W-NA-S-12	132	2605	44.89275	-92.95605	3.5	Chipped & Rounded Top	Low	Hamburg Sample
W-NA-S-13	124	2606	44.8927	-92.95609	3.5		Low	Perm Tested(12/5), No water level movement @ 20 min
W-NA-S-14	180	2607	44.89265	-92.95606	3.5		Low	Hamburg Sample Chip seal removed with saw
W-NA-S-15	130	2608	44.8926	-92.95607	3.5	Chipped & Rounded Top	Low	Hamburg Sample Chip seal removed with saw
W-NA-S-16	91	2609	44.89257	-92.95611	3.25	Chipped & Rounded Top	Low	

APPENDIX B

MIX TESTING AND PROPERTIES

Project Road	Year	Mix	Extracted A/C	Gradation Sieves											
				3/4"	1/2"	3/8"	#4	#8	#10	#16	#30	#40	#50	#100	#200
Blaine - 93rd Ave East End	1994	2340/41A wear	5.3	100	99	91	70	56		46	34		17	8	4.4
Blaine - 93rd Ave West End	1995	2340/41A wear	4.8	100	99	95	81	69		56	39		19	9	5.0
Brooklyn Park - 73rd Ave	1998	2340/41 wear	4.2	100	98	93	71	57		48	32		12	3	1.9
Brooklyn Park - Louisiana Ave	1995	2340/41 wear	5.5	100	100	97	79	66		53	38		21	10	5.6
Brooklyn Park - Winnetka Ave	1995	2340/41 Wear	5.8	100	100	969	73	58		45	29		14	6	3.8
Burnsville - 134th St	2005	2350 MV3-B	4.9	100	95	88	69	56		44	29		12	6	4.1
Burnsville - Heritage Cir Area	1994	2331-31/41	5.0	100	100	97	72	56		43	27		13	6	3.8
Burnsville - Knob Hill Area	1996	2331-31/41	5.1	100	100	98	77	62		48	31		14	7	5.1
Cottage Grove - Hyde Ave S	1996	2340/41B wear	4.6	100	93	83	67	54		40	24		11	6	4.4
Cottage Grove - Ingberg Trail	1995	2341	4.9	100	91	83	72	63		56	45		25	10	5.2
Cottage Grove - Jensen Ave	1986	2340/41B wear	4.4	100	93	85	68	54		45	34		19	9	5.4
Inver Grove Heights - Brooks Blvd	2009	MVWE3503 5B R	4.6	100	97	90	74	59		47	34		18	8	3.8
Osseo - 8th Ave	1992		4.8	100	99	96	78	61		46	30		14	7	3.6
Sibley County - CSAH 9 North Portion	1996	31B Wear	5.4	100	97	93	77	60		46	32		13	6	4.1
Sibley County - CSAH 9 South Portion	1997	31B Wear	5.6	100	96	92	74	57		43	30		14	11	8.5
Woodbury - Bridgewater	1998	41 Wear	4.9	100	93	86	74	64		54	41		22	10	5.2
Woodbury - Newbury Alcove Cul de sac	1998	41B Wear	5.0	100	91	83	62	47		35	24		11	6	2.9
Woodbury - Newbury Alcove Striaht Portion	1995	41B Wear	4.7	100	94	90	70	54		42	29		14	7	4.3

Project Road	SpG	SpG -#4	Core Gmm	Core Gmb	Core Air Voids	Core VMA	Core AFT	Core VFA	TSR 7% Air Voids	TSR 11% Air Voids	Perm Test
Blaine - 93rd Ave East End	2.684	2.684	2.474	154.1	2.400	3.0	15.3	9.0	80.5	76.0	67.0
Blaine - 93rd Ave West End	2.652	2.652	2.468	153.8	2.302	6.7	17.4	7.3	61.3	69.0	61.0
Brooklyn Park - 73rd Ave	2.658	2.658	2.493	155.3	2.284	8.4	17.7	9.2	52.6	70.0	65.0
Brooklyn Park - Louisiana Ave	2.668	2.668	2.455	152.9	2.337	4.8	17.2	8.2	72.1	77.0	74.0
Brooklyn Park - Winnetka Ave	2.697	2.697	2.466	153.6	2.404	2.5	16.0	10.9	84.3	93.0	87.0
Burnsville - 134th St	2.698	2.698	2.502	155.9	2.327	7.0	18.0	9.1	61.1	79.0	70.0
Burnsville - Heritage Cir Area	2.667	2.667	2.471	153.9	2.292	7.2	18.4	9.7	60.5	75.0	66.0
Burnsville - Knob Hill Area	2.683	2.683	2.480	154.5	2.281	8.0	19.3	8.7	58.5	70.0	65.0
Cottage Grove - Hyde Ave S	2.672	2.672	2.491	155.2	2.335	6.3	16.6	8.9	62.3	77.0	70.0
Cottage Grove - Ingberg Trail	2.698	2.698	2.502	155.9	2.314	7.5	18.4	7.1	59.2	73.0	66.0
Cottage Grove - Jensen Ave	2.697	2.697	2.518	156.9	2.325	7.7	17.6	7.0	56.4	65.0	51.0
Inver Grove Heights - Brooks Blvd	2.671	2.671	2.489	155.1	2.376	4.5	15.1	7.9	70.0	76.0	63.0
Osseo - 8th Ave	2.679	2.679	2.491	155.2	2.311	7.2	17.9	8.7	59.6	81.0	76.0
Sibley County - CSAH 9 North Portion	2.622	2.622	2.423	151.0	2.285	5.7	17.6	9.7	67.6	78.0	69.0
Sibley County - CSAH 9 South Portion	2.623	2.623	2.417	150.6	2.323	3.9	16.4	8.2	76.3	84.0	78.0
Woodbury - Bridgewater	2.700	2.700	2.503	155.9	2.382	4.8	16.1	7.3	70.0	91.0	69.0
Woodbury - Newbury Alcove Cul de sac	2.699	2.699	2.499	155.7	2.465	1.4	13.2	11.0	89.7	97.0	78.0
Woodbury - Newbury Alcove Striaht Portion	2.671	2.671	2.485	154.8	2.433	2.1	13.2	8.5	84.1	76.0	65.0

APPENDIX C

FRACTURE ENERGY TESTING



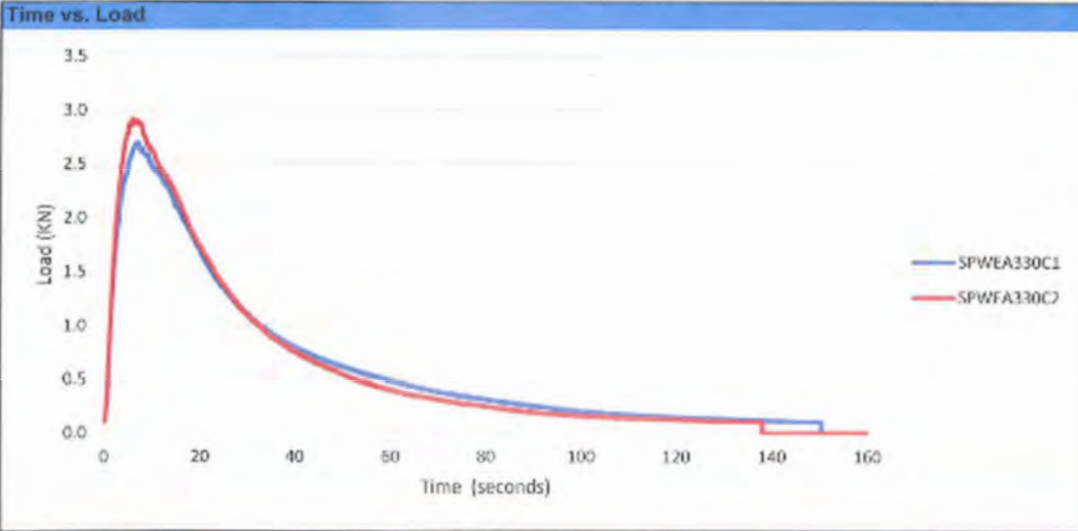
**AMERICAN
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American engineering testing, inc.
 Saint Paul
 550 Cleveland Ave N
 St. Paul, MN 55114
 Toll Free: (800)972-6364
 www.aengetest.com

Disk-Shaped Compact Tension Test Report

Client: LRRB	CC:	This document is not to be reproduced or distributed without the express written consent of American Engineering Testing, Inc.
Project: 27-00006 LRRB Asphalt Stripping Study		

Sample Information	
Asphalt Mixture Type: SPWEA330C	Testing Temperature: -24.0 C



Specimen Information								Area	Length
ID	Air Voids %	Thickness mm	Ligament mm	Peak Load kN	Actual Slope mm/s	Fracture Energy J/m ²	Under the Curve Nmm	of Test s	
SPWEA330 C1		49.88	80.10	2.70	0.017	412.53	1648.21	150.40	
SPWEA330 C2		49.75	80.78	2.92	0.017	394.79	1586.60	138.16	
Average Fracture Energy:						403.66 J/m ²			
Standard Deviation:						12.54 J/m ²			

Tested By	Remarks

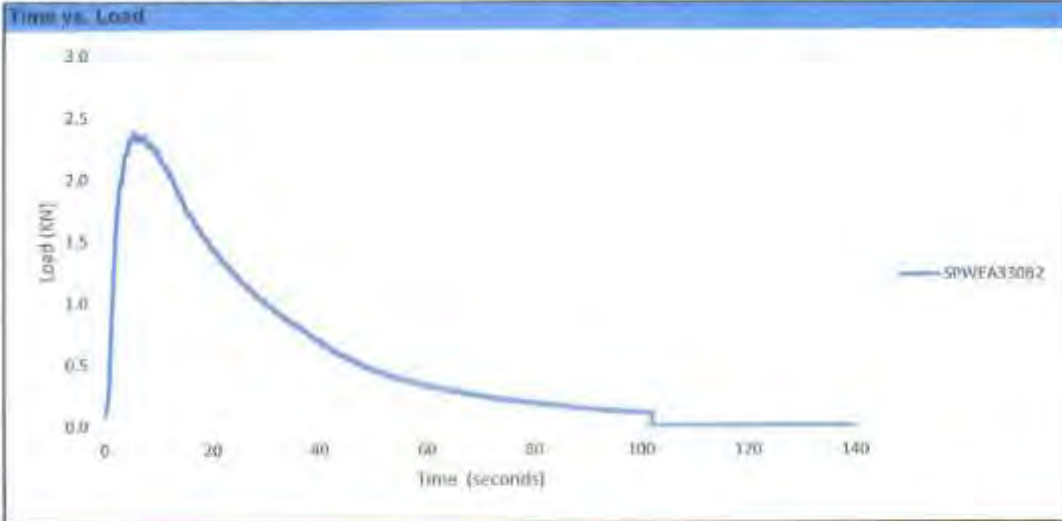


American Engineering Testing, Inc.
 Selma, PA 15
 550 Cleveland Ave N
 St. Paul, MN 55114
 Toll free: (800)972-6364
 www.aemtest.com

Disk-Shaped Compact Tension Test Report

Client: LRRB	CC:	This document is the copyrighted property of American Engineering Testing, Inc. Date of _____ Reviewed By: _____
Project: 27-00006 LRRB Asphalt Stripping Study		

Sample Information		
Asphalt Mixture Type: SPWEA330B	Testing Temperature:	-18.0 C



Specimen Information									
ID	Air Voids %	Thickness mm	Ligament mm	Peak Load kN	Actual Slope mm/s	Fracture Energy J/m ²	Area Under the Curve Nmm	Length of Test s	
SPWEA330B2		49.91	79.28	2.39	0.017	322.30	1275.31	102.20	
Average Fracture Energy:						322.30 J/m ² ±			
Standard Deviation:						N/A J/m ²			

Tested By	Remarks



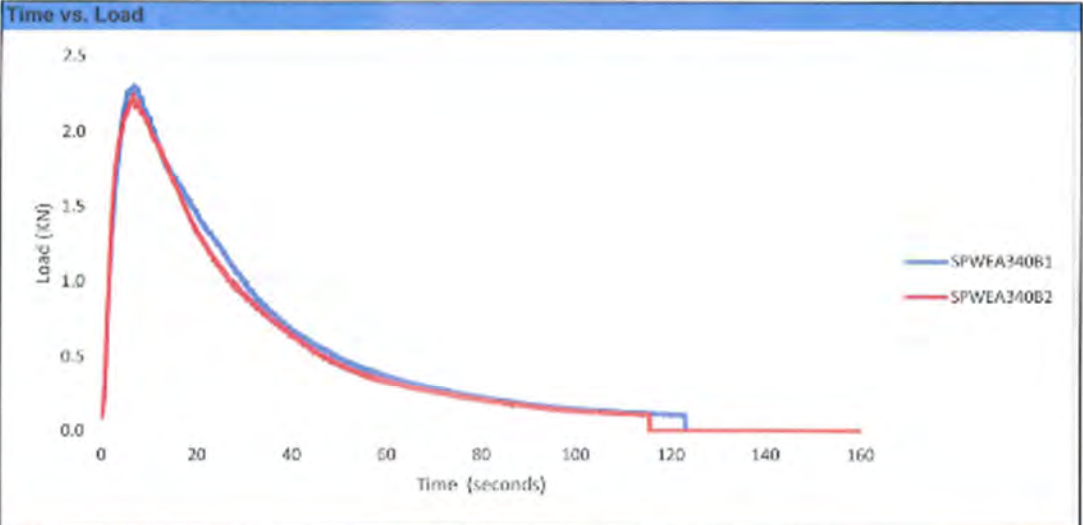
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American Engineering Testing, Inc.
 Saint Paul
 530 Cleveland Ave N
 St. Paul, MN 55114
 Toll Free: (800) 572-6364
 www.aetngtest.com

Disk-Shaped Compact Tension Test Report

Client: LRRB	CC:	This document is the intellectual property of American Engineering Testing, Inc. Date of Reviewed By:
Project: 27-00006 LRRB Asphalt Stripping Study		

Sample Information		
Asphalt Mixture Type: SPWEA340B	Testing Temperature:	-18.0 C



Specimen Information									
ID	Air Voids %	Thickness mm	Ligament mm	Peak Load kN	Actual Slope mm/s	Fracture Energy J/m ²	Area Under the Curve Nmm	Length of Test s	
SPWEA340 B1		49.72	79.24	2.31	0.017	335.30	1321.02	123.28	
SPWEA340 B2		50.00	78.88	2.25	0.017	314.06	1238.65	115.78	
Average Fracture Energy:						324.68 J/m ²			
Standard Deviation:						15.02 J/m ²			

Tested By	Remarks

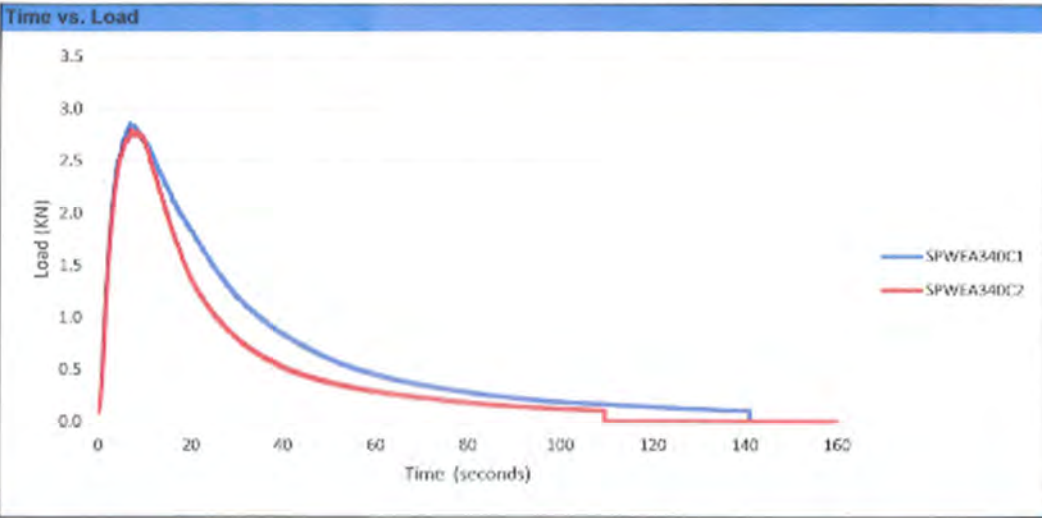


American Engineering Testing, Inc.
 Saint Paul
 550 Cleveland Ave N
 St. Paul, MN 55114
 Toll Free: (800)972-6364
 www.aetntest.com

Disk-Shaped Compact Tension Test Report

Client: LRRB	CC:	File location of test data: \\server\americantesting\americantesting.com Date of Review: _____ Reviewed By: _____
Project: 27-00006 LRRB Asphalt Stripping Study		

Sample Information		
Asphalt Mixture Type:	SPWEA340C	Testing Temperature: -24.0 C



Specimen Information								
ID	Air Voids %	Thickness mm	Ligament mm	Peak Load kN	Actual Slope mm/s	Fracture Energy J/m ²	Area Under the Curve Nmm	Length of Test s
SPWEA340 C1		49.88	80.22	2.86	0.017	420.32	1681.86	141.18
SPWEA340 C2		49.88	79.59	2.80	0.017	318.88	1265.93	109.68
Average Fracture Energy:						369.60 J/m ²		
Standard Deviation:						71.73 J/m ²		

Tested By	Remarks

APPENDIX D

LAB PERMEABILITY TESTING

Location	Permeability (10-5 cm/sec)	Sample 1	Sample 2	Sample 3	Sample 4	Average
Blaine - 93rd Ave East End	K=	0.9	0.0	2.3	0.1	0.8
	K20=	0.6	0.0	1.7	0.0	0.6
Blaine - 93rd Ave West End	K=	1.5	0.5	-	-	1.0
	K20=	1.1	0.4	-	-	0.8
Brooklyn Park 73rd Ave	K=	1.0	9.4	12.5	19.9	10.7
	K20=	0.7	6.8	9.1	14.4	7.8
Brooklyn Park - Louisiana Ave	K=	0.0	0.0	0.0	0.0	0.0
	K20=	0.0	0.0	0.0	0.0	0.0
Brooklyn Park - Winnetka Ave	K=	0.0	0.0	0.1	0.0	0.0
	K20=	0.0	0.0	0.0	0.0	0.0
Burnsville - 134th St	K=	9.8	1.2	1.5	0.1	3.1
	K20=	7.1	0.9	1.1	0.1	2.3
Burnsville - Heritage Cir Area	K=	0.1	0.1	1.2	0.3	0.4
	K20=	0.0	0.1	0.9	0.2	0.3
Burnsville - Knob Hill Area	K=	0.0	0.9	0.3	0.3	0.4
	K20=	0.0	0.7	0.2	0.2	0.3
Cottage Grove - Hyde Ave S	K=	0.0	0.5	0.1	0.5	0.2
	K20=	0.0	0.3	0.0	0.3	0.2
Cottage Grove - Ingberg Trl S	K=	12.7	0.1	1.3	0.0	3.5
	K20=	9.2	0.0	1.0	0.0	2.5
Cottage Grove - Jensen Ave	K=	3.7	0.0	0.1	23.7	6.9
	K20=	2.7	0.0	0.1	17.2	5.0
Inver Grove Heights - Brooks Blvd	K=	0.0	0.0	0.0	0.0	0.0
	K20=	0.0	0.0	0.0	0.0	0.0
Osseo 8th Ave SE	K=	0.0	4.2	11.9	0.0	4.0
	K20=	0.0	3.1	8.6	0.0	2.9
Sibley County CSAH 9 North Portion	K=	0.0	0.0	0.2	0.0	0.0
	K20=	0.0	0.0	0.1	0.0	0.0
Sibley County CSAH 9 South Portion	K=	0.0	0.0	0.1	0.0	0.0
	K20=	0.0	0.0	0.0	0.0	0.0
Woodbury - Bridgewater	K=	1.0	0.0	0.0	0.0	0.3
	K20=	0.8	0.0	0.0	0.0	0.2
Woodbury - Newbury Alcove Cul de sac	K=	0.0	0.0	-	-	0.0
	K20=	0.0	0.0	-	-	0.0
Woodbury - Newbury Alcove Straight Portion	K=	0.0	0.0	0.0	0.0	0.0
	K20=	0.0	0.0	0.0	0.0	0.0

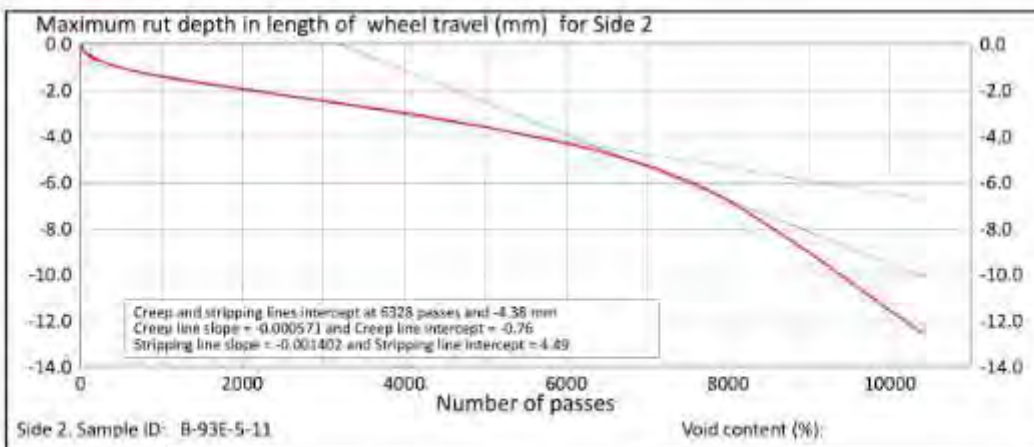
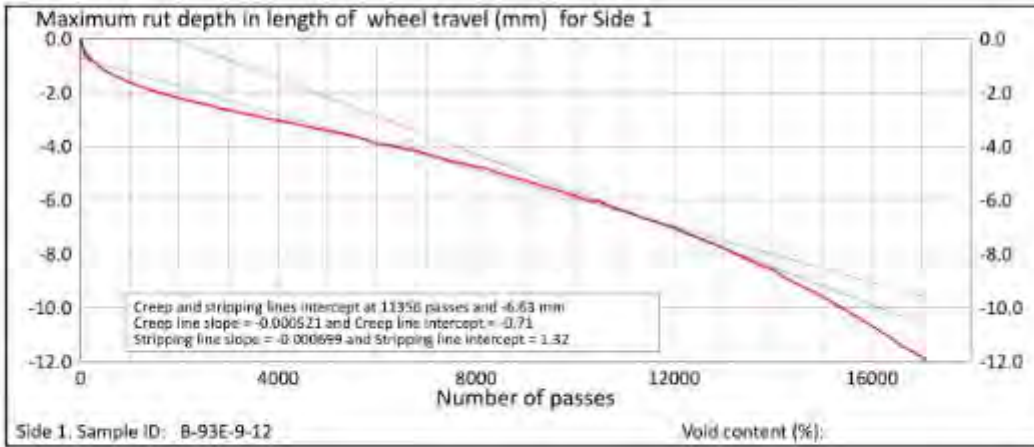
APPENDIX E

HAMBURG TEST DATA

Hamburg Wheel-Tracker Test Results

AASHTO 324 (Modified)
 Date/time of test: 12/29/2014 6:56 AM
 Lab. No.: B-93E
 Project name: LRRB Study
 Submitted by:

Date sampled:
 Job No.:
 Project No.:
 Project Engineer.:



Rut depths (mm)		
Pass No.	Side 1	Side 2
5000	-3.42	-3.57
10000	-5.83	-11.54
15000	-9.55	
10384		-12.51
17102	-11.98	

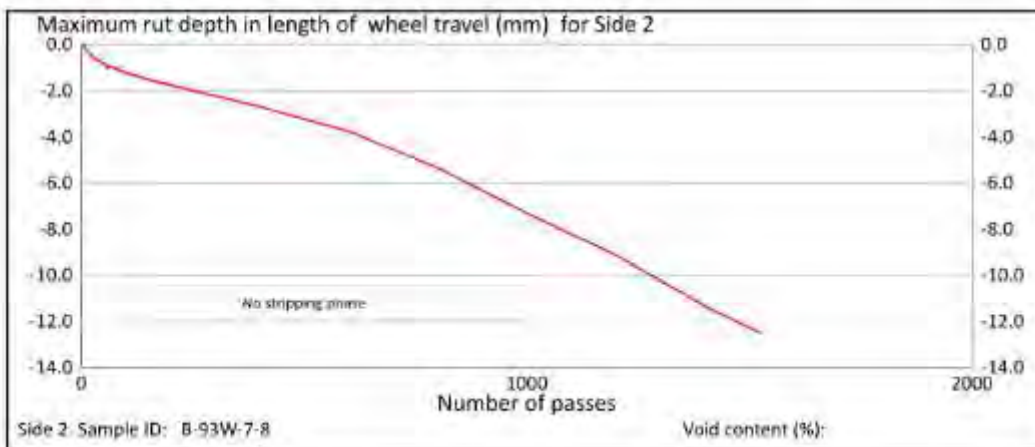
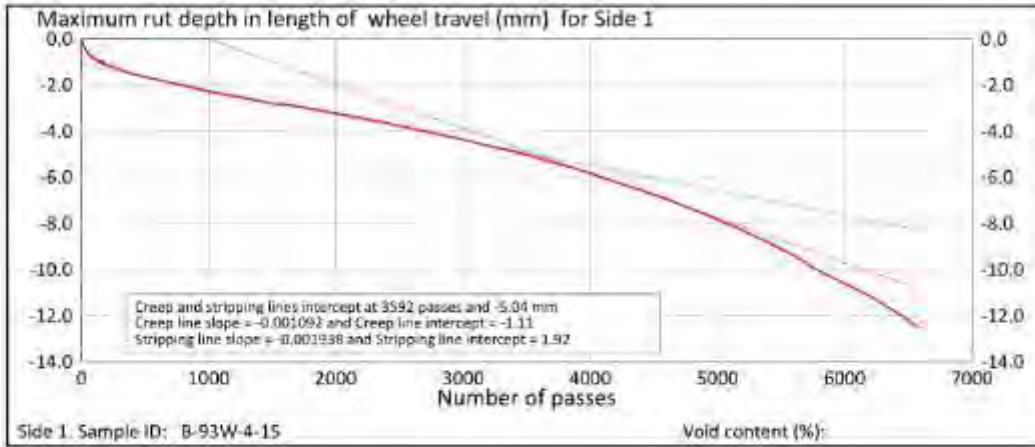
Mix type:
 Asphalt grade:
 Mix source:
 Test temperature (°C): 50.0
 Mix depth (mm): 60.0

Signature

Hamburg Wheel-Tracker Test Results

AASHTO 324 (Modified)
 Date/time of test: 12/23/2014 7:10 AM
 Lab. No.: B-93W
 Project name: LRRB Study
 Submitted by:

Date sampled:
 Job No.:
 Project No.:
 Project Engineer.:



Pass No.	Rut depths (mm)	
	Side 1	Side 2
5000	-7.82	
1526		-12.53
6586	-12.52	

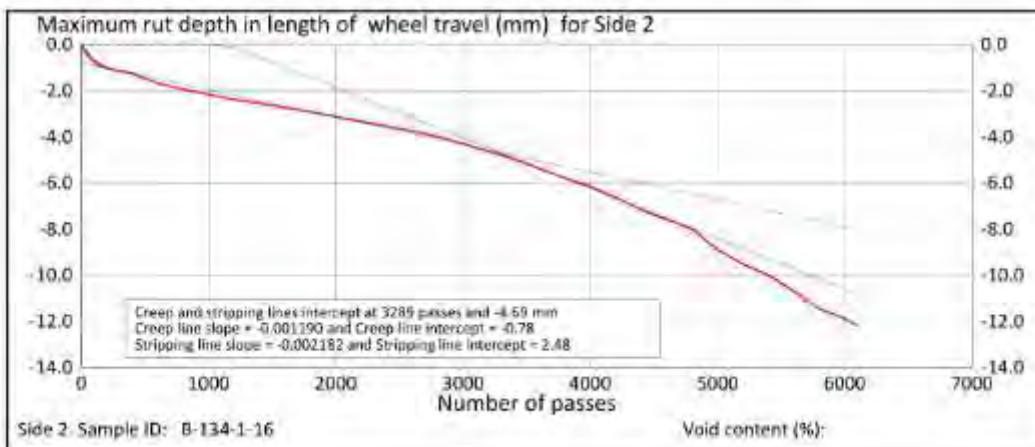
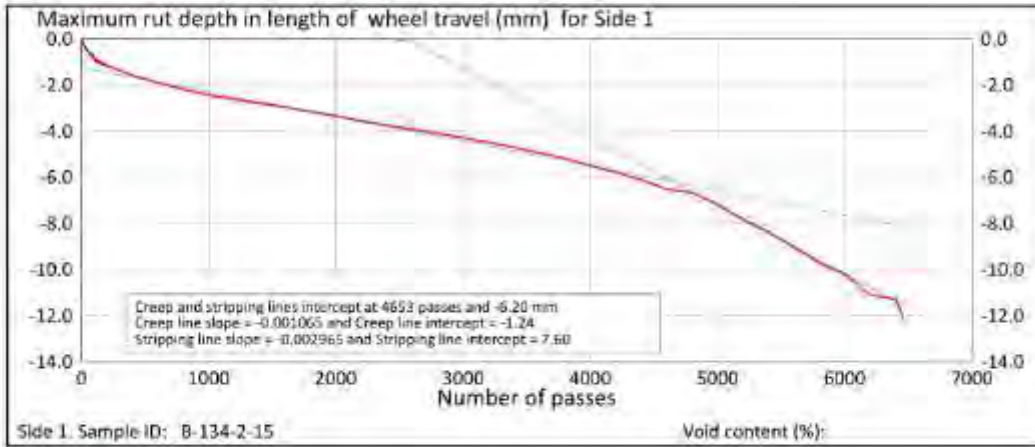
Mix type:
 Asphalt grade:
 Mix source:
 Test temperature (°C): 50.0
 Mix depth (mm): 60.0

Signature:

Hamburg Wheel-Tracker Test Results

AASHTO 324 (Modified)
 Date/time of test: 12/22/2014 7:27 AM
 Lab. No.: B-134
 Project name: LRRB Study
 Submitted by:

Date sampled:
 Job No.:
 Project No.:
 Project Engineer.:



Rut depths (mm)		
Pass No.	Side 1	Side 2
5000	-7.17	-8.9
6090		-12.18
6460	-12.11	

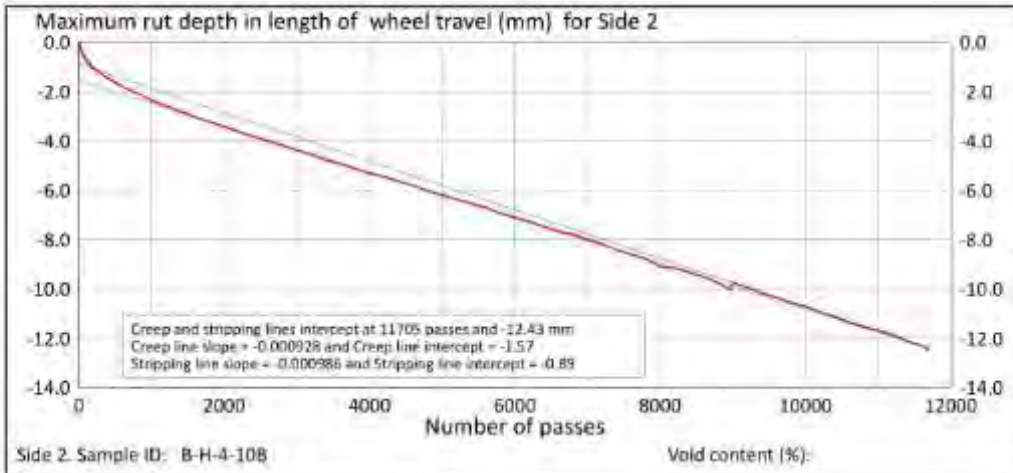
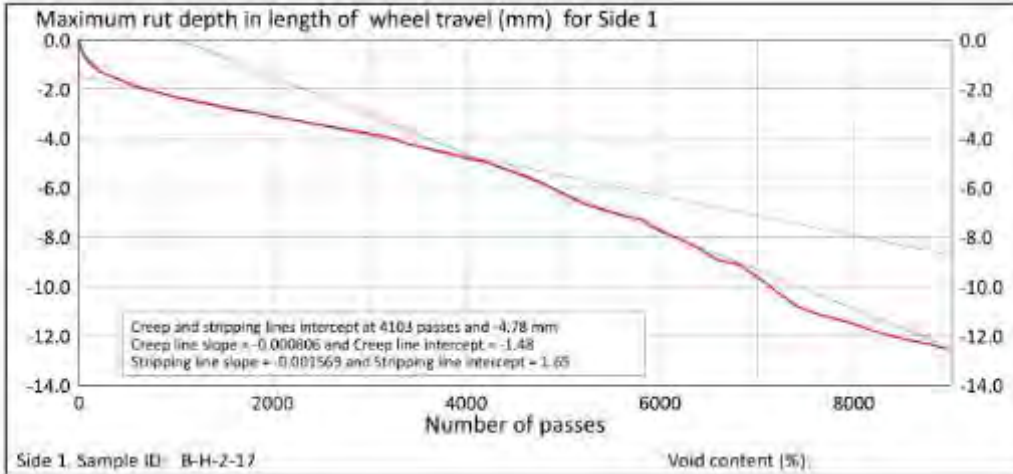
Mix type:
 Asphalt grade:
 Mix source:
 Test temperature (°C): 50.0
 Mix depth (mm): 60.0

Signature:

Hamburg Wheel-Tracker Test Results

AASHTO 324 (Modified)
 Date/time of test: 1/7/2015 6:39 AM
 Lab. No.: B-H
 Project name: LRRB Study
 Submitted by:

Date sampled:
 Job No.:
 Project No.:
 Project Engineer.:



Rut depths (mm)		
Pass No.	Side 1	Side 2
5000	-6.25	-6.2
10000		-10.72
8968	-12.53	
11696		-12.51

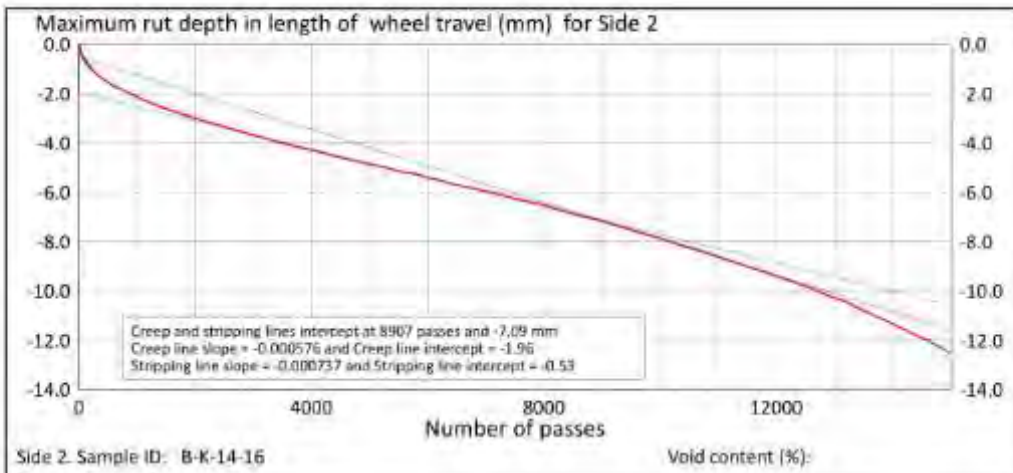
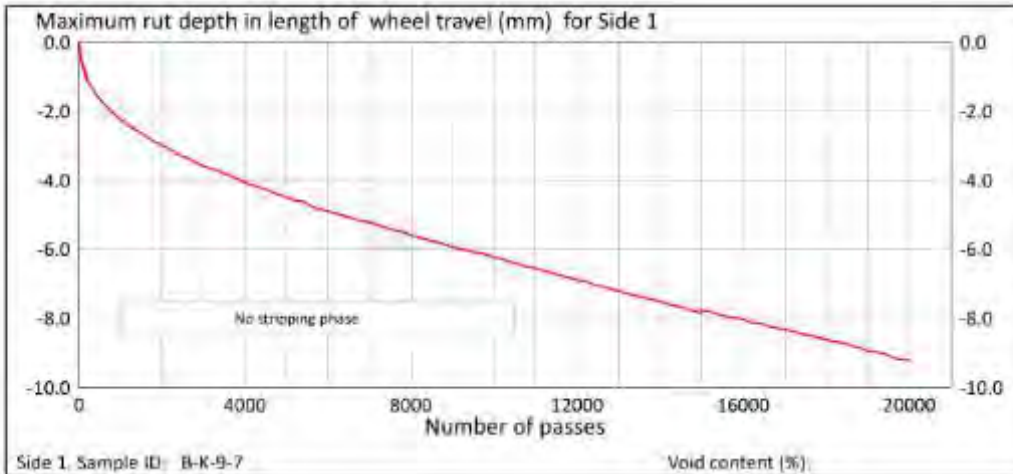
Mix type:
 Asphalt grade:
 Mix source:
 Test temperature (°C): 50.0
 Mix depth (mm): 60.0

Signature

Hamburg Wheel-Tracker Test Results

AASHTO 324 (Modified)
 Date/time of test: 1/6/2015 9:12 AM
 Lab. No.: B-K
 Project name: LRRB Study
 Submitted by:

Date sampled:
 Job No.:
 Project No.:
 Project Engineer.:



Rut depths (mm)		
Pass No.	Side 1	Side 2
5000	-4.5	-4.87
10000	-6.25	-7.87
15000	-7.76	
20000	-9.22	
14976		-12.56

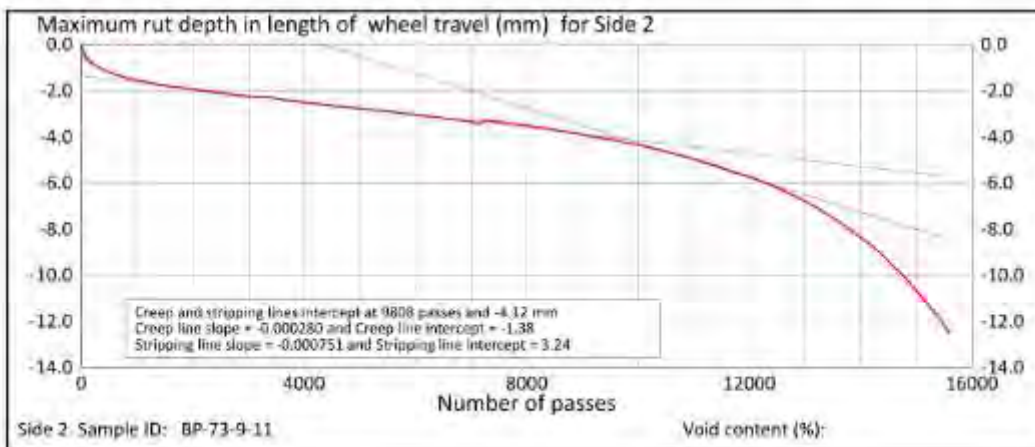
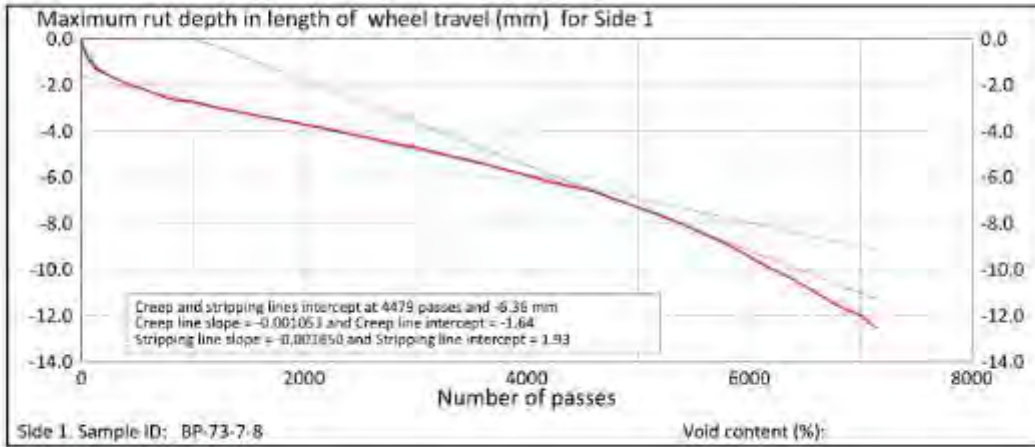
Mix type:
 Asphalt grade:
 Mix source:
 Test temperature (°C): 50.0
 Mix depth (mm): 60.0

Signature

Hamburg Wheel-Tracker Test Results

AASHTO 324 (Modified)
 Date/time of test: 12/22/2014 12:15 PM
 Lab. No.: BP-73
 Project name: LRRB Study
 Submitted by:

Date sampled:
 Job No.:
 Project No.:
 Project Engineer.:



Rut depths (mm)		
Pass No.	Side 1	Side 2
5000	-7.31	-2.79
10000		-4.36
15000		-10.69
7134	-12.51	
15590		-12.5

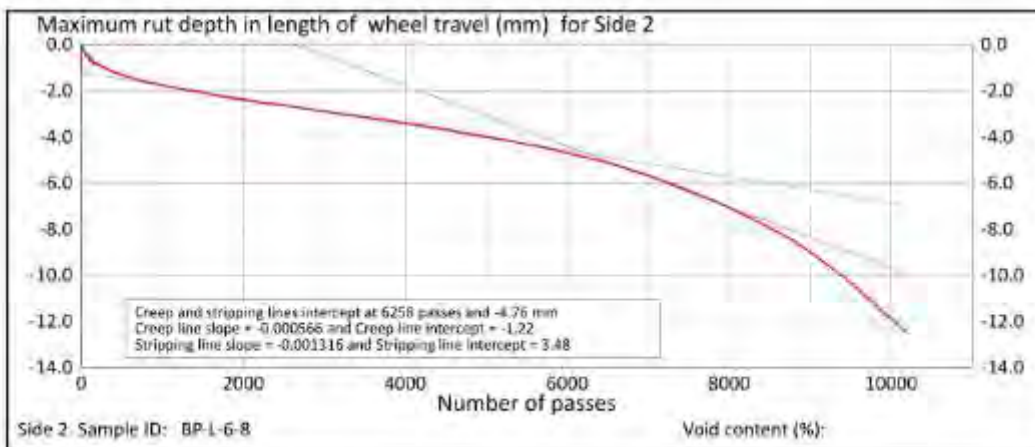
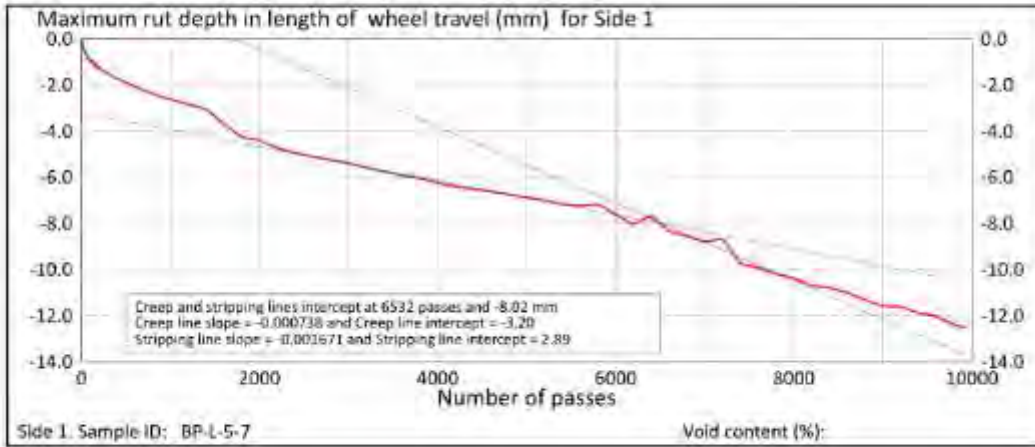
Mix type:
 Asphalt grade:
 Mix source:
 Test temperature (°C): 50.0
 Mix depth (mm): 60.0

Signature:

Hamburg Wheel-Tracker Test Results

AASHTO 324 (Modified)
 Date/time of test: 12/17/2014 4:25 PM
 Lab. No.: BP-L
 Project name: LRRB Study
 Submitted by:

Date sampled:
 Job No.:
 Project No.:
 Project Engineer.:



Rut depths (mm)		
Pass No.	Side 1	Side 2
5000	-6.87	-4.01
10000		-11.86
9936	-12.5	
10194		-12.51

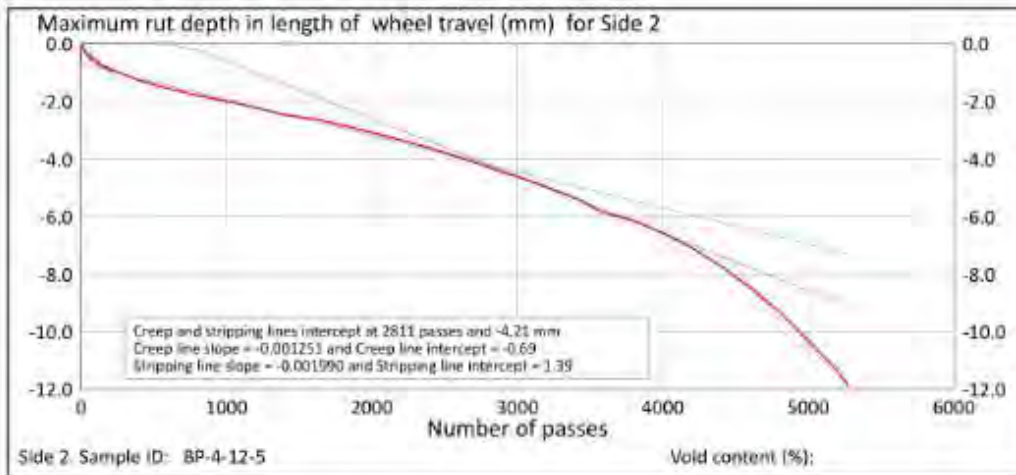
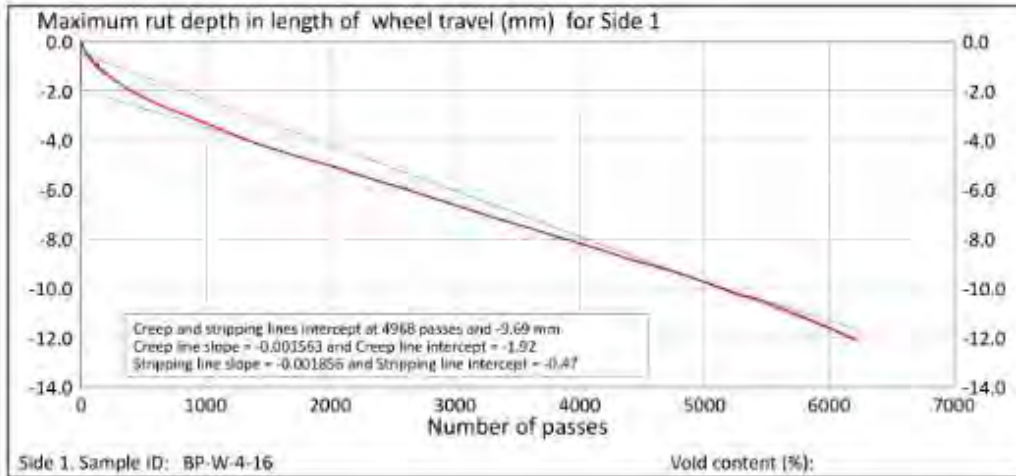
Mix type:
 Asphalt grade:
 Mix source:
 Test temperature (°C): 50.0
 Mix depth (mm): 60.0

Signature:

Hamburg Wheel-Tracker Test Results

AASHTO 324 (Modified)
 Date/time of test: 1/7/2015 1:05 PM
 Lab. No.: BP-W
 Project name: LRRB Study
 Submitted by:

Date sampled:
 Job No.:
 Project No.:
 Project Engineer.:



Rut depths (mm)		
Pass No.	Side 1	Side 2
5000	-9.74	-10.32
5272		-11.85
6220	-12.11	

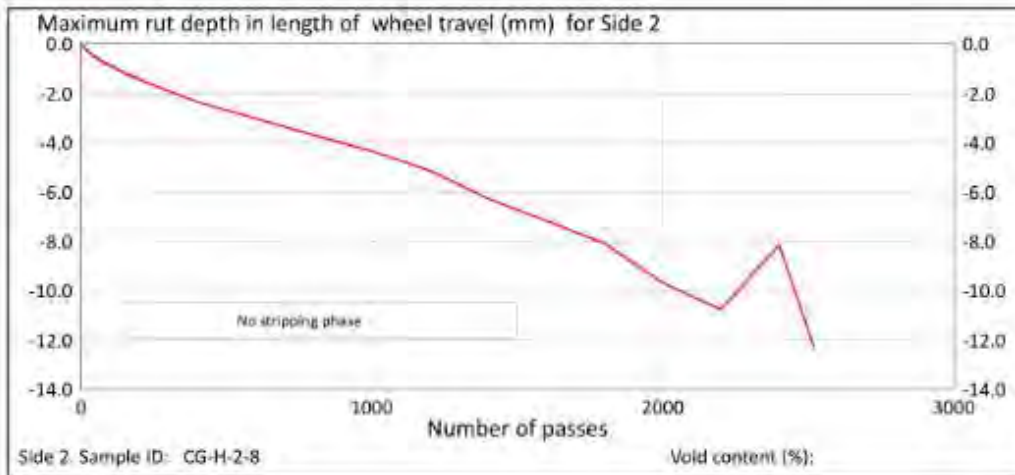
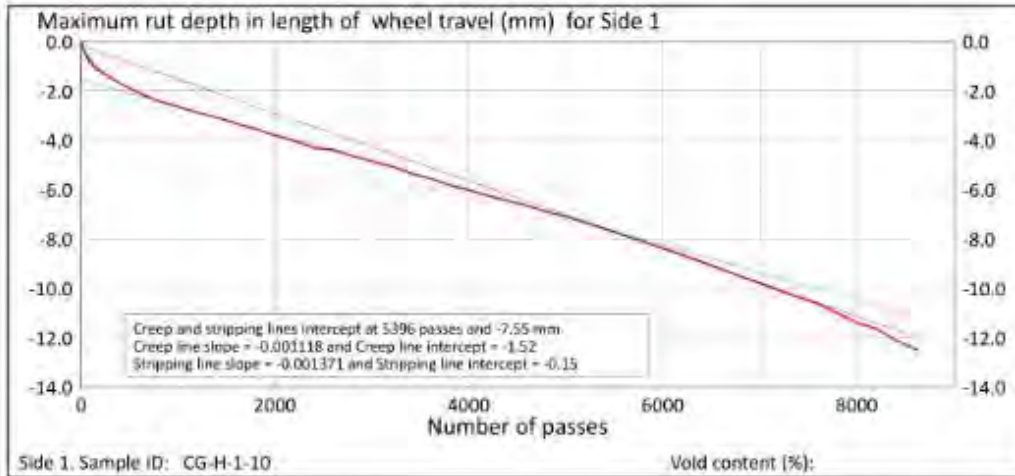
Mix type:
 Asphalt grade:
 Mix source:
 Test temperature (°C): 50.0
 Mix depth (mm): 60.0

Signature

Hamburg Wheel-Tracker Test Results

AASHTO 324 (Modified)
 Date/time of test: 1/5/2015 1:56 PM
 Lab. No.: CG-H
 Project name: LRRB Study
 Submitted by:

Date sampled:
 Job No.:
 Project No.:
 Project Engineer.:



Rut depths (mm)		
Pass No.	Side 1	Side 2
5000	-7.09	
2518		-12.25
8626	-12.5	

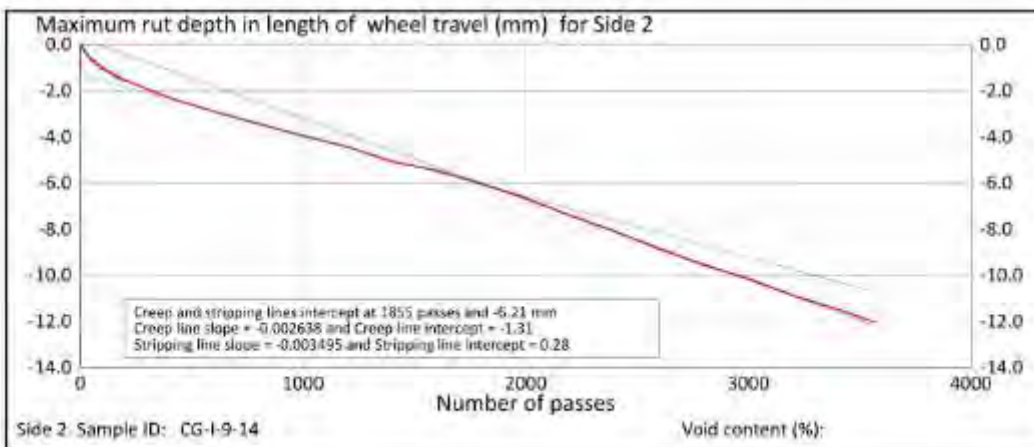
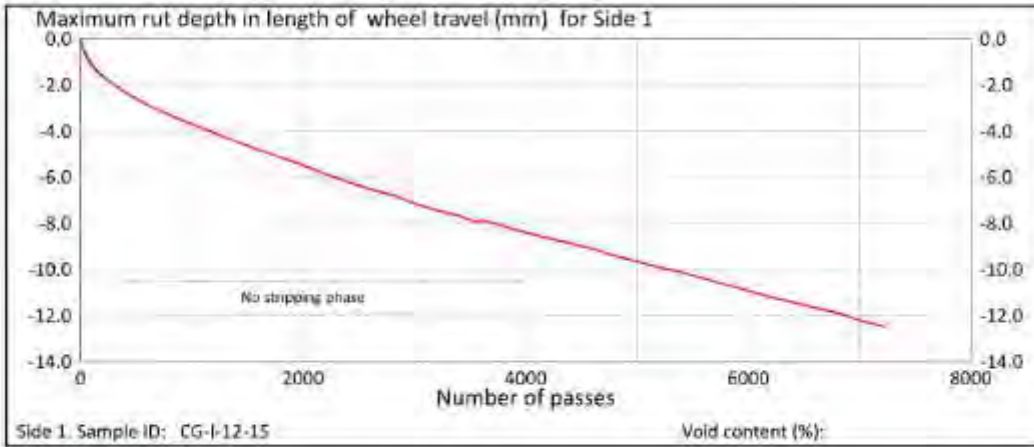
Mix type:
 Asphalt grade:
 Mix source:
 Test temperature (°C): 50.0
 Mix depth (mm): 60.0

Signature

Hamburg Wheel-Tracker Test Results

AASHTO 324 (Modified)
 Date/time of test: 12/30/2014 7:02 AM
 Lab. No.: CG-1
 Project name: LRRB Study
 Submitted by:

Date sampled:
 Job No.:
 Project No.:
 Project Engineer.:



Rut depths (mm)		
Pass No.	Side 1	Side 2
5000	-9.65	
3564		-12.04
7224	-12.53	

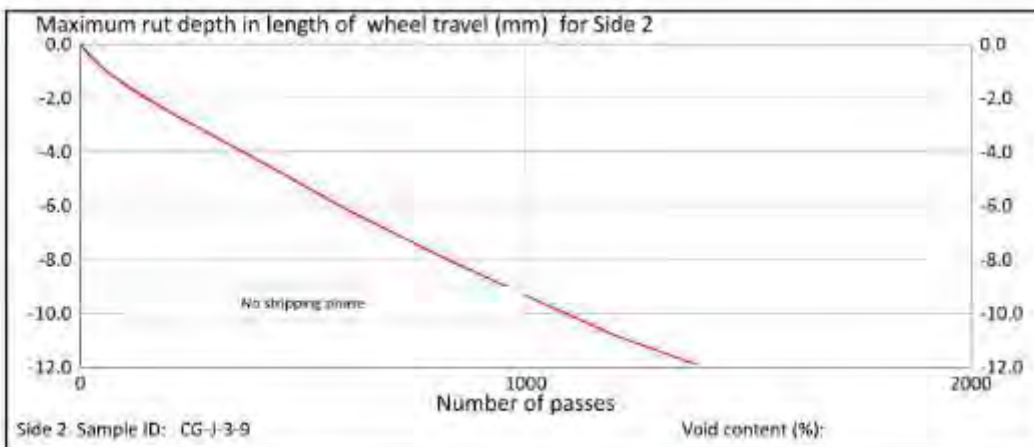
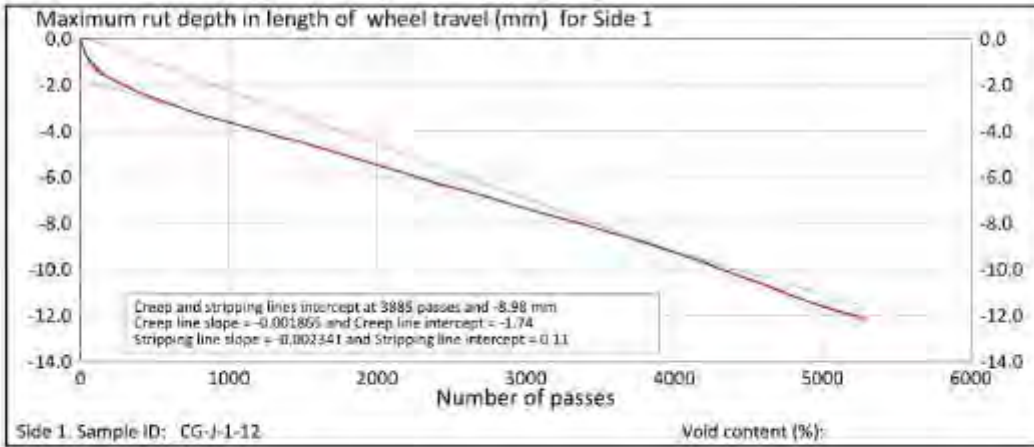
Mix type:
 Asphalt grade:
 Mix source:
 Test temperature (°C): 50.0
 Mix depth (mm): 60.0

Signature:

Hamburg Wheel-Tracker Test Results

AASHTO 324 (Modified)
 Date/time of test: 12/31/2014 6:58 AM
 Lab. No.: CG-J
 Project name: LRRB Study
 Submitted by:

Date sampled:
 Job No.:
 Project No.:
 Project Engineer:



Rut depths (mm)		
Pass No.	Side 1	Side 2
5000	-11.6	
1382		-11.89
5288	-12.15	

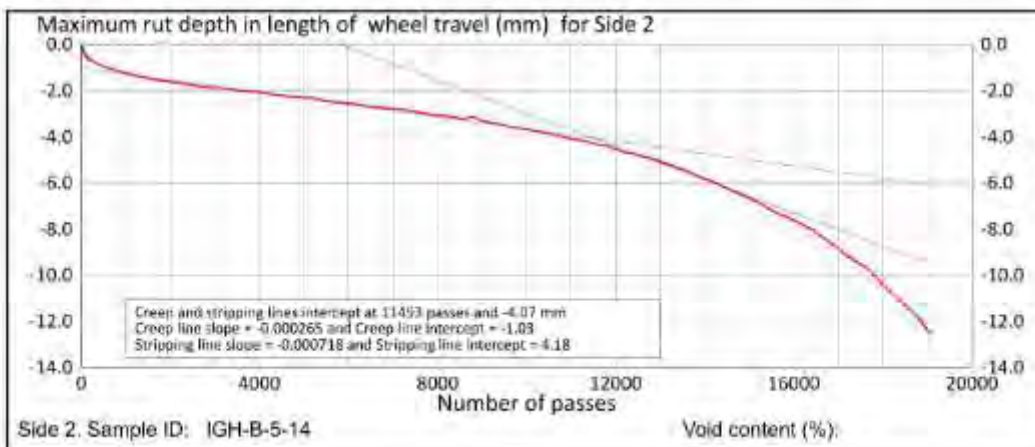
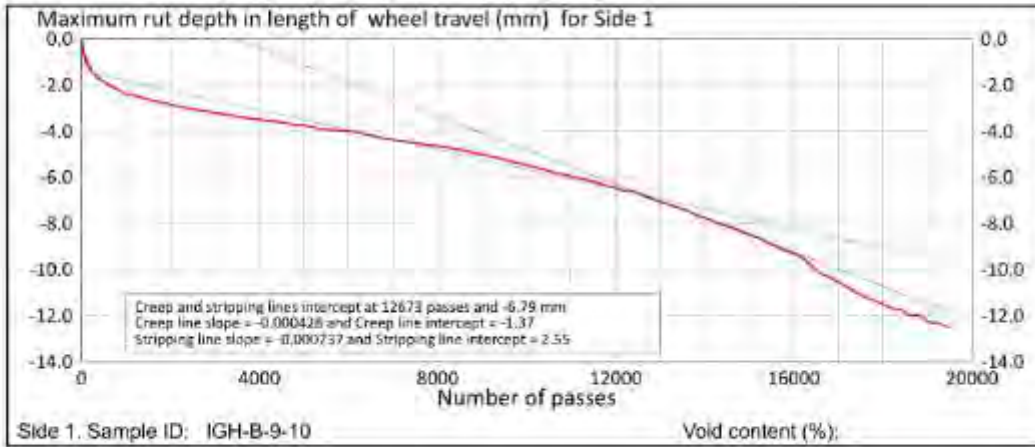
Mix type:
 Asphalt grade:
 Mix source:
 Test temperature (°C): 50.0
 Mix depth (mm): 60.0

Signature:

Hamburg Wheel-Tracker Test Results

AASHTO 324 (Modified)
 Date/time of test: 12/17/2014 8:13 AM
 Lab. No.: IGH-B
 Project name: LRRB Study
 Submitted by:

Date sampled:
 Job No.:
 Project No.:
 Project Engineer.:



Rut depths (mm)		
Pass No.	Side 1	Side 2
5000	-3.75	-2.31
10000	-5.47	-3.68
15000	-8.48	-6.68
19078		-12.51
19472	-12.51	

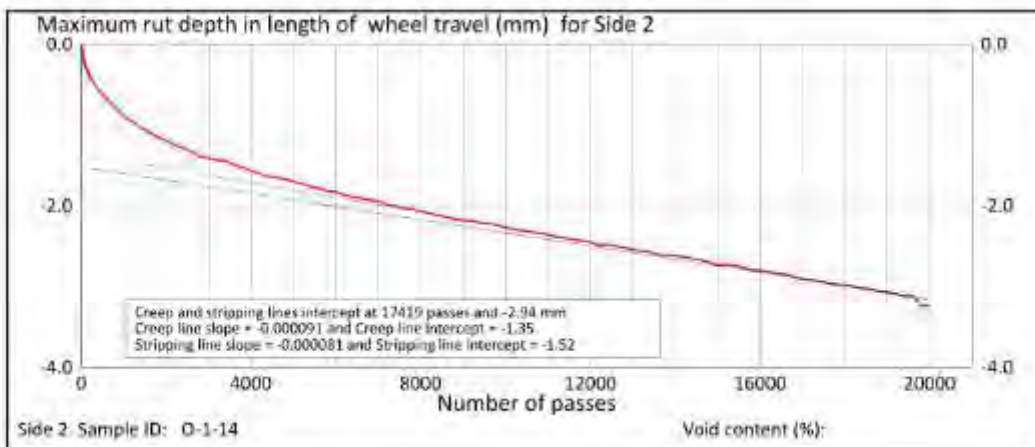
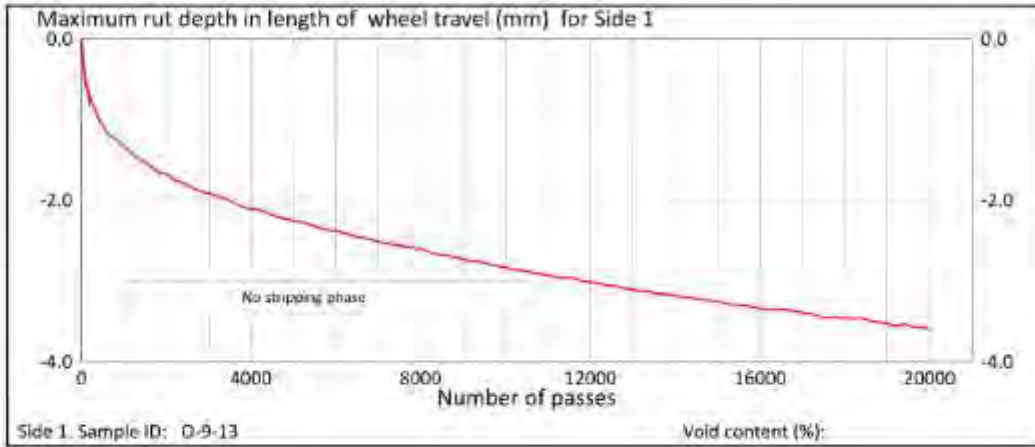
Mix type:
 Asphalt grade:
 Mix source:
 Test temperature (°C): 45.0
 Mix depth (mm): 60.0

Signature

Hamburg Wheel-Tracker Test Results

AASHTO 324 (Modified)
 Date/time of test: 12/19/2014 7:05 AM
 Lab. No.: 0
 Project name: LRRB Study
 Submitted by:

Date sampled:
 Job No.:
 Project No.:
 Project Engineer.:



Rut depths (mm)		
Pass No.	Side 1	Side 2
5000	-2.25	-1.7
10000	-2.83	-2.27
15000	-3.25	-2.74
20000	-3.59	-3.24

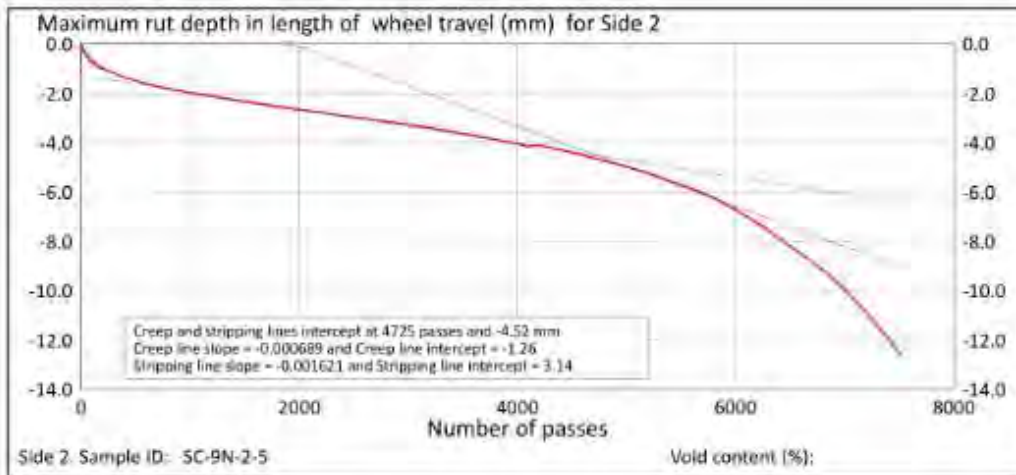
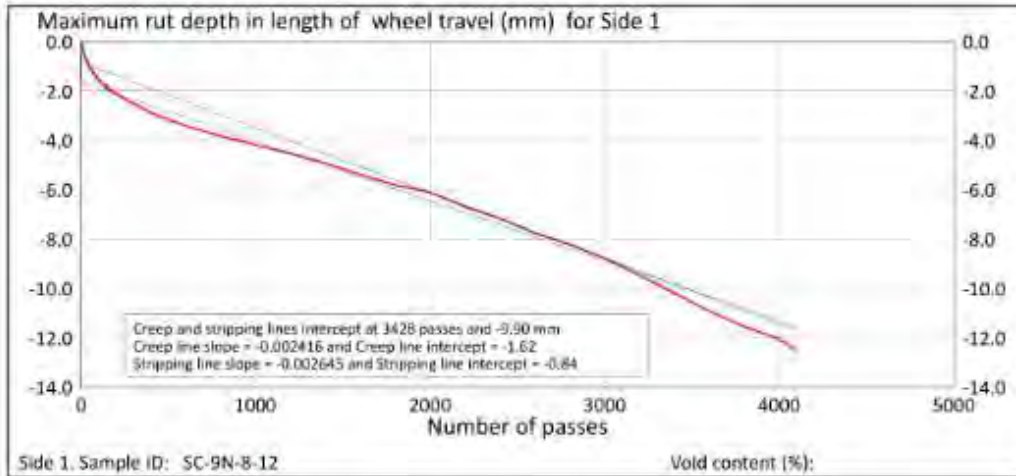
Mix type:
 Asphalt grade:
 Mix source:
 Test temperature (°C): 50.0
 Mix depth (mm): 60.0

Signature:

Hamburg Wheel-Tracker Test Results

AASHTO 324 (Modified)
 Date/time of test: 1/5/2015 8:01 AM
 Lab. No.: 5C-9N
 Project name: LRRB Study
 Submitted by:

Date sampled:
 Job No.:
 Project No.:
 Project Engineer:



Rut depths (mm)		
Pass No.	Side 1	Side 2
5000		-4.98
4102	-12.53	
7506		-12.59

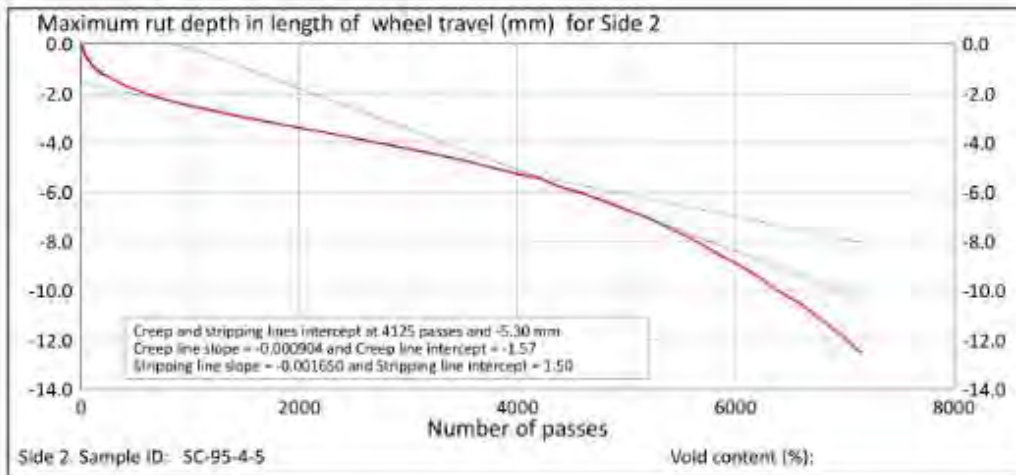
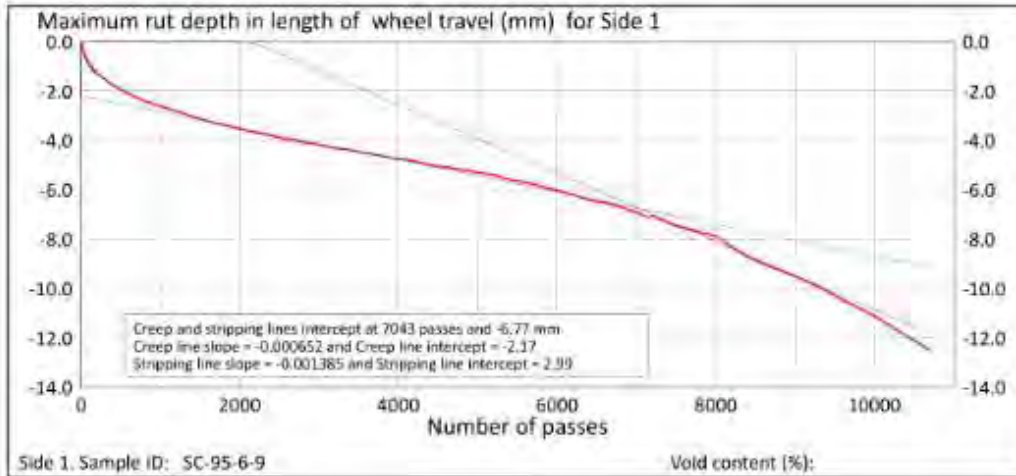
Mix type:
 Asphalt grade:
 Mix source:
 Test temperature (°C): 50.0
 Mix depth (mm): 60.0

Signature

Hamburg Wheel-Tracker Test Results

AASHTO 324 (Modified)
 Date/time of test: 12/31/2014 11:23 AM
 Lab. No.: SC-95
 Project name: LRRB Study
 Submitted by:

Date sampled:
 Job No.:
 Project No.:
 Project Engineer.:



Rut depths (mm)		
Pass No.	Side 1	Side 2
5000	-5.3	-6.72
10000	-11.12	
7150		-12.53
10702	-12.51	

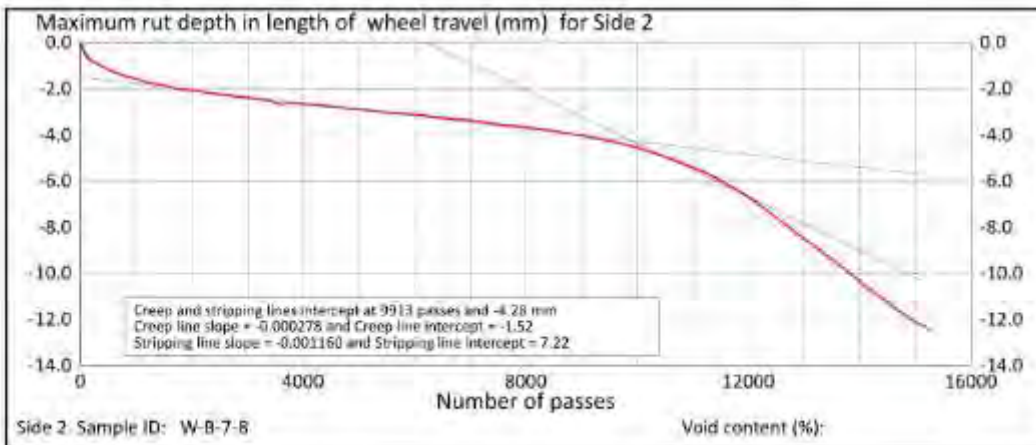
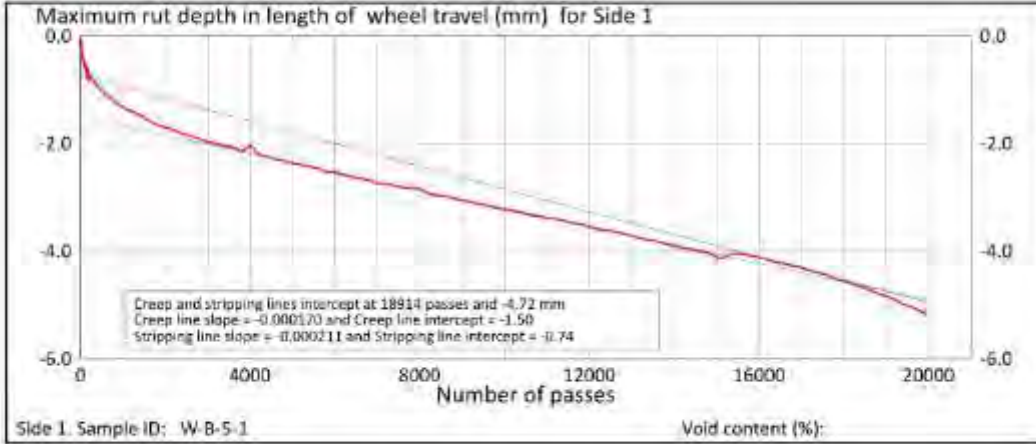
Mix type:
 Asphalt grade:
 Mix source:
 Test temperature (°C): 50.0
 Mix depth (mm): 60.0

Signature

Hamburg Wheel-Tracker Test Results

AASHTO 324 (Modified)
 Date/time of test: 12/18/2014 7:09 AM
 Lab. No.: W-B
 Project name: LRRB Study
 Submitted by:

Date sampled:
 Job No.:
 Project No.:
 Project Engineer.:



Rut depths (mm)		
Pass No.	Side 1	Side 2
5000	-2.37	-2.91
10000	-3.23	-4.56
15000	-4.11	-12.14
20000	-5.19	
15254		-12.53

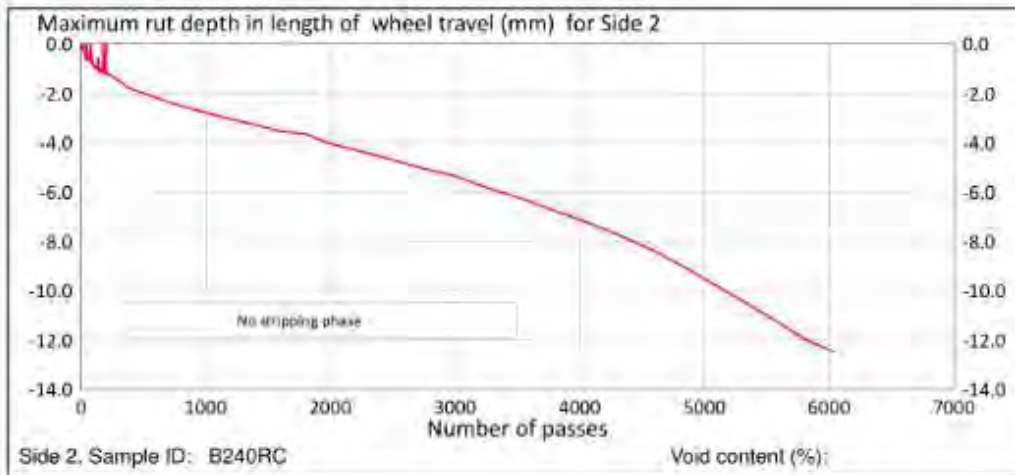
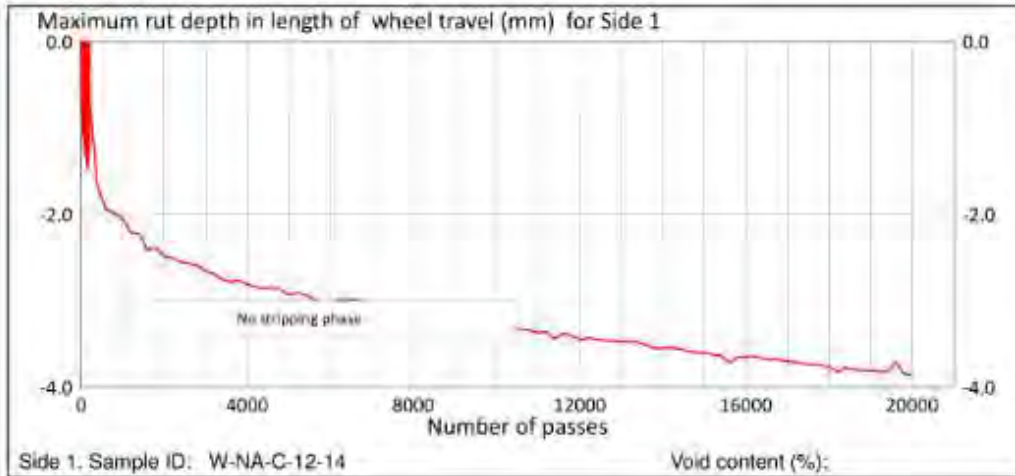
Mix type:
 Asphalt grade:
 Mix source:
 Test temperature (°C): 50.0
 Mix depth (mm): 60.0

Signature:

Hamburg Wheel-Tracker Test Results

AASHTO 324 (Modified)
 Date/time of test: 12/15/2014 9:45 AM
 Lab. No.:
 Project name:
 Submitted by:

Date sampled:
 Job No.:
 Project No.: 27-00006
 Project Engineer.:



Rut depths (mm)		
Pass No.	Side 1	Side 2
5000	-2.93	-9.51
10000	-3.29	
15000	-3.6	
20000	-3.86	
6036		-12.5

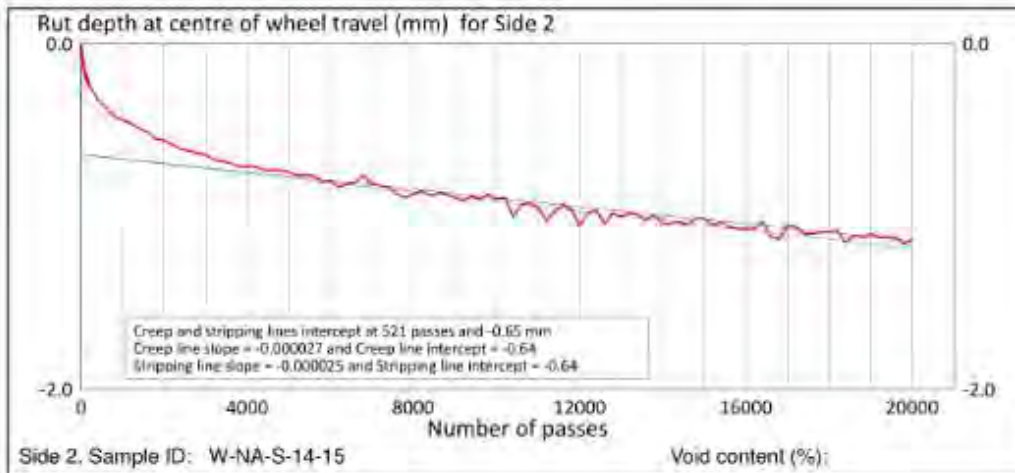
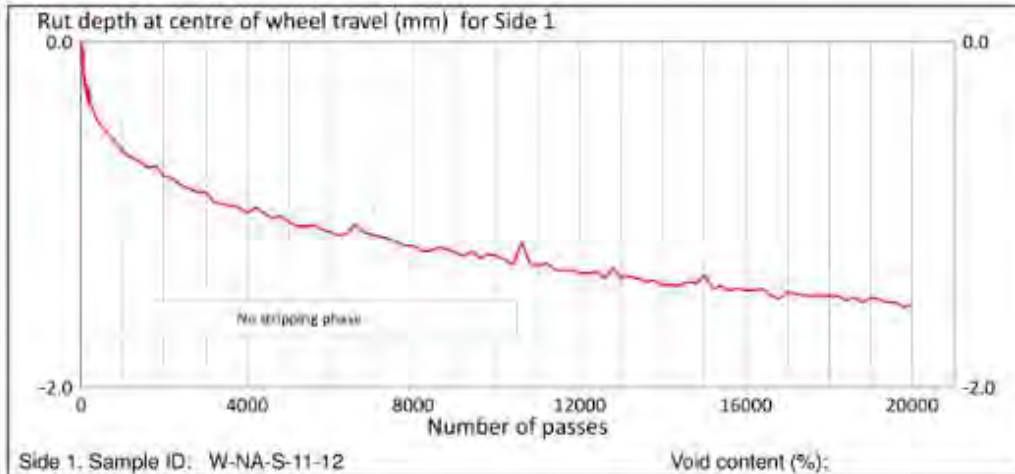
Mix type:
 Asphalt grade:
 HMA Production: Field
 Compaction method: SGC
 Mix source:
 Test temperature (°C): 45.0
 Mix depth (mm): 60.0

Signature

Hamburg Wheel-Tracker Test Results

AASHTO 324 (Modified)
 Date/time of test: 12/16/2014 8:14 AM
 Lab. No.:
 Project name:
 Submitted by:

Date sampled:
 Job No.:
 Project No.: 27-00006
 Project Engineer.:



Rut depths (mm)		
Pass No.	Side 1	Side 2
5000	-1.04	-.74
10000	-1.24	-.9
15000	-1.35	-1.01
20000	-1.52	-1.13

Mix type:
 Asphalt grade:
 HMA Production: Not selected
 Compaction method: Not selected
 Mix source:
 Test temperature (°C): 45.0
 Mix depth (mm): 60.0

Signature

APPENDIX F

GROUND PENETRATING RADAR AND NUCLEAR DENSITY DATA

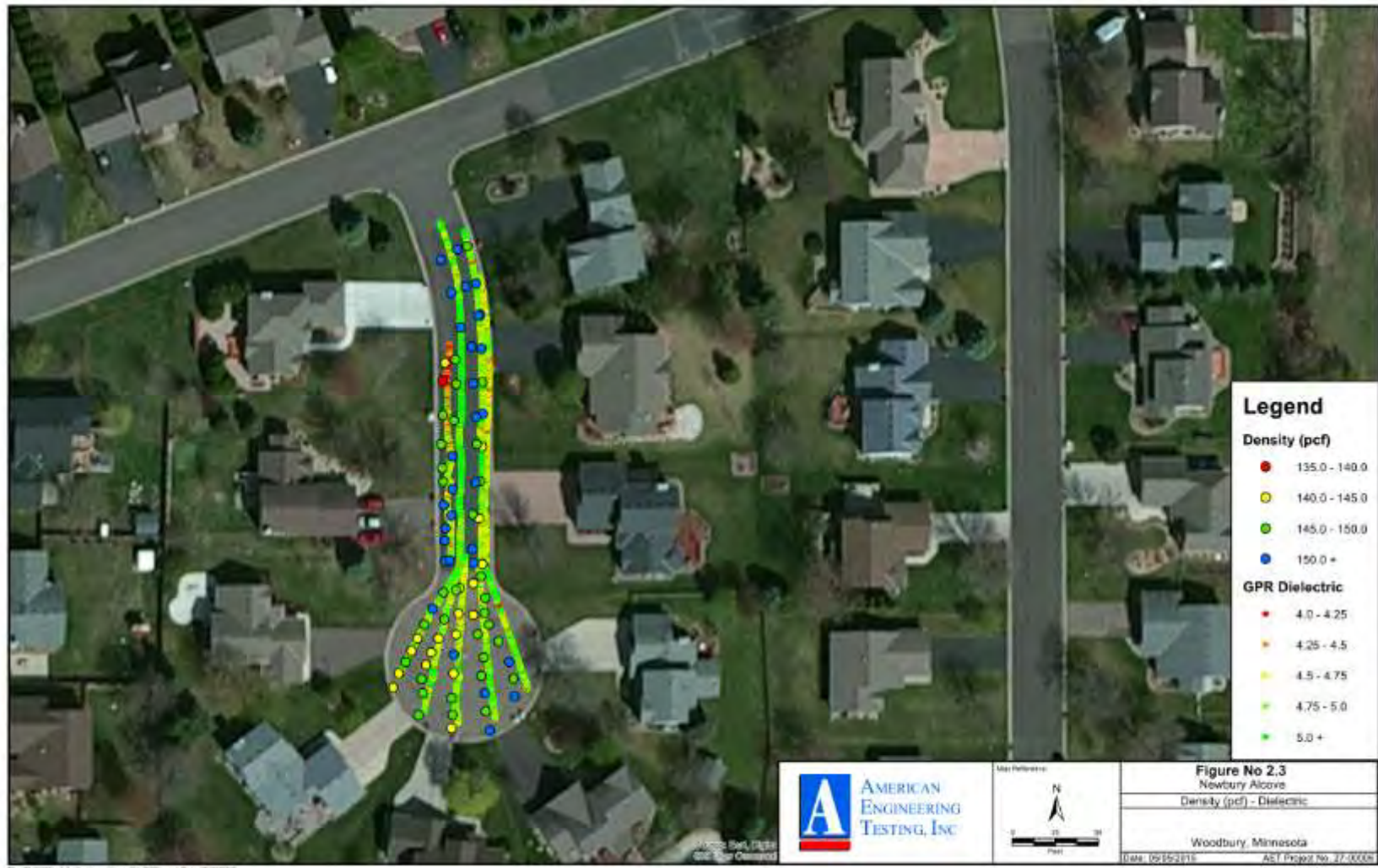
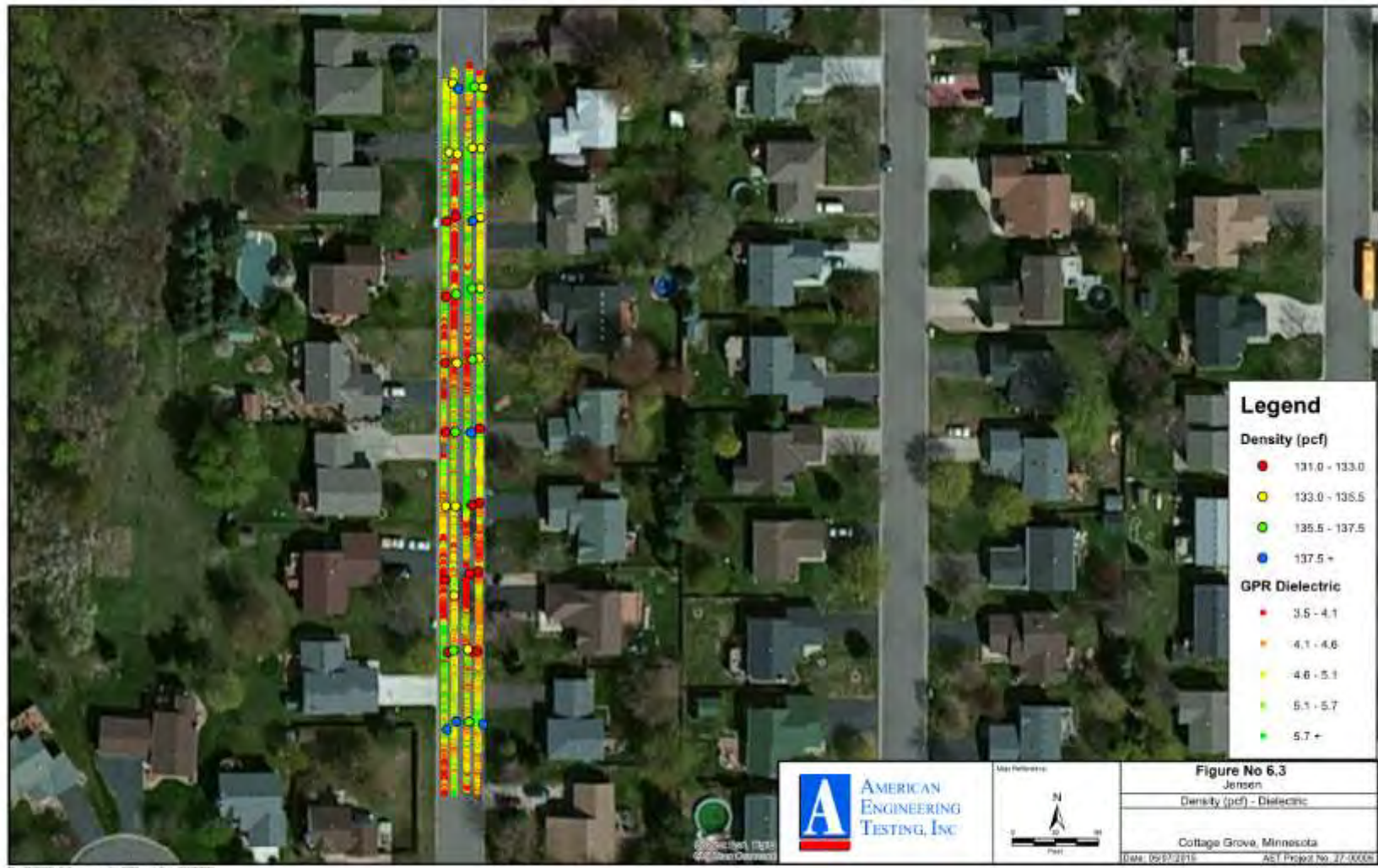


Fig. 2.3-0000 - 2.3 - Newbury Above (Aerial, GPR) and Data (Colorized)



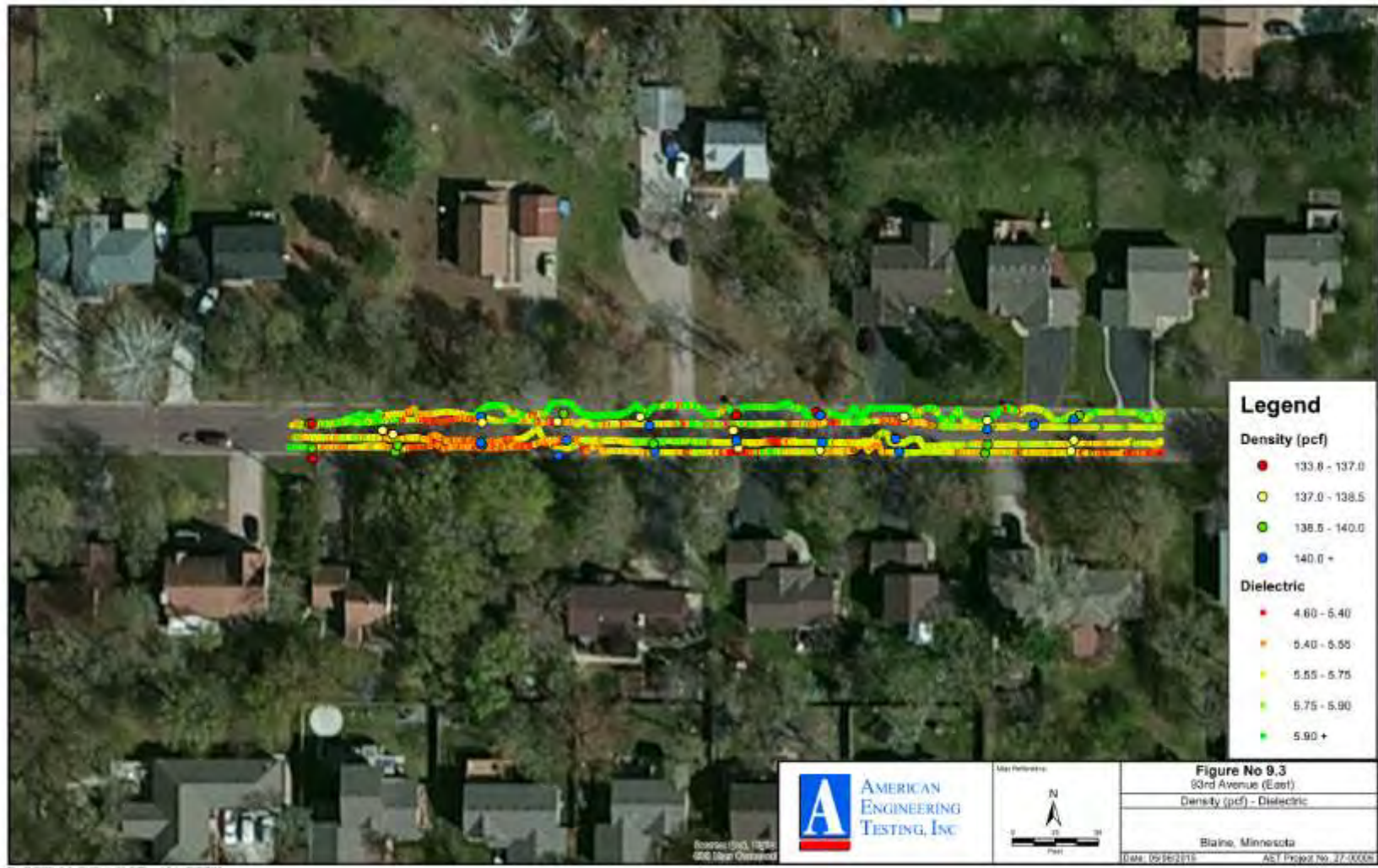


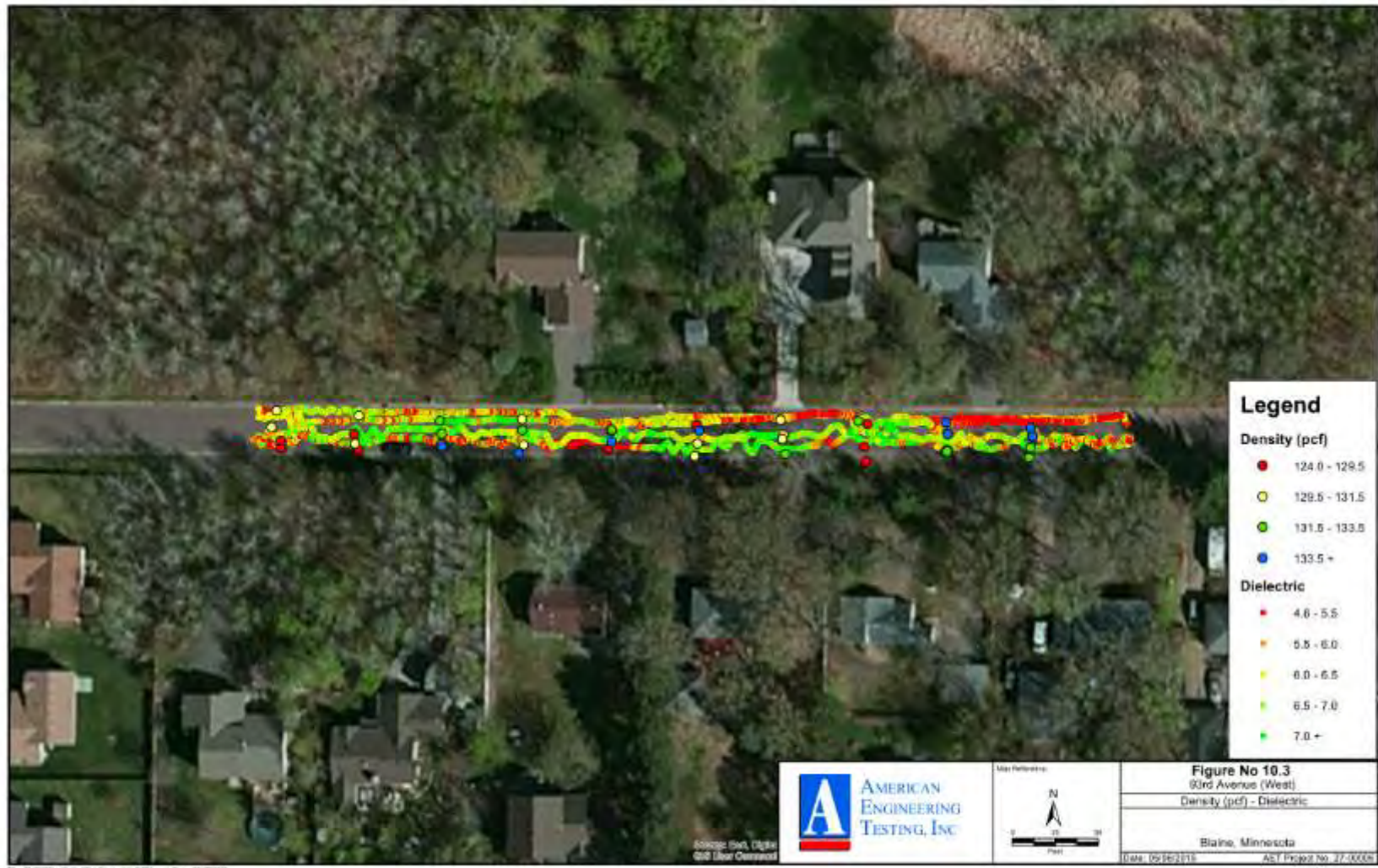


















APPENDIX G

TENSILE STRENGTH RATIO DATA

MODIFIED LOTTMAN

SPEC 2360 MIX TYPE SPWEA330B 7% DATE 5/7/2015

TREATED SPECIMENS

UNTREATED SPECIMENS

SAMPLE I.D.	2		3		1		4	
DIAMETER	150		150		150		150	
THICKNESS	95.00		95		95.00		95.00	
DRY WT. IN AIR	3760.7		3759.6		3726.0		3762.5	
SSD WT.	3773.7		3766.3		3743.2		3770.1	
WT. IN H2O	2114.3		2109.1		2100.0		2111.6	
VOLUME	1659.4		1657.2		1643.2		1658.5	
BULK Sp. Gr.	2.266		2.269	2.267	2.268		2.269	2.268
MAX Sp. Gr.	2.438		2.438	2.438	2.438		2.438	2.438
% AIR VOIDS	7.0		6.9	7.0	7.0		6.9	7.0
VOLUME AIR VOIDS	116.87		115.12	115.99				
LOAD, POUNDS					2110		2225	2168

SATURATED FOR MIN. @ mm.Hg

SSD WT.	3837.0		3835.0	
WT. IN H2O	2177.0		2176.9	
VOLUME	1660.0		1658.1	
VOL. OF ABS. H2O	76.3		75.4	
% SATURATION	65.3		65.5	65.4
% SWELL	0.04		0.05	0.0

BLOWS na

CONDITIONED 24 HOURS IN 140 DEGREE F. WATER

DIAMETER	149.82		149.96				
THICKNESS	95.050		95.030				
SSD WT.	3822.4		3823.3				
WT. IN H2O.	2162.1		2164.5				
VOLUME	1660.3		1658.8				
VOL. OF ABS. H2O	61.7		63.7				
% SATURATION	52.8		55.3				
% SWELL	0.05		0.10	0.08			
LOAD IN POUNDS	1994		1970	1982			
DRY STRENGTH					60.8		64.1 62.5
WET STRENGTH	57.5		56.8	57.1			
TSR	92.1		90.9	91.5			
% VIS. STRIPPING	<10	----->			<10	----->	
% BROKEN AGG.	<10	----->			<10	----->	

Tested By: CW
Date: 5/8/15

Reviewed By: AH
Date: 5/12/15

MODIFIED LOTTMAN

SPEC 2360 MIX TYPE SPWEA340C 7% DATE 5/28/2015

TREATED SPECIMENS

UNTREATED SPECIMENS

SAMPLE I.D.	1		4		2		3	
DIAMETER	150		150		150		150	
THICKNESS	95.00		95		95.00		95.00	
DRY WT. IN AIR	3754.7		3753.5		3756.8		3756.9	
SSD WT.	3763.3		3758.9		3764.5		3764.4	
WT. IN H2O	2113.0		2108.7		2114.3		2110.8	
VOLUME	1650.3		1650.2		1650.2		1653.6	
BULK Sp. Gr.	2.275		2.275	2.275	2.277		2.272	2.274
MAX Sp. Gr.	2.451		2.451	2.451	2.451		2.451	2.451
% AIR VOIDS	7.2		7.2	7.2	7.1		7.3	7.2
VOLUME AIR VOIDS	118.39		118.78	118.59				
LOAD, POUNDS					2040		2040	2040

SATURATED FOR MIN. @ mm.Hg

SSD WT.	3828.5		3829.0	
WT. IN H2O	2174.8		2178.2	
VOLUME	1653.7		1650.8	
VOL. OF ABS. H2O	73.8		75.5	
% SATURATION	62.3		63.6	62.9
% SWELL	0.21		0.04	0.1

BLOWS na

CONDITIONED 24 HOURS IN 140 DEGREE F. WATER

DIAMETER	149.65		150.2			
THICKNESS	94.950		95.020			
SSD WT.	3820.8		3824.1			
WT. IN H2O.	2162.3		2165.6			
VOLUME	1658.5		1658.5			
VOL. OF ABS. H2O	66.1		70.6			
% SATURATION	55.8		59.4			
% SWELL	0.50		0.50	0.50		
LOAD IN POUNDS	1645		1645	1645		
DRY STRENGTH					58.8	58.8
WET STRENGTH	47.5		47.3	47.4		
TSR	80.9		80.5	80.7		
% VIS. STRIPPING	<10				<10	
% BROKEN AGG.	<10				<10	

Tested By: CW
Date: 5/8/15

Reviewed By: AH
Date: 5/12/15

MODIFIED LOTTMAN

SPEC 2360 MIX TYPE SPWEA340B 7% DATE 5/7/2015

TREATED SPECIMENS

UNTREATED SPECIMENS

SAMPLE I.D.	2		3		1		4	
DIAMETER	150		150		150		150	
THICKNESS	95.00		95		95.00		95.00	
DRY WT. IN AIR	3786.8		3780.7		3746.0		3782.0	
SSD WT.	3794.3		3786.9		3759.3		3790.4	
WT. IN H2O	2141.2		2135.2		2106.1		2144.4	
VOLUME	1653.1		1651.7		1653.2		1646.0	
BULK Sp. Gr.	2.291		2.289	2.290	2.266		2.298	2.282
MAX Sp. Gr.	2.451		2.451	2.451	2.451		2.451	2.451
% AIR VOIDS	6.5		6.6	6.6	7.6		6.3	6.9
VOLUME AIR VOIDS	108.10		109.19	108.64				
LOAD, POUNDS					2295		2133	2214

SATURATED FOR MIN. @ mm.Hg

SSD WT.	3858.1		3851.9	
WT. IN H2O	2204.1		2193.5	
VOLUME	1654.0		1658.4	
VOL. OF ABS. H2O	71.3		71.2	
% SATURATION	66.0		65.2	65.6
% SWELL	0.05		0.41	0.2

BLOWS na

CONDITIONED 24 HOURS IN 140 DEGREE F. WATER

DIAMETER	149.95		150.09				
THICKNESS	94.920		94.930				
SSD WT.	3788.1		3779.7				
WT. IN H2O.	2192.6		2184.3				
VOLUME	1595.5		1595.4				
VOL. OF ABS. H2O	1.3		-1.0				
% SATURATION	1.2		-0.9				
% SWELL	-3.48		-3.41	-3.45			
LOAD IN POUNDS	1994		1970	1982			
DRY STRENGTH					66.1		61.5 63.8
WET STRENGTH	57.5		56.8	57.2			
TSR	90.2		89.0	89.6			
% VIS. STRIPPING	<10	----->			<10	----->	
% BROKEN AGG.	<10	----->			<10	----->	

Tested By: CW
Date: 5/8/15

Reviewed By: AH
Date: 5/12/15

MODIFIED LOTTMAN

SPEC 2360 MIX TYPE SPWEA340C 11% DATE 5/28/2015

TREATED SPECIMENS

UNTREATED SPECIMENS

	1		2		3		4	
SAMPLE I.D.	150		150		150		150	
DIAMETER	150		150		150		150	
THICKNESS	95.00		95		95.00		95.00	
DRY WT. IN AIR	3564.4		3561.1		3564.5		3561.6	
SSD WT.	3586.0		3576.0		3578.5		3576.2	
WT. IN H2O	1935.9		1941.2		1934.8		1919.5	
VOLUME	1650.1		1634.8		1643.7		1656.7	
BULK Sp. Gr.	2.160		2.178	2.169	2.169		2.150	2.159
MAX Sp. Gr.	2.438		2.438	2.438	2.438		2.438	2.438
% AIR VOIDS	11.4		10.7	11.0	11.1		11.8	11.4
VOLUME AIR VOIDS	188.08		174.14	181.11				
LOAD, POUNDS					1367		1413	1390

SATURATED FOR MIN. @ mm.Hg

SSD WT.	3688.0		3675.0	
WT. IN H2O	2013.0		2038.6	
VOLUME	1675.0		1636.4	
VOL. OF ABS. H2O	123.6		113.9	
% SATURATION	65.7		65.4	65.6
% SWELL	1.51		0.10	0.8

BLOWS na

CONDITIONED 24 HOURS IN 140 DEGREE F. WATER

DIAMETER	149.74		149.58			
THICKNESS	94.280		94.720			
SSD WT.	3647.6		3644.9			
WT. IN H2O.	2005.7		2016.8			
VOLUME	1641.9		1628.1			
VOL. OF ABS. H2O	83.2		83.8			
% SATURATION	44.2		48.1			
% SWELL	-0.50		-0.41	-0.45		
LOAD IN POUNDS	1062		1086	1074		
DRY STRENGTH					39.4	40.7
WET STRENGTH	30.9		31.5	31.2		40.1
TSR	77.1		78.6	77.9		
% VIS. STRIPPING	<10	----->			<10	----->
% BROKEN AGG.	<10	----->			<10	----->

Tested By: DK
Date: 6/2/15

Reviewed By: AH
Date: 6/2/15

MODIFIED LOTTMAN

SPEC 2360 MIX TYPE SPWEA340C 7% DATE 5/28/2015

TREATED SPECIMENS

UNTREATED SPECIMENS

SAMPLE I.D.	1		4		2		3	
DIAMETER	150		150		150		150	
THICKNESS	95.00		95		95.00		95.00	
DRY WT. IN AIR	3754.7		3753.5		3756.8		3756.9	
SSD WT.	3763.3		3758.9		3764.5		3764.4	
WT. IN H2O	2113.0		2108.7		2114.3		2110.8	
VOLUME	1650.3		1650.2		1650.2		1653.6	
BULK Sp. Gr.	2.275		2.275	2.275	2.277		2.272	2.274
MAX Sp. Gr.	2.451		2.451	2.451	2.451		2.451	2.451
% AIR VOIDS	7.2		7.2	7.2	7.1		7.3	7.2
VOLUME AIR VOIDS	118.39		118.78	118.59				
LOAD, POUNDS					2040		2040	2040

SATURATED FOR MIN. @ mm.Hg

SSD WT.	3828.5		3829.0	
WT. IN H2O	2174.8		2178.2	
VOLUME	1653.7		1650.8	
VOL. OF ABS. H2O	73.8		75.5	
% SATURATION	62.3		63.6	62.9
% SWELL	0.21		0.04	0.1

BLOWS na

CONDITIONED 24 HOURS IN 140 DEGREE F. WATER

DIAMETER	149.65		150.2			
THICKNESS	94.950		95.020			
SSD WT.	3820.8		3824.1			
WT. IN H2O.	2162.3		2165.6			
VOLUME	1658.5		1658.5			
VOL. OF ABS. H2O	66.1		70.6			
% SATURATION	55.8		59.4			
% SWELL	0.50		0.50	0.50		
LOAD IN POUNDS	1645		1645	1645		
DRY STRENGTH					58.8	58.8
WET STRENGTH	47.5		47.3	47.4		
TSR	80.9		80.5	80.7		
% VIS. STRIPPING	<10	----->			<10	----->
% BROKEN AGG.	<10	----->			<10	----->

Tested By: CW
Date: 5/8/15

Reviewed By: AH
Date: 5/12/15

MODIFIED LOTTMAN

SPEC 2360 MIX TYPE SPWEA340B 11% DATE 5/7/2015

TREATED SPECIMENS

UNTREATED SPECIMENS

SAMPLE I.D.	1		3		2		4	
DIAMETER	150		150		150		150	
THICKNESS	95.00		95		95.00		95.00	
DRY WT. IN AIR	3587.7		3591.1		3588.7		3592.0	
SSD WT.	3597.0		3602.0		3600.1		3604.3	
WT. IN H2O	1950.9		1958.0		1961.0		1960.2	
VOLUME	1646.1		1644.0		1639.1		1644.1	
BULK Sp. Gr.	2.180		2.184	2.182	2.189		2.185	2.187
MAX Sp. Gr.	2.451		2.451	2.451	2.451		2.451	2.451
% AIR VOIDS	11.1		10.9	11.0	10.7		10.9	10.8
VOLUME AIR VOIDS	182.33		178.84	180.59				
LOAD, POUNDS					2249		2296	2273

SATURATED FOR MIN. @ mm.Hg

SSD WT.	3706.4		3707.5	
WT. IN H2O	2052.2		2051.5	
VOLUME	1654.2		1656.0	
VOL. OF ABS. H2O	118.7		116.4	
% SATURATION	65.1		65.1	65.1
% SWELL	0.49		0.73	0.6

BLOWS na

CONDITIONED 24 HOURS IN 140 DEGREE F. WATER

DIAMETER	150.1		149.95				
THICKNESS	94.780		94.500				
SSD WT.	3672.2		3676.8				
WT. IN H2O.	2029.5		2029.2				
VOLUME	1642.7		1647.6				
VOL. OF ABS. H2O	84.5		85.7				
% SATURATION	46.3		47.9				
% SWELL	-0.21		0.22	0.01			
LOAD IN POUNDS	1529		1529	1529			
DRY STRENGTH					64.8		66.2 65.5
WET STRENGTH	44.1		44.3	44.2			
TSR	67.4		67.7	67.5			
% VIS. STRIPPING	<10	----->			<10	----->	
% BROKEN AGG.	<10	----->			<10	----->	

Tested By: CW
Date: 5/8/15

Reviewed By: AH
Date: 5/12/15

MODIFIED LOTTMAN

SPEC 2360 MIX TYPE SPWEA340C 11% DATE 5/28/2015

TREATED SPECIMENS

UNTREATED SPECIMENS

SAMPLE I.D.	1	2	3	4
DIAMETER	150	150	150	150
THICKNESS	95.00	95	95.00	95.00
DRY WT. IN AIR	3564.4	3561.1	3564.5	3561.6
SSD WT.	3586.0	3576.0	3578.5	3576.2
WT. IN H2O	1935.9	1941.2	1934.8	1919.5
VOLUME	1650.1	1634.8	1643.7	1656.7
BULK Sp. Gr.	2.160	2.178	2.169	2.159
MAX Sp. Gr.	2.438	2.438	2.438	2.438
% AIR VOIDS	11.4	10.7	11.0	11.1
VOLUME AIR VOIDS	188.08	174.14	181.11	
LOAD, POUNDS			1367	1413

SATURATED FOR MIN. @ mm.Hg

SSD WT.	3688.0	3675.0
WT. IN H2O	2013.0	2038.6
VOLUME	1675.0	1636.4
VOL. OF ABS. H2O	123.6	113.9
% SATURATION	65.7	65.4
% SWELL	1.51	0.10

BLOWS na

CONDITIONED 24 HOURS IN 140 DEGREE F. WATER

DIAMETER	149.74	149.58
THICKNESS	94.280	94.720
SSD WT.	3647.6	3644.9
WT. IN H2O.	2005.7	2016.8
VOLUME	1641.9	1628.1
VOL. OF ABS. H2O	83.2	83.8
% SATURATION	44.2	48.1
% SWELL	-0.50	-0.41
LOAD IN POUNDS	1062	1086
DRY STRENGTH		39.4
WET STRENGTH	30.9	31.5
TSR	77.1	78.6
% VIS. STRIPPING	<10	<10
% BROKEN AGG.	<10	<10

Tested By: DK
Date: 6/2/15

Reviewed By: AH
Date: 6/2/15

MODIFIED LOTTMAN

SPEC 2360

MIX TYPE SPWEA340B 11% DATE

5/7/2015

TREATED SPECIMENS

UNTREATED SPECIMENS

SAMPLE I.D.	1		2		3		4
DIAMETER	150		150		150		150
THICKNESS	95.00		95		95.00		95.00
DRY WT. IN AIR	3569.3		3576.9		3566.3		3570.7
SSD WT.	3579.8		3586.9		3578.1		3582.2
WT. IN H2O	1930.5		1939.7		1924.6		1934.4
VOLUME	1649.3		1647.2		1653.5		1647.8
BULK Sp. Gr.	2.164		2.172	2.168	2.157		2.167
MAX Sp. Gr.	2.438		2.438	2.438	2.438		2.438
% AIR VOIDS	11.2		10.9	11.1	11.5		11.1
VOLUME AIR VOIDS	185.27		180.05	182.66			
LOAD, POUNDS					1947		1924
							1936

SATURATED FOR MIN. @ mm.Hg

SSD WT.	3691.0		3695.0	
WT. IN H2O	2037.0		2041.1	
VOLUME	1654.0		1653.9	
VOL. OF ABS. H2O	121.7		118.1	
% SATURATION	65.7		65.6	65.6
% SWELL	0.28		0.41	0.3

BLOWS na

CONDITIONED 24 HOURS IN 140 DEGREE F. WATER

DIAMETER	149.85		149.91			
THICKNESS	94.900		94.800			
SSD WT.	3664.9		3658.5			
WT. IN H2O.	2010.6		2018.2			
VOLUME	1654.3		1640.3			
VOL. OF ABS. H2O	95.6		81.6			
% SATURATION	51.6		45.3			
% SWELL	0.30		-0.42	-0.06		
LOAD IN POUNDS	1250		1297	1274		
DRY STRENGTH					56.1	55.5
WET STRENGTH	36.1		37.5	36.8		55.8
TSR	64.7		67.2	66.0		
% VIS. STRIPPING	<10	----->			<10	----->
% BROKEN AGG.	<10	----->			<10	----->

Tested By: CW
Date: 5/8/15

Reviewed By: AH
Date: 5/12/15

MODIFIED LOTTMAN

SPEC 2360

MIX TYPE SPWEA340C PM 11 DATE

4/27/2015

TREATED SPECIMENS

UNTREATED SPECIMENS

	1		2		3		4	
SAMPLE I.D.	150		150		150		150	
DIAMETER	150		150		150		150	
THICKNESS	95.00		95		95.00		95.00	
DRY WT. IN AIR	3596.5		3583.9		3584.4		3584.5	
SSD WT.	3609.0		3592.9		3607.3		3607.3	
WT. IN H2O	1965.5		1945.0		1962.4		1960.2	
VOLUME	1643.5		1647.9		1644.9		1647.1	
BULK Sp. Gr.	2.188		2.175	2.182	2.179		2.176	2.178
MAX Sp. Gr.	2.456		2.456	2.456	2.456		2.456	2.456
% AIR VOIDS	10.9		11.4	11.2	11.3		11.4	11.3
VOLUME AIR VOIDS	179.13		188.66	183.89				
LOAD, POUNDS					2272.3		2434	2353

SATURATED FOR MIN. @ mm.Hg

SSD WT.	3719.6		3707.1	
WT. IN H2O	2078.6		2048.5	
VOLUME	1641.0		1658.6	
VOL. OF ABS. H2O	123.1		123.2	
% SATURATION	68.7		65.3	67.0
% SWELL	-0.15		0.65	0.2

BLOWS na

CONDITIONED 24 HOURS IN 140 DEGREE F. WATER

DIAMETER	150.01		150.04			
THICKNESS	94.380		94.780			
SSD WT.	3709.0		3696.6			
WT. IN H2O.	2058.1		2041.1			
VOLUME	1650.9		1655.5			
VOL. OF ABS. H2O	112.5		112.7			
% SATURATION	62.8		59.7			
% SWELL	0.45		0.46	0.46		
LOAD IN POUNDS	1529		1413	1471		
DRY STRENGTH					65.5	70.2
WET STRENGTH	44.4		40.8	42.6		67.8
TSR	65.4		60.2	62.8		
% VIS. STRIPPING	<10	----->			<10	----->
% BROKEN AGG.	<10	----->			<10	----->

Tested By: CW
Date: 4/27/15

Reviewed By: AH
Date: 4/27/15

MODIFIED LOTTMAN

SPEC 2360

MIX TYPE SPWEA340C PM 7% DATE

4/27/2015

TREATED SPECIMENS

UNTREATED SPECIMENS

	1		2		3		4	
SAMPLE I.D.	150		150		150		150	
DIAMETER	150		150		150		150	
THICKNESS	95.00		95		95.00		95.00	
DRY WT. IN AIR	3755.8		3755.1		3756.8		3755.9	
SSD WT.	3763.2		3764.8		3766.7		3764.2	
WT. IN H2O	2114.7		2113.6		2116.6		2116.7	
VOLUME	1648.5		1651.2		1650.1		1647.5	
BULK Sp. Gr.	2.278		2.274	2.276	2.277		2.280	2.278
MAX Sp. Gr.	2.456		2.456	2.456	2.456		2.456	2.456
% AIR VOIDS	7.2		7.4	7.3	7.3		7.2	7.2
VOLUME AIR VOIDS	119.27		122.25	120.76				
LOAD, POUNDS					3239		3216	3228

SATURATED FOR MIN. @ mm.Hg

SSD WT.	3834.7		3836.7	
WT. IN H2O	2185.3		2184.5	
VOLUME	1649.4		1652.2	
VOL. OF ABS. H2O	78.9		81.6	
% SATURATION	66.2		66.7	66.5
% SWELL	0.05		0.06	0.1

BLOWS na

CONDITIONED 24 HOURS IN 140 DEGREE F. WATER

DIAMETER	150		150			
THICKNESS	94.680		94.680			
SSD WT.	3826.6		3824.2			
WT. IN H2O.	2164.3		2161.7			
VOLUME	1662.3		1662.5			
VOL. OF ABS. H2O	70.8		69.1			
% SATURATION	59.4		56.5			
% SWELL	0.84		0.68	0.76		
LOAD IN POUNDS	2411		2434	2423		
DRY STRENGTH					93.4	92.7 93.0
WET STRENGTH	69.7		70.4	70.1		
TSR	75.0		75.7	75.3		
% VIS. STRIPPING	<10	----->			<10	----->
% BROKEN AGG.	<10	----->			<10	----->

Tested By: CW
Date: 4/27/15

Reviewed By: AH
Date: 4/27/15

MODIFIED LOTTMAN

SPEC 2360

MIX TYPE SPWEA340B 7% DATE

4/27/2015

TREATED SPECIMENS

UNTREATED SPECIMENS

	1		2		3		4	
SAMPLE I.D.	150		150		150		150	
DIAMETER	150		150		150		150	
THICKNESS	95.00		95		95.00		95.00	
DRY WT. IN AIR	3754.6		3751.8		3754.5		3755.9	
SSD WT.	3763.0		3758.6		3762.7		3764.2	
WT. IN H2O	2113.3		2115.0		2112.5		2116.7	
VOLUME	1649.7		1643.6		1650.2		1647.5	
BULK Sp. Gr.	2.276		2.283	2.279	2.275		2.280	2.277
MAX Sp. Gr.	2.456		2.456	2.456	2.456		2.456	2.456
% AIR VOIDS	7.3		7.1	7.2	7.4		7.2	7.3
VOLUME AIR VOIDS	120.95		115.99	118.47				
LOAD, POUNDS					2710		2733	2722

SATURATED FOR MIN. @ mm.Hg

SSD WT.	3833.7		3827.9	
WT. IN H2O	2177.6		2183.1	
VOLUME	1656.1		1644.8	
VOL. OF ABS. H2O	79.1		76.1	
% SATURATION	65.4		65.6	65.5
% SWELL	0.39		0.07	0.2

BLOWS na

CONDITIONED 24 HOURS IN 140 DEGREE F. WATER

DIAMETER	149.99		150.01			
THICKNESS	95.020		94.150			
SSD WT.	3829.1		3825.9			
WT. IN H2O.	2169.5		2175.7			
VOLUME	1659.6		1650.2			
VOL. OF ABS. H2O	74.5		74.1			
% SATURATION	61.6		63.9			
% SWELL	0.60		0.40	0.50		
LOAD IN POUNDS	2179		2272	2226		
DRY STRENGTH					78.1	78.8 78.4
WET STRENGTH	62.8		66.1	64.4		
TSR	80.1		84.2	82.1		
% VIS. STRIPPING	<10	----->			<10	----->
% BROKEN AGG.	<10	----->			<10	----->

Tested By: CW
Date: 4/27/15

Reviewed By: AH
Date: 4/27/15

MODIFIED LOTTMAN

SPEC 2360

MIX TYPE SPWEA340B 11% DATE

4/27/2015

TREATED SPECIMENS

UNTREATED SPECIMENS

	1		2		3		4	
SAMPLE I.D.	150		150		150		150	
DIAMETER	150		150		150		150	
THICKNESS	95.00		95		95.00		95.00	
DRY WT. IN AIR	3586.8		3589.9		3591.9		3591.8	
SSD WT.	3609.0		3593.5		3607.3		3606.2	
WT. IN H2O	1962.5		1947.1		1964.0		1960.2	
VOLUME	1646.5		1646.4		1643.3		1646.0	
BULK Sp. Gr.	2.178		2.180	2.179	2.186		2.182	2.184
MAX Sp. Gr.	2.456		2.456	2.456	2.456		2.456	2.456
% AIR VOIDS	11.3		11.2	11.3	11.0		11.2	11.1
VOLUME AIR VOIDS	186.08		184.71	185.40				
LOAD, POUNDS					1900.7		1923.9	1912

SATURATED FOR MIN. @ mm.Hg

SSD WT.	3712.6		3715.1	
WT. IN H2O	2068.4		2071.0	
VOLUME	1644.2		1644.1	
VOL. OF ABS. H2O	125.8		125.2	
% SATURATION	67.6		67.8	67.7
% SWELL	-0.14		-0.14	-0.1

BLOWS na

CONDITIONED 24 HOURS IN 140 DEGREE F. WATER

DIAMETER	149.83		150.03			
THICKNESS	94.370		94.600			
SSD WT.	3707.0		3700.1			
WT. IN H2O.	2060.7		2055.5			
VOLUME	1646.3		1644.6			
VOL. OF ABS. H2O	120.2		110.2			
% SATURATION	64.6		59.7			
% SWELL	-0.01		-0.11	-0.06		
LOAD IN POUNDS	1343		1390	1367		
DRY STRENGTH					54.8	55.5 55.1
WET STRENGTH	39.0		40.2	39.6		
TSR	70.8		73.0	71.9		
% VIS. STRIPPING	<10	----->			<10	----->
% BROKEN AGG.	<10	----->			<10	----->

Tested By: CW
Date: 4/27/15

Reviewed By: AH
Date: 4/27/15

MODIFIED LOTTMAN

SPEC 2360 MIX TYPE SPWEA340B 7% DATE 4/27/2015

TREATED SPECIMENS

UNTREATED SPECIMENS

	1		2		3		4	
SAMPLE I.D.	150		150		150		150	
DIAMETER	150		150		150		150	
THICKNESS	95.00		95		95.00		95.00	
DRY WT. IN AIR	3754.6		3751.8		3754.5		3755.9	
SSD WT.	3763.0		3758.6		3762.7		3764.2	
WT. IN H2O	2113.3		2115.0		2112.5		2116.7	
VOLUME	1649.7		1643.6		1650.2		1647.5	
BULK Sp. Gr.	2.276		2.283	2.279	2.275		2.280	2.277
MAX Sp. Gr.	2.456		2.456	2.456	2.456		2.456	2.456
% AIR VOIDS	7.3		7.1	7.2	7.4		7.2	7.3
VOLUME AIR VOIDS	120.95		115.99	118.47				
LOAD, POUNDS					2710		2733	2722

SATURATED FOR MIN. @ mm.Hg

SSD WT.	3833.7		3827.9	
WT. IN H2O	2177.6		2183.1	
VOLUME	1656.1		1644.8	
VOL. OF ABS. H2O	79.1		76.1	
% SATURATION	65.4		65.6	65.5
% SWELL	0.39		0.07	0.2

BLOWS na

CONDITIONED 24 HOURS IN 140 DEGREE F. WATER

DIAMETER	149.99		150.01			
THICKNESS	95.020		94.150			
SSD WT.	3829.1		3825.9			
WT. IN H2O.	2169.5		2175.7			
VOLUME	1659.6		1650.2			
VOL. OF ABS. H2O	74.5		74.1			
% SATURATION	61.6		63.9			
% SWELL	0.60		0.40	0.50		
LOAD IN POUNDS	2179		2272	2226		
DRY STRENGTH					78.1	78.8 78.4
WET STRENGTH	62.8		66.1	64.4		
TSR	80.1		84.2	82.1		
% VIS. STRIPPING	<10	----->			<10	----->
% BROKEN AGG.	<10	----->			<10	----->

Tested By: CW
Date: 4/27/15

Reviewed By: AH
Date: 4/27/15

MODIFIED LOTTMAN

SPEC 2360

MIX TYPE SPWEA330C PM 7% DATE

4/27/2015

TREATED SPECIMENS

UNTREATED SPECIMENS

SAMPLE I.D.	3		4		1		2	
DIAMETER	150		150		150		150	
THICKNESS	95.00		95		95.00		95.00	
DRY WT. IN AIR	3732.7		3730.5		3702.0		3711.2	
SSD WT.	3742.6		3742.0		3714.0		3720.1	
WT. IN H2O	2096.5		2089.7		2067.0		2081.7	
VOLUME	1646.1		1652.3		1647.0		1638.4	
BULK Sp. Gr.	2.268		2.258	2.263	2.248		2.265	2.256
MAX Sp. Gr.	2.439		2.439	2.439	2.439		2.439	2.439
% AIR VOIDS	7.0		7.4	7.2	7.8		7.1	7.5
VOLUME AIR VOIDS	115.68		122.78	119.23				
LOAD, POUNDS					2917		2917	2917

SATURATED FOR MIN. @ mm.Hg

SSD WT.	3811.1		3813.8	
WT. IN H2O	2166.1		2163.6	
VOLUME	1645.0		1650.2	
VOL. OF ABS. H2O	78.4		83.3	
% SATURATION	67.8		67.8	67.8
% SWELL	-0.07		-0.13	-0.1

BLOWS na

CONDITIONED 24 HOURS IN 140 DEGREE F. WATER

DIAMETER	150.35		150.48					
THICKNESS	94.600		94.760					
SSD WT.	3816.5		3819.1					
WT. IN H2O.	2165.4		2164.0					
VOLUME	1651.1		1655.1					
VOL. OF ABS. H2O	83.8		88.6					
% SATURATION	72.4		72.2					
% SWELL	0.30		0.17	0.24				
LOAD IN POUNDS	2318.7		2202.6	2261				
DRY STRENGTH					84.1		84.1	84.1
WET STRENGTH	67.0		63.4	65.2				
TSR	79.6		75.5	77.5				
% VIS. STRIPPING	<10	----->			<10	----->		
% BROKEN AGG.	<10	----->			<10	----->		

Tested By: CW
Date: 4/27/15

Reviewed By: AH
Date: 4/27/15

MODIFIED LOTTMAN

SPEC 2360

MIX TYPE SPWEA330C PM 11 DATE

4/27/2015

TREATED SPECIMENS

UNTREATED SPECIMENS

	1		2		3		4	
SAMPLE I.D.								
DIAMETER	150		150		150		150	
THICKNESS	95.00		95		95.00		95.00	
DRY WT. IN AIR	3592.6		3596.4		3587.0		3586.9	
SSD WT.	3604.6		3608.9		3607.3		3597.3	
WT. IN H2O	1952.2		1957.5		1962.4		1956.2	
VOLUME	1652.4		1651.4		1644.9		1641.1	
BULK Sp. Gr.	2.174		2.178	2.176	2.181		2.186	2.183
MAX Sp. Gr.	2.439		2.439	2.439	2.439		2.439	2.439
% AIR VOIDS	10.9		10.7	10.8	10.6		10.4	10.5
VOLUME AIR VOIDS	179.42		176.86	178.14				
LOAD, POUNDS					2480		2457	2469

SATURATED FOR MIN. @ mm.Hg

SSD WT.	3710.5		3711.4	
WT. IN H2O	2065.1		2075.9	
VOLUME	1645.4		1635.5	
VOL. OF ABS. H2O	117.9		115.0	
% SATURATION	65.7		65.0	65.4
% SWELL	-0.42		-0.96	-0.7

BLOWS na

CONDITIONED 24 HOURS IN 140 DEGREE F. WATER

DIAMETER	150.15		150.08			
THICKNESS	94.840		94.440			
SSD WT.	3727.2		3722.4			
WT. IN H2O.	2069.1		2085.3			
VOLUME	1658.1		1637.1			
VOL. OF ABS. H2O	134.6		126.0			
% SATURATION	75.0		71.2			
% SWELL	0.34		-0.87	-0.26		
LOAD IN POUNDS	1622		1622	1622		
DRY STRENGTH					71.5	70.8 71.1
WET STRENGTH	46.8		47.0	46.9		
TSR	65.8		66.1	65.9		
% VIS. STRIPPING	<10	----->			<10	----->
% BROKEN AGG.	<10	----->			<10	----->

Tested By: CW
Date: 4/27/15

Reviewed By: AH
Date: 4/27/15

MODIFIED LOTTMAN

SPEC 2360 MIX TYPE SPWEA330B 7% DATE 4/27/2015

TREATED SPECIMENS

UNTREATED SPECIMENS

	1		2		3		4	
SAMPLE I.D.	150		150		150		150	
DIAMETER	150		150		150		150	
THICKNESS	95.00		95		95.00		95.00	
DRY WT. IN AIR	3729.4		3731.9		3723.9		3729.4	
SSD WT.	3739.3		3740.6		3736.6		3748.2	
WT. IN H2O	2087.4		2088.3		2082.1		2091.1	
VOLUME	1651.9		1652.3		1654.5		1657.1	
BULK Sp. Gr.	2.258		2.259	2.258	2.251		2.251	2.251
MAX Sp. Gr.	2.439		2.439	2.439	2.439		2.439	2.439
% AIR VOIDS	7.4		7.4	7.4	7.7		7.7	7.7
VOLUME AIR VOIDS	122.83		122.21	122.52				
LOAD, POUNDS					2411		2457	2434

SATURATED FOR MIN. @ mm.Hg

SSD WT.	3809.2		3812.0	
WT. IN H2O	2159.1		2166.3	
VOLUME	1650.1		1645.7	
VOL. OF ABS. H2O	79.8		80.1	
% SATURATION	65.0		65.5	65.3
% SWELL	-0.11		-0.40	-0.3

BLOWS na

CONDITIONED 24 HOURS IN 140 DEGREE F. WATER

DIAMETER	150.47		149.94			
THICKNESS	95.160		94.900			
SSD WT.	3822.2		3826.5			
WT. IN H2O.	2170.0		2175.9			
VOLUME	1652.2		1650.6			
VOL. OF ABS. H2O	92.8		94.6			
% SATURATION	75.6		77.4			
% SWELL	0.02		-0.10	-0.04		
LOAD IN POUNDS	2318.7		2434	2376		
DRY STRENGTH					69.5	70.8 70.2
WET STRENGTH	66.5		70.3	68.4		
TSR	94.8		100.1	97.5		
% VIS. STRIPPING	<10	----->			<10	----->
% BROKEN AGG.	<10	----->			<10	----->

Tested By: CW
Date: 4/27/15

Reviewed By: AH
Date: 4/27/15

MODIFIED LOTTMAN

SPEC 2360 MIX TYPE SPWEA330B 11% DATE 4/27/2015

TREATED SPECIMENS

UNTREATED SPECIMENS

	1		2		3		4	
SAMPLE I.D.	150		150		150		150	
DIAMETER	150		150		150		150	
THICKNESS	95.00		95		95.00		95.00	
DRY WT. IN AIR	3588.5		3588.3		3587.0		3586.9	
SSD WT.	3599.6		3608.9		3607.3		3597.3	
WT. IN H2O	1952.2		1948.5		1962.4		1956.2	
VOLUME	1647.4		1660.4		1644.9		1641.1	
BULK Sp. Gr.	2.178		2.161	2.170	2.181		2.186	2.183
MAX Sp. Gr.	2.439		2.439	2.439	2.439		2.439	2.439
% AIR VOIDS	10.7		11.4	11.0	10.6		10.4	10.5
VOLUME AIR VOIDS	176.10		189.18	182.64				
LOAD, POUNDS					1761.4		1993.6	1878

SATURATED FOR MIN. @ mm.Hg

SSD WT.	3705.4		3717.3	
WT. IN H2O	2068.4		2061.9	
VOLUME	1637.0		1655.4	
VOL. OF ABS. H2O	116.9		129.0	
% SATURATION	66.4		68.2	67.3
% SWELL	-0.63		-0.30	-0.5

BLOWS na

CONDITIONED 24 HOURS IN 140 DEGREE F. WATER

DIAMETER	150.55		150.85			
THICKNESS	94.350		94.180			
SSD WT.	3724.7		3740.1			
WT. IN H2O.	2083.1		2080.6			
VOLUME	1641.6		1659.5			
VOL. OF ABS. H2O	136.2		151.8			
% SATURATION	77.3		80.2			
% SWELL	-0.35		-0.05	-0.20		
LOAD IN POUNDS	1622		1459.5	1541		
DRY STRENGTH					50.8	57.5
WET STRENGTH	46.9		42.2	44.5		54.1
TSR	86.7		78.0	82.3		
% VIS. STRIPPING	<10	----->			<10	----->
% BROKEN AGG.	<10	----->			<10	----->

Tested By: CW
Date: 4/27/15

Reviewed By: AH
Date: 4/27/15

APPENDIX H

FIELD SITE SECTION PLANS AND INFORMATION

CONSTRUCTION PLANS FOR: IMPROVEMENT PROJECT 94-06 SOUTH CENTRAL AREA IMPROVEMENTS

CONSTRUCTION OF: AGGREGATE BASE, BITUMINOUS SURFACING, TRUNK SANITARY SEWER,
TRUNK WATERMAIN, STORM SEWER AND CURB & GUTTER.



LOCATION MAP

CONTRACTOR: **Bentley Construction**
Elk River, MN
SUBCONTRACTORS: **STURMANS & ASSOCIATES - PAVEMENT AND CURB & GUTTER - MINNEAPOLIS, MN**
ENGINEERING: **CITY OF BLAINE**
SURVEYING: **E. G. RUD & SONS INC. - CIRCLER DUFFER MN**
CONSTRUCTION: **APR, 1994 - NOV, 1994**
AS-BUILT: **E. G. RUD & SONS INC. - APR, 1995 - CITY OF BLAINE**



ENGINEERING DEPARTMENT
9150 Central Ave., N.E. Blaine, Minnesota 55434
Phone (612) 784-6700

I hereby certify that this plan, specification or report was prepared by me or under my direct supervision and that I am a duly Registered Professional Engineer under the laws of the State of Minnesota.

John W. Kelly
Date: 7 July 99 Minnesota Registration No. 20672

INDEX TO PLANS

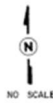
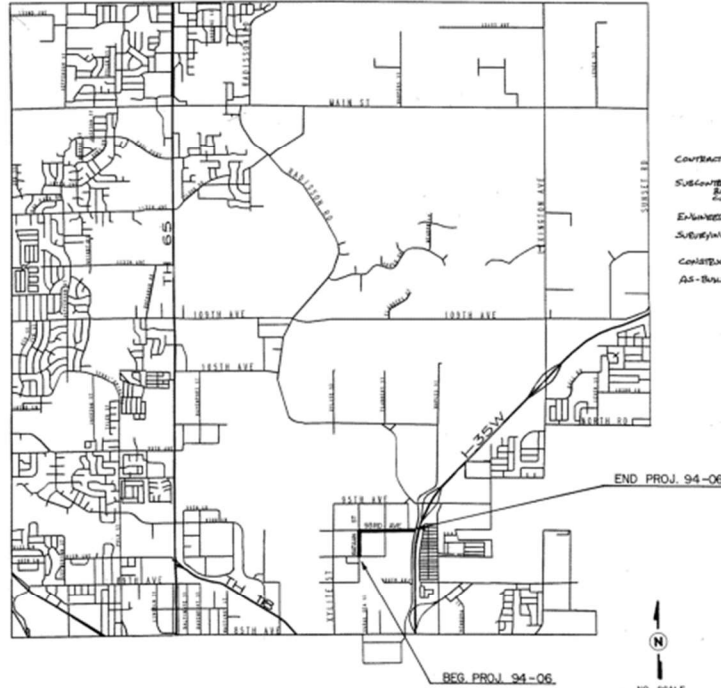
SHEET	DRAWING NO.
TITLE SHEET	1
TYPICAL SECTION, SIGNING & NOTES	2
DETAILS	3-7
SANITARY SEWER & WATERMAIN	8-10
STREET & STORM SEWER	11-13
X-SECTIONS	14-21

EXISTING

LEGEND	DESCRIPTION
	STORM SEWER & MANHOLE
	SANITARY SEWER & MANHOLE
	WATERMAIN, HYDRANT VALVE & MANHOLE
	CULVERT
	CATCH BASIN
	BULKHEAD
	UNDERGROUND TELEPHONE CABLE OR CONDUIT
	TELEPHONE MANHOLE
	UNDERGROUND ELECTRIC CABLE OR CONDUIT
	ELECTRIC MANHOLE
	GAS MAIN & VALVE
	STREET LIGHT
	MAILBOX
	SIGN (HWY, PARK, STOP, ETC.)
	STREET SIGN
	POWER POLE W/GUY WIRE
	TREE (DECIDUOUS)
	TREE (CONIFEROUS)
	BUSH-SHRUB
	HEDGE
	WOODED AREA
	FENCE
	GUARD RAIL
	DITCH
	TRAFFIC SIGNAL
	MANHOLE
	CONCRETE CURB & GUTTER
	BITUMINOUS CURB
	CONCRETE PAVEMENT
	BUILDING
	SECTION LINE
	QUARTER LINE
	SIXTEENTH LINE
	RIGHT OF WAY LINE

PROPOSED

	SLOPE EASEMENT
	CONSTRUCTION CENTERLINE
	RIGHT OF WAY
	STORM SEWER & MANHOLE
	SANITARY SEWER & MANHOLE
	WATERMAIN, HYDRANT VALVE & MANHOLE
	CULVERT
	CATCH BASIN
	BULKHEAD
	CONCRETE CURB & GUTTER



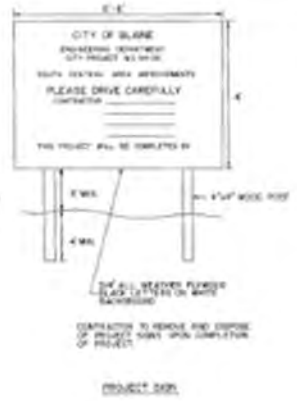
PLAN SET NO.

- SIGNING**
- ◆ STOP SIGN (S1)
 - ▼ FIELD SIGN (S2)
 - + STREET SIGN (S3)
 - ◆ PROJECT SIGN (S4)

NOTE: LOCATION OF SIGN WILL BE DETERMINED IN THE FIELD BY ENGINEER



SIGNING



PROJECT SIGN

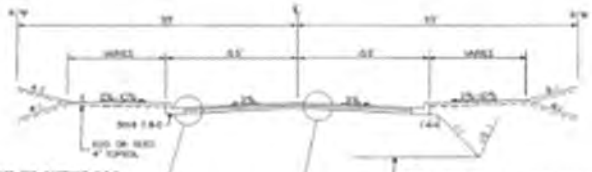
GENERAL CONSTRUCTION NOTES

STREET & SIDEWALK

ALL WORK SHALL BE CONFINED TO WITHIN THE R/W
 CONTRACTOR SHALL CLEAR & BRUSH OUT TO THE R/W UNLESS OTHERWISE DIRECTED BY THE ENGINEER
 SIGNING PREVIOUSLY INSTALLED, TRAFFIC CONTROL DEVICES, AND FLAG PERSONS SHALL BE IN ACCORDANCE WITH THE JOB MANUAL, MINNAPOLIS, IN UNIFORM TRAFFIC CONTROL DEVICES INCLUDING SIGNAGE & TRAFFIC SIGNALS SHALL BE USED
 ALL ROAD APPROACHES SHALL BE CONFINED TO A WIDTH OF 2' FEET TO EACH SIDE OF CURB AND FINISH TO R/W UNLESS OTHERWISE NOTED
 AT ROAD APPROACHES, CONTRACTOR SHALL END SIDEWALK AT END OF PAVED. CLASS 5 SHALL BE PLACED WHEN WATERSHED INTO EXISTING DRIVEWAY
 CONTRACTOR SHALL INSTALL A 2" TAPER AT EACH OF CURB AND BUTTER
 CONTRACTOR SHALL SEE ALL DISTURBED AREAS ADJACENT TO EXISTING DRIVEWAYS AND DRIVEWAY REMAINING AREAS LOCATIONS WILL BE CLEARING IN FIELD. BID PRICE SHALL INCLUDE PLACING 4" TOPSOIL
 CONTRACTOR SHALL REMOVE ALL EXISTING DRIVE AND STREET MARKINGS. SIGNAGE SHALL BE DELIVERED TO BLAINE'S PUBLIC WORKS
 DRIVEWAYS WILL BE PAVED TO R/W LINE WITH 2" TYPE 4A WEAR AND 4" CLASS 5 SUBGRADE UNLESS SHOWN OTHERWISE
 CONTRACTOR SHALL VERIFY DEPTH OF CURB AT ALL DRIVEWAYS
 CONTRACTOR LISTS ARE SHOWN AS EXISTING R/W UNLESS SHOWN OTHERWISE
 CONCRETE DRIVEWAYS SHALL BE PLACED 6" IN DEPTH
 CLASS 5 FOR DRIVEWAYS & SIDEWALKS

SANITARY, WATERWAY & STORM SEWER

NO EXTENDING OR ADJUSTMENTS NEEDS TO PLACE FORWARD AND SETS VALUE AT FINISHED GRADE IS NECESSARY
 ALL SANITARY AND WATERWAY SERVICES SHALL END 5 FEET FROM R/W AND BE FULLY VENTED AS TO PREVIOUS SHEETS
 FLUSH FOR STORM SEWER ARE NECESSARY



NOTE: PLACE 6\"/>

NOTE: CURBS TO BE 6\"/>

TYPICAL SECTION

EARTHWORK SUMMARY

- WEEK EXCAVATION - 074 CY (EST)
- COMMON EXCAVATION - 4043 CY (EST)
- GRANULAR EMPAVEMENT - 2746 CY (EST)
- NOTE: USE SHORTRATE FACTOR OF 0.974 FOR NORMAL GRADES EX. TO 2'

ENGINEERING DEPARTMENT
 9150 Central Ave. NE, Blaine, Minnesota 55434
 Phone (612) 784-6700

DATE: _____
 REVISION: _____
 PROJECT NO: 04-06-06
 DESIGN BY: S. JENSEN
 CHECKED BY: S. JENSEN
 APPROVED BY: _____
 DATE: _____

SOUTH CENTRAL AREA IMPROVEMENTS
 TYPICAL SECTION, SIGNING & NOTES
 SHEET NO. 2 OF 2 SHEETS



GENERAL CONSTRUCTION NOTES

STREET & SIGNING

ALL WORK SHALL BE CONFINED TO WITHIN THE R/W
 CONTRACTOR SHALL CLEAR & GRUB OUT TO THE R/W UNLESS OTHERWISE DIRECTED BY THE ENGINEER

SIGNING, PAINTING, MARKING, TRAFFIC CONTROL DEVICES, AND FLAG PERSON SHALL BE IN ACCORDANCE WITH THE 2009 MICHIGAN MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES INCLUDING APPROVED & LISTED SIGNAGE ONLY

EXISTING SIGNING SHALL REMAIN IN PLACE UNTIL NEW SIGNING IS INSTALLED

THE CONTRACTOR SHALL PROVIDE AND MAINTAIN A TRAFFIC CONTROL PLAN AND HAVE ALL CONTROL DEVICES INSTALLED PRIOR TO THE BEGINNING OF ANY WORK

CONTRACTOR SHALL INSTALL A 2" SIGN AT ENDS OF CURB AND SLOPE

CONTRACTOR SHALL USE ALL DEFURROW AREAS ADJACENT TO EXISTING HOUSES AND SEED REMAINING AREAS LOCATIONS WILL BE DETERMINED IN FIELD

CONTRACTOR SHALL REMOVE ALL EXISTING SIGNS AND STREET MARKINGS. SIGNS SHALL BE DELIVERED TO BLAINE PUBLIC WORKS

DRIVEWAYS WILL BE PAVED TO R/W LINE WITH 2" FINE #54 NEAR AND # CLASS 3 ASPHALT. SLOTTING GRUB OUT SHALL BE INCIDENTAL

CONTRACTOR SHALL SPREAD BACK OF CURB AT ALL DRIVEWAYS

CONTRACTOR LAMPS ARE DEFINED AS EXISTING R/W UNLESS SHOWN OTHERWISE

CLASS 3 FOR DRIVEWAYS + 100 TONS

TEMPORARY MARKINGS SHALL BE INSTALLED PRIOR TO RECONSTRUCTION AND THEY SHALL MEET ALL U.S. POSTAL SERVICE REQUIREMENTS

SANITARY, WASTEWATER & STORM SEWERS

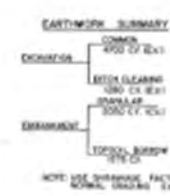
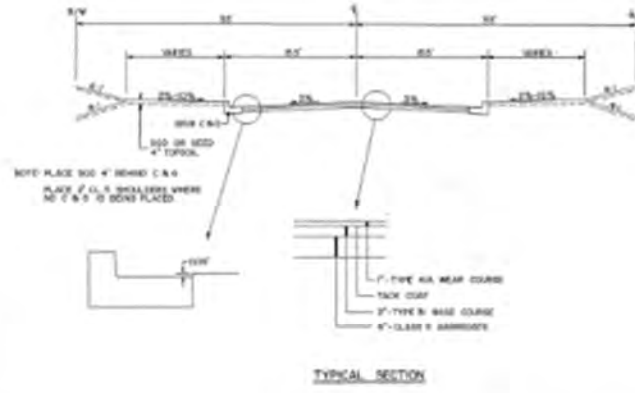
ANY EXTENSIONS OR ADJUSTMENTS NEEDING TO PLACE WASTEWATER AND SANITARY SHALL BE FINISHED BEFORE IS ACCIDENTAL

ALL SANITARY AND WASTEWATER SERVICES SHALL END AT FRONT YARD. SANITARY AND WASTEWATER SHALL BE TO PREVENTIVE TRENCH

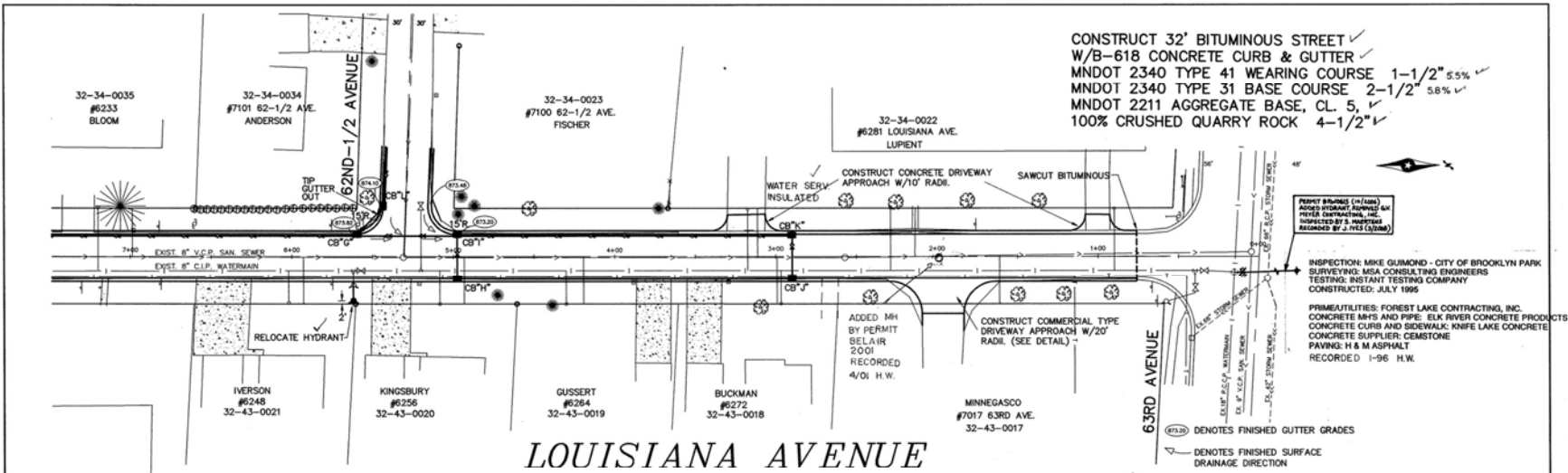
PLACES FOR STORM SEWERS ARE INDICATED

STORM SEWERS LOCATING (DOWN) DO NOT INCLUDE WHICH LOCATING APPROX AND SEPARATE

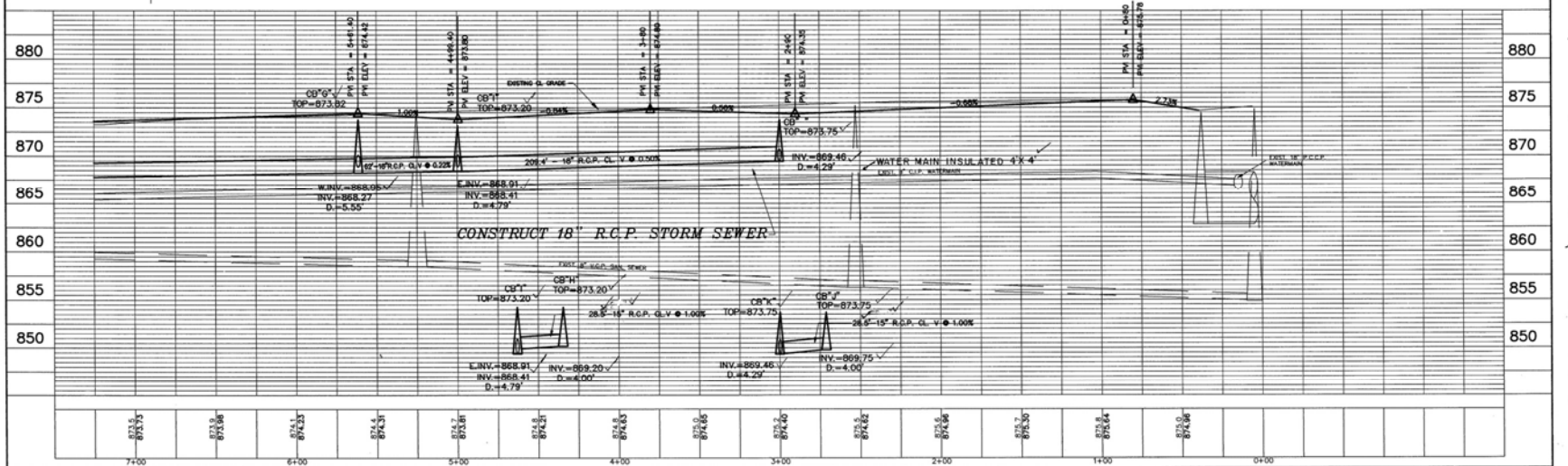
NOTE: EXACT SIGN LOCATIONS SHALL BE DETERMINED IN THE FIELD BY THE CONTRACTOR



<p>ENGINEERING DEPARTMENT 9150 Central Ave., N.E. Blaine, Minnesota 55434 Phone (612) 784-6700</p>	<p>DATE: _____</p> <p>REVISION: _____</p>	<p>PROJECT NO. 94-04</p>	<p>SOUTH CENTRAL AREA IMPROVEMENTS TYPICAL SECTION, SIGNING & NOTES</p>
		<p>DESIGNED BY: _____</p> <p>CHECKED BY: _____</p> <p>DATE: _____</p>	
<p>SHEET NO. 2 OF 21 SHEETS</p>			



LOUISIANA AVENUE



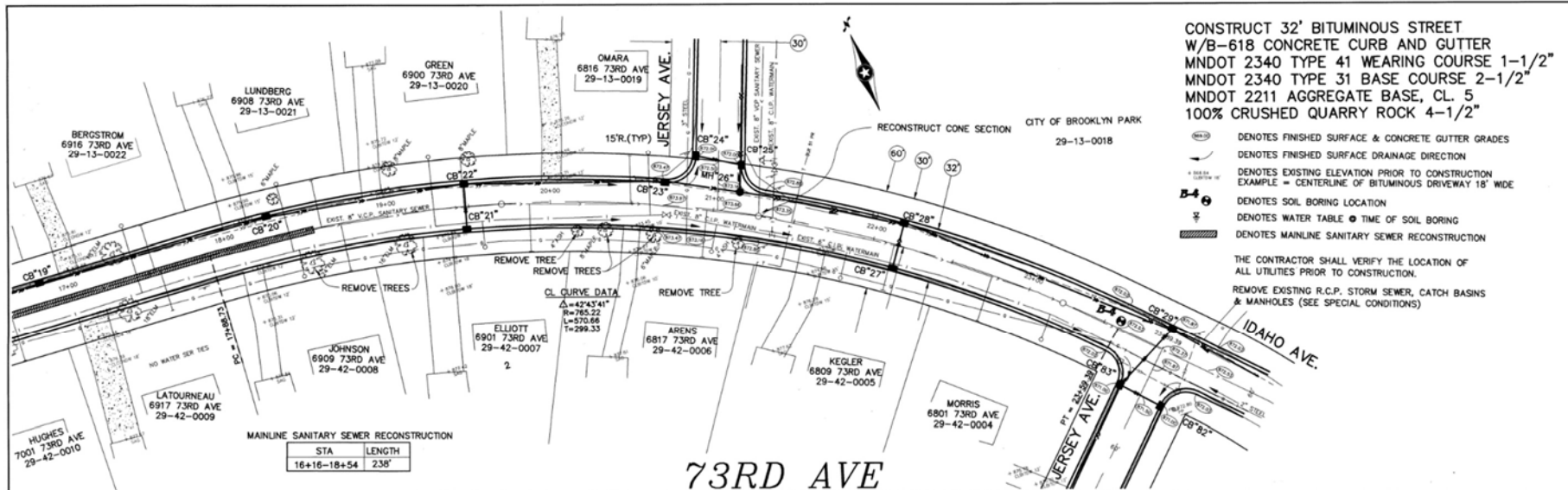
NO.	DATE	BY	CHKD	REVISION

**CITY OF BROOKLYN PARK
ENGINEERING DEPARTMENT**
5200 85TH AVE. N.
BROOKLYN PARK, MN 55443
PH# 612/493-8100
FAX# 612/493-8391

I HEREBY CERTIFY THAT THIS PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.
David C. Deanna
DATE: 8-12-95 REG. NO. 19877
GARY H. BELOW, P.E. DIRECTOR OF ENGINEERING

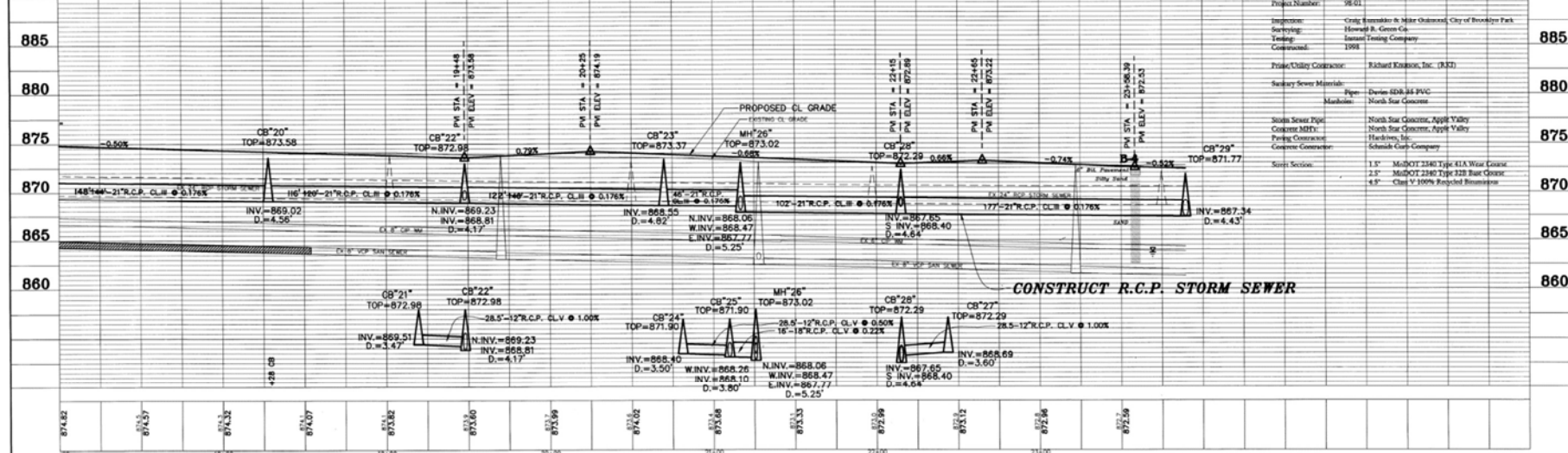
**LOUISIANA AVENUE
63RD AVE. - 62-1/2 AVE.**

CITY PROJ. NO. ST-1142	DRAWN BY S.A.M.	DATE APPROVED 8-12-95	SHEET 4
CITY IMPROV. NO. 95-02	DESIGNED BY J.C.L.	HORIZ. SCALE 1"=30'	OF 6
STATE AID PROJ. NO.	CHECKED BY G.E.R.	VERT. SCALE 1"=5'	



CONSTRUCT 32' BITUMINOUS STREET
 W/B-618 CONCRETE CURB AND GUTTER
 MNDOT 2340 TYPE 41 WEARING COURSE 1-1/2"
 MNDOT 2340 TYPE 31 BASE COURSE 2-1/2"
 MNDOT 2211 AGGREGATE BASE, CL. 5
 100% CRUSHED QUARRY ROCK 4-1/2"

- DENOTES FINISHED SURFACE & CONCRETE GUTTER GRADES
 - DENOTES FINISHED SURFACE DRAINAGE DIRECTION
 - DENOTES EXISTING ELEVATION PRIOR TO CONSTRUCTION
 EXAMPLE = CENTERLINE OF BITUMINOUS DRIVEWAY 18' WIDE
 - ⊕ DENOTES SOIL BORING LOCATION
 - ⊕ DENOTES WATER TABLE ⊕ TIME OF SOIL BORING
 - ▬ DENOTES MAINLINE SANITARY SEWER RECONSTRUCTION
- THE CONTRACTOR SHALL VERIFY THE LOCATION OF ALL UTILITIES PRIOR TO CONSTRUCTION.
 REMOVE EXISTING R.C.P. STORM SEWER, CATCH BASINS & MANHOLES (SEE SPECIAL CONDITIONS)



Project Number:	9801
Design:	Crane Remediator & Mike Oshinski, City of Brooklyn Park
Surveying:	Howard R. Green Co.
Testing:	Soonest Testing Company
Completed:	1998
Prime/Utility Contractor:	Richard Krasovic, Inc. (RKT)
Sanitary Sewer Material:	Durian 4008-34 PVC
Manholes:	North Star Concrete
Storm Sewer Pipe:	North Star Concrete, Apple Valley
Concrete Manholes:	North Star Concrete, Apple Valley
Precast Concrete:	Hartway, Inc.
Concrete Contractor:	Schmidt Construction Company
Street Section:	1.5" - MNDOT 2340 Type 41A Wearing Course 2.5" - MNDOT 2340 Type 31 Base Course 4.5" - Class V 100% Projected Bituminous

NO.	DATE	BY	CHKD	REVISION

CITY OF BROOKLYN PARK ENGINEERING

5200 85TH AVE. N.
 BROOKLYN PARK, MN. 55443
 PH# 612/493-8100
 FAX# 612/493-8391

HEREBY CERTIFY THAT THE PLANS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

DATE: 2-23-98 REG. NO. 23395

DORAN COLE, P.E. CITY ENGINEER

73RD AVE
 W.BROADWAY - 350'± E. OF HARTKOPF LA.

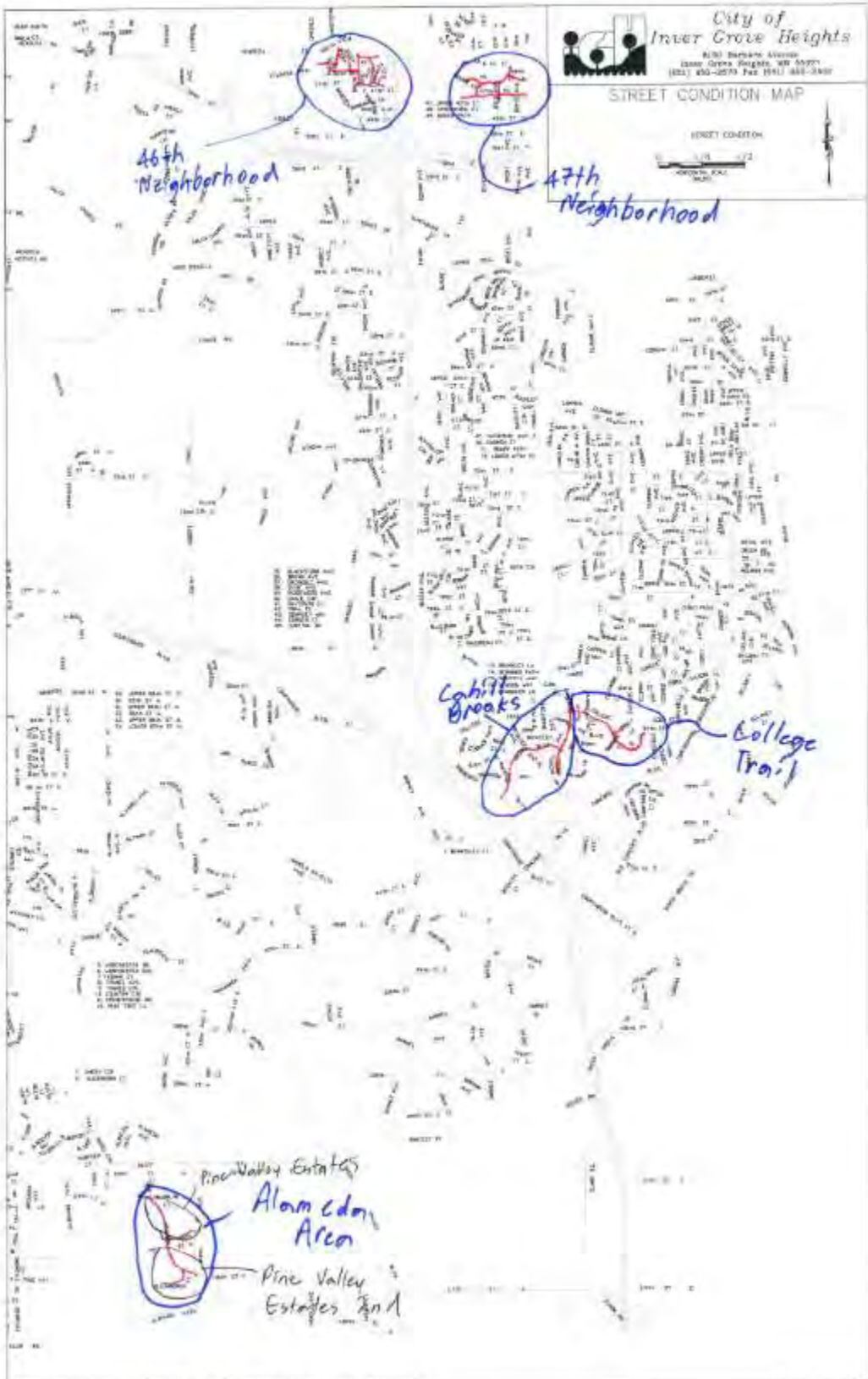
CITY PROJ. NO.	ST-1222 PHASE I	DESIGNED BY	KANKERUDS	DATE APPROVED	2-23-98
CITY IMPROV. NO.	SS-1223 PHASE I	CHECKED BY	GDD/KCL	HORIZ. SCALE	1"=30'
STATE AID PROJ. NO.		CHECKED BY	DMC	VERT. SCALE	1"=5'

City of Burnsville Stripping Under Seal Coat

Owner's Project Name	Owner's Project No.	General Contractor	Paving Contractor / Supplier	Spec	Paving Date	Stripping Observations
1990 Street Paving	90/Reson - 1	Progressive Contractors Inc.	Costa Asphalt / Alexander Const. Co.	231 + 231	Base 6-5/91, Wear 6-7/91	Mod throughout project
1992 Street Paving	92/Reson - 1	Valley Paving, Inc.	Valley Paving Inc.	231 Type 31 & 41	Base 6-5/92, Wear 6-7/92	Mod to Severe throughout project
1992 Street Paving	92/Reson - 1	Ryan Contracting Inc.	McNamara Contracting Inc.	231 Type 31 & 41	Base 6-5/92, Wear 6-7/92	mod Area Severe / Friction Light
1993 Street Paving	93/Reson - 1	Remarc-Knudson Inc.	McNamara - we think Valley	231 Type 31 & 41	Base 6-5/93, Wear 6-7/93	Severe throughout project
1995 Street Paving	95-101	Valley Paving Inc.	Valley Paving Inc.	231 Type 31 & 41	Base 6-5/95, Wear 6-7/95	Light to Mod scattered
1996 Street Paving	95-101	McNamara Contracting Inc.	McNamara Contracting Inc.	2 + 480 230 487 18	6/31/2006	Light along front - long wear - friction?



Map created by Burnsville Engineering Services on 07/23/2015 using MicroStation Civil 3D v8i



T:\PublicWorks\Engineering\PAVEMENT_MGMT_PROGRAM\2015\StreetConditions.mxd

REVISED: 9/17/2014

Listing of Historical Maintenance Projects

	<u>Date</u>	<u>Project Type</u>	<u>Strategy</u>
<u>BROOKS BOULEVARD</u>			
From	87TH STREET EAST		
To	BREWSTER AVENUE		
	6/1/1994	Global	Construction-AC
	9/17/2001	Local	Crack Seal
	6/5/2002	Global	Seal Coat
	9/30/2009	Global	Overlay 1
	6/15/2010	Local	Crack Seal
	6/30/2011	Local	Crack Seal
From	BAXTER WAY		
To	87TH STREET EAST		
	6/1/1994	Global	Construction-AC
	9/17/2001	Local	Crack Seal
	6/5/2002	Global	Seal Coat
	9/30/2009	Global	Overlay 1
From	BECHTEL AVENUE		
To	CAHILL AVENUE EAS		
	6/1/1994	Global	Construction-AC
	9/17/2001	Local	Crack Seal
	6/5/2002	Global	Seal Coat
	9/30/2009	Global	Overlay 1
	6/15/2010	Local	Crack Seal
	6/30/2011	Local	Crack Seal
From	BEVERLY WAY		
To	BECHTEL AVENUE		
	6/1/1994	Global	Construction-AC
	9/17/2001	Local	Crack Seal
	6/5/2002	Global	Seal Coat
	9/30/2009	Global	Overlay 1
	6/15/2010	Local	Crack Seal
	6/30/2011	Local	Crack Seal
From	BRANSON AVENUE		
To	BAXTER WAY		
	6/1/1994	Global	Construction-AC
	9/17/2001	Local	Crack Seal
	6/5/2002	Global	Seal Coat
	9/30/2009	Global	Overlay 1
	6/15/2010	Local	Crack Seal
	6/30/2011	Local	Crack Seal
From	BREWSTER AVENUE		
To	BEVERLY WAY		
	6/1/1994	Global	Construction-AC
	9/17/2001	Local	Crack Seal
	6/5/2002	Global	Seal Coat
	9/30/2009	Global	Overlay 1
	6/15/2010	Local	Crack Seal
From	BRODERICK BOULEV		
To	BRANSON AVENUE		
	6/1/1994	Global	Construction-AC
	9/17/2001	Local	Crack Seal
	6/5/2002	Global	Seal Coat
	9/30/2009	Global	Overlay 1
	6/15/2010	Local	Crack Seal

AGGREGATE TEST REPORT - BITUMINOUS AGGREGATE Lab Nos: D7-BA97057
 Tested At: DISTRICT 7 Lab - Mankato, MN Submitted By: -57- EHLERS
 Project Nos: SF 72-609-17 (G.ISAKSON) Bridge Nos: NA
 -57- Geo-Code: 7211402533340 Pit: DUFFY
 Sampled From: -57- REC 7-97014 "BELT" PRODUCTION
 To Be Used For: -57- 3139-2331-31B-BA2 31LEVEL

Lab. No.	BA 97	57	FIELD	REQ'D.
Date Sampled		05/30/97		3139
Date Received		06/30/97		TYPE
Field ID/Result #		31LV112	32LV112	31B
19.0 mm (3/4") SIEVE		100	100	100-100
16.0 mm (5/8") SIEVE		99	98	
12.5 mm (1/2") SIEVE		96	96	
9.5 mm (3/8") SIEVE		92	92	
4.75 mm (#4) SIEVE		72	73	40-85
2.00 mm (#10) SIEVE		57	50	
0.850 mm (#20) SIEVE		40		
0.425 mm (#40) SIEVE		23	19	
0.180 mm (#80) SIEVE		8		
0.075 mm (#200) SIEV		4.5	4	2-8

NO QUALITY TESTS PERFORMED

MEETS REQUIREMENTS



APPROVED BY

Copies: ~~111 ENG~~
 PROJ ENG (2)

MINNESOTA DEPARTMENT OF TRANSPORTATION

CONSTRUCTION PLAN FOR 2009 BITUMINOUS SEAL COAT
 LOCATED ON CSAH 9, 10, 21, CR 117 & ARLINGTON SHOP LOT

COUNTY PROJECT 1101

GOVERNING SPECIFICATIONS

THE 2005 EDITION OF THE MINNESOTA DEPARTMENT OF TRANSPORTATION
 STANDARD SPECIFICATIONS FOR CONSTRUCTION, SHALL GOVERN.

ALL TRAFFIC CONTROL DEVICES SHALL CONFORM TO THE LATEST EDITION OF
 THE MINNESOTA MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES' (MUTCD),
 INCLUDING THE LATEST 'FIELD MANUAL FOR TEMPORARY TRAFFIC CONTROL ZONE
 LAYOUTS.'

CSAH 9 FROM TRUNK HIGHWAY 5 TO NORTH COUNTY LINE
 CSAH 10 FROM CSAH 3 SOUTH TO TRUNK HIGHWAY 15
 CSAH 21 FROM 13TH STREET EAST TO CSAH 12
 CR 117 FROM TRUNK HIGHWAY 5 TO 0.5 MILES NORTH
 SIBLEY COUNTY SHOP LOT AT ARLINGTON

SEE SHEETS 4-7 FOR LOCATION MAPS

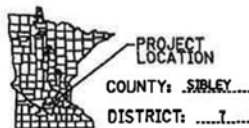
INDEX

SHEET NO.	SHEET DESCRIPTION
1	TITLE SHEET
2	ESTIMATED QUANTITIES/NOTES
3	TYPICAL SECTIONS
4-7	LOCATION MAPS
8-11	TRAFFIC CONTROL PLANS

THIS PLAN CONTAINS 11 SHEETS.

I HEREBY CERTIFY THAT THIS PLAN WAS PREPARED BY ME OR
 UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY LICENSED
 PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

SIGNATURE: Brett Benzkofer
 DATE: 4/22/09 LIC. NO. 25434 PRINT NAME: BRETT BENZKOEFER



SibleyCounty
 Public Works

SIBLEY COUNTY PUBLIC WORKS
 111 8TH STREET
 P.O. BOX 897
 GAYLORD, MN 55334
 P (507) 237.4092
 F (507) 237.4356
 www.co.sibley.mn.us

S.A.P. _____
 COUNTY PROJECT 1101 SHEET NO. 1 OF 11 SHEETS

2:17:28 PM
 4/23/2009
 S:\Pub\1101\Sorka\Highway\Project\1101\Des\gn\Sealcoat\plan\Sealcoat\TITLE SHEET.dgn

APPENDIX I

FIELD CORES AND FIELD CORE OPERATION PHOTOGRAPHS

Full core photographs can be found online at:

<ftp://ftp2.dot.state.mn.us/pub/outbound/researchservices/Chip%20Seal%20Research/>



Figure I-1. Coring operations and sample core extracted from the east end of 93rd Avenue in Blaine, MN



Figure I-2. Coring operations and sample core extracted from the east end of 93rd Avenue in Blaine, MN



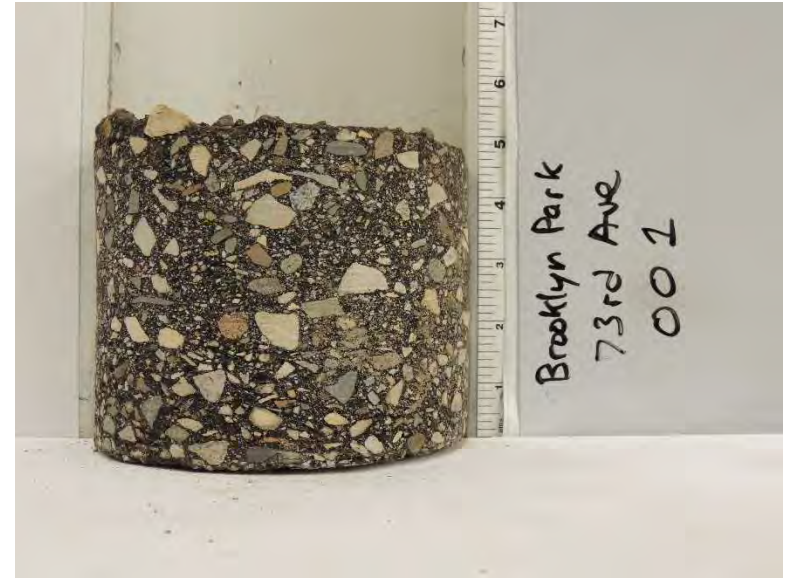


Figure I-3. Coring operations and sample core extracted from 73rd Avenue in Brooklyn Park, MN

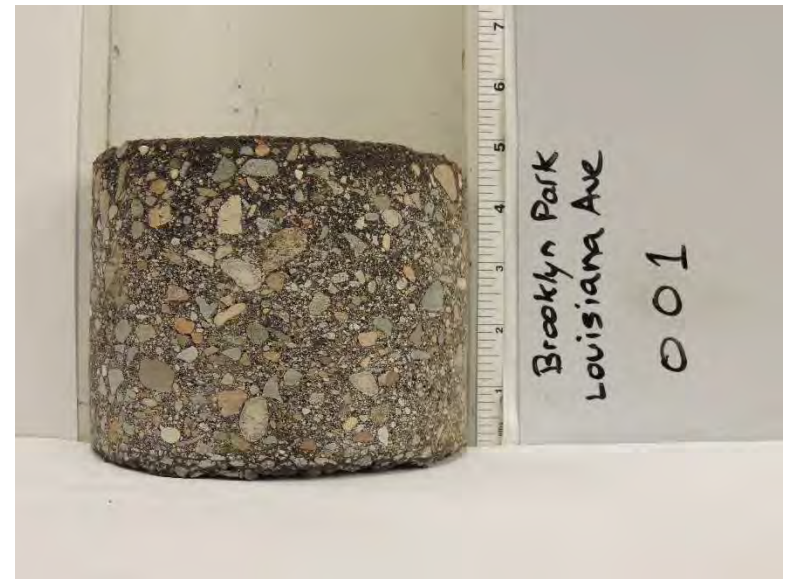


Figure I-4. Coring operations and sample core extracted from Louisiana Avenue in Brooklyn Park



Figure I-5. Coring operations and sample core extracted from Winnetka Avenue in Brooklyn Park, MN



Figure I-6. Coring operations and sample core extracted from 134th Street in Burnsville, MN



Figure I-7. Coring operations and sample core extracted from Heritage Circle in Burnsville, MN



Figure I-8. Coring operations and sample core extracted from Knob Hill in Burnsville, MN





Figure I-9. Coring operations and sample core extracted from Hyde Ave in Cottage Grove, MN



Figure I-10. Coring operations and sample core extracted from Ingberg Trail in Cottage Grove, MN



Figure I-11. Coring operations and sample core extracted from Jensen Ave in Cottage Grove, MN

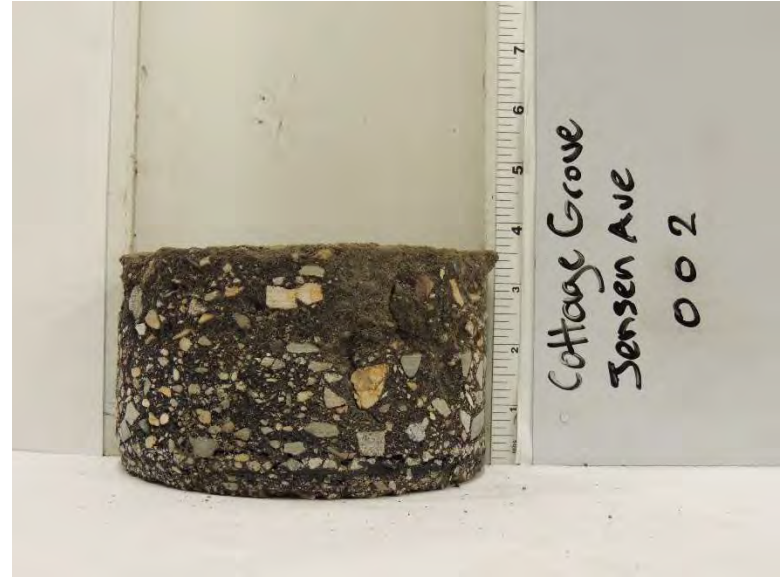


Figure I-12. Coring operations and sample core extracted from Brooks Blvd. in Inver Grove Heights, MN



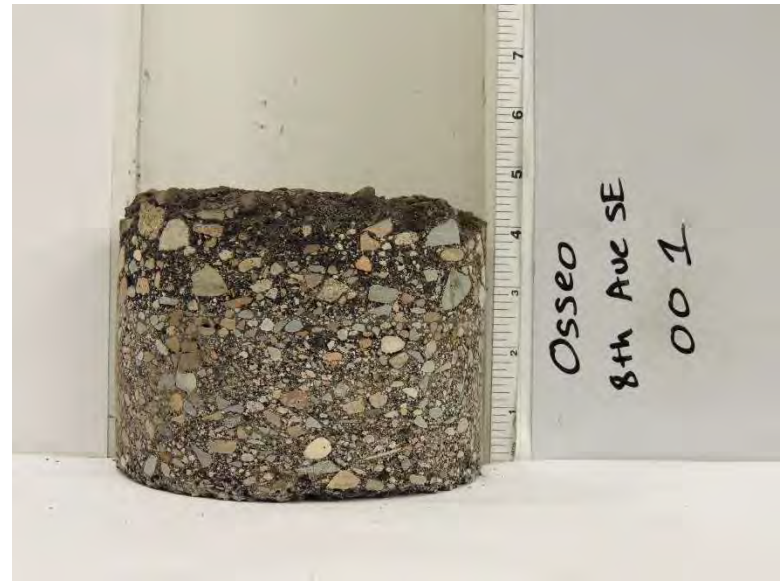


Figure I-13. Coring operations and sample core extracted from Osseo, MN



Figure I-14. Coring operations and sample core extracted from the north part of CSAH 9 in Sibley County, MN

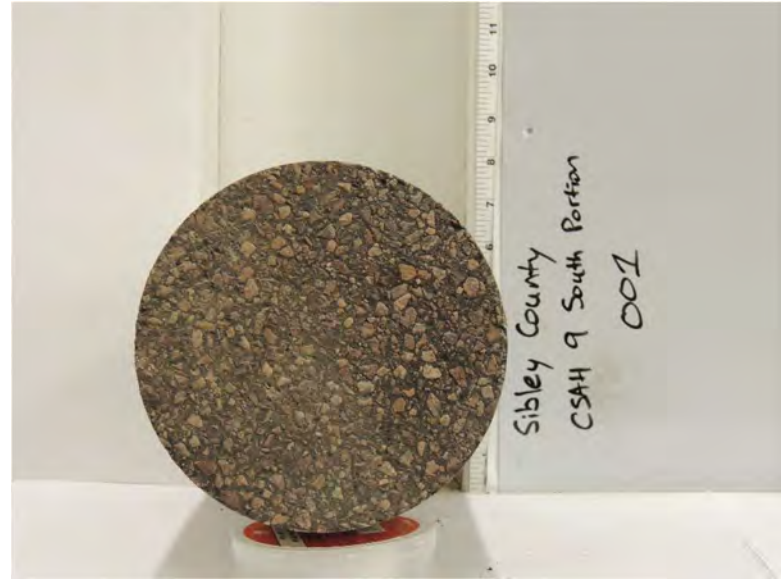


Figure I-15. Coring operations and sample core extracted from the south part of CSAH 9 in Sibley County, MN

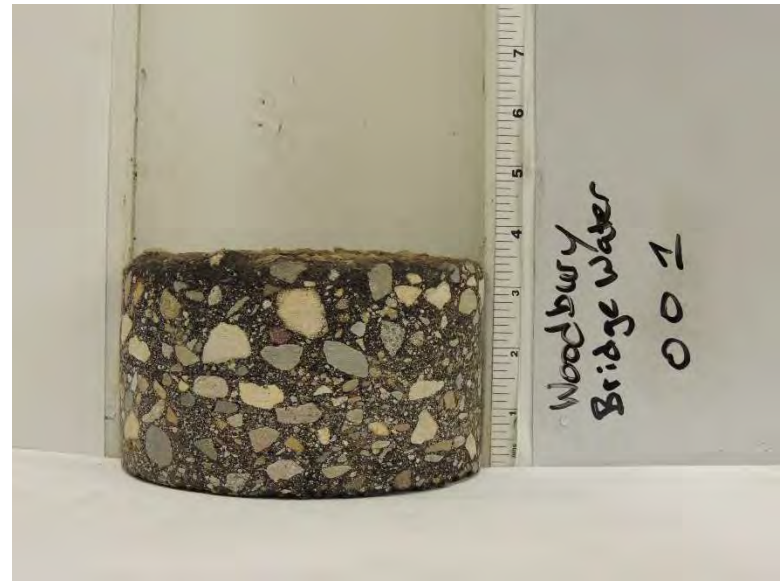


Figure I-16. Coring operations and sample core extracted from Bridgewater Road in Woodbury, MN

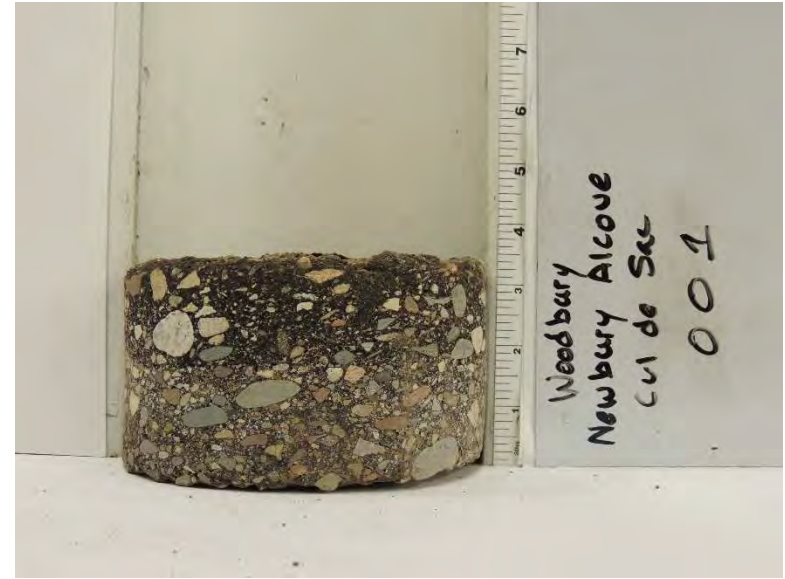


Figure I-17. Coring operations and sample core extracted from Newbury Alcove Cul de sac in Woodbury, MN



Figure I-18. Coring operations and sample core extracted from Newbury Alcove straight portion in Woodbury, MN

APPENDIX J

HAMBURG TEST PHOTOGRAPHS

Full core photographs can be found online at:

<ftp://ftp2.dot.state.mn.us/pub/outbound/researchservices/Chip%20Seal%20Research/>



Figure J-1. Paired specimen from the east end of 93rd Avenue in Blaine, MN, before Hamburg test

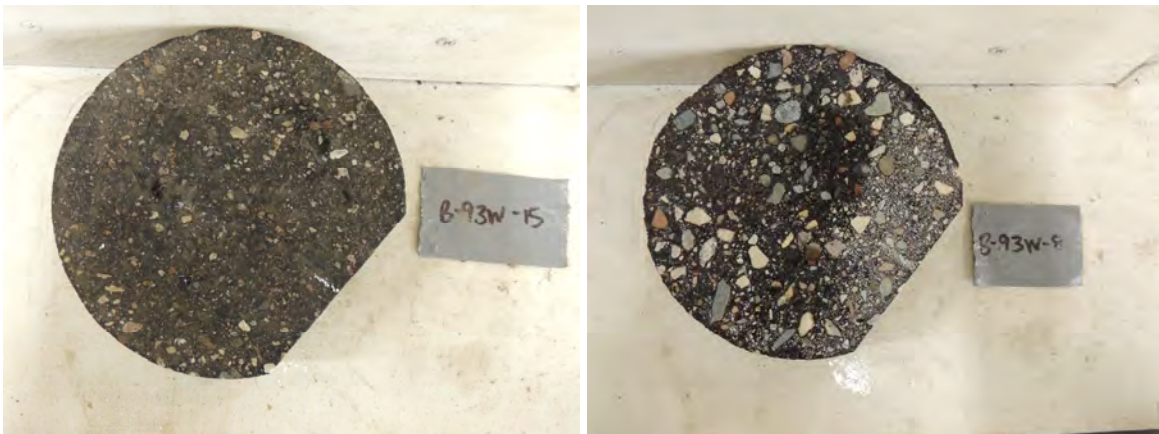


Figure J-2. Specimen from the west end of 93rd Avenue in Blaine, MN, before Hamburg test



Figure J-3. Specimen from 73rd Avenue in Brooklyn Park, MN, after Hamburg test

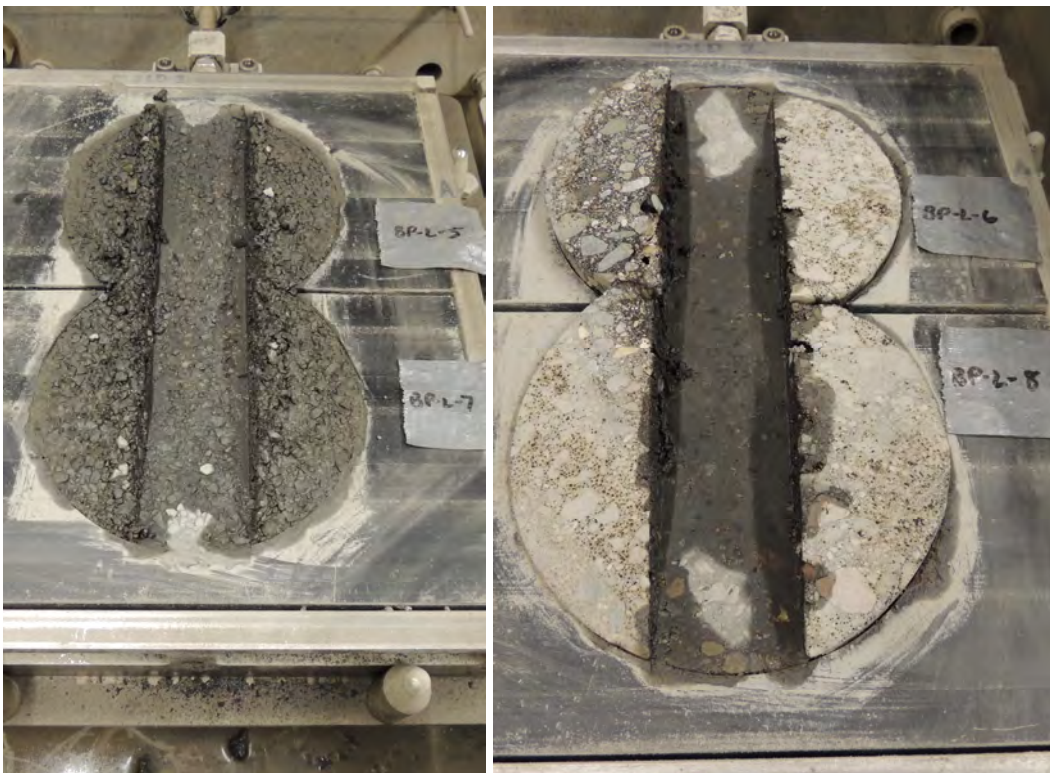


Figure J-4. Paired specimens from Louisiana Avenue in Brooklyn Park, MN, after Hamburg test



Figure J-5. Paired specimens from 134th Avenue in Burnsville, MN, before Hamburg test



Figure J-6. Paired specimen from Brooks Blvd in Inver Grove Heights, MN, after Hamburg test

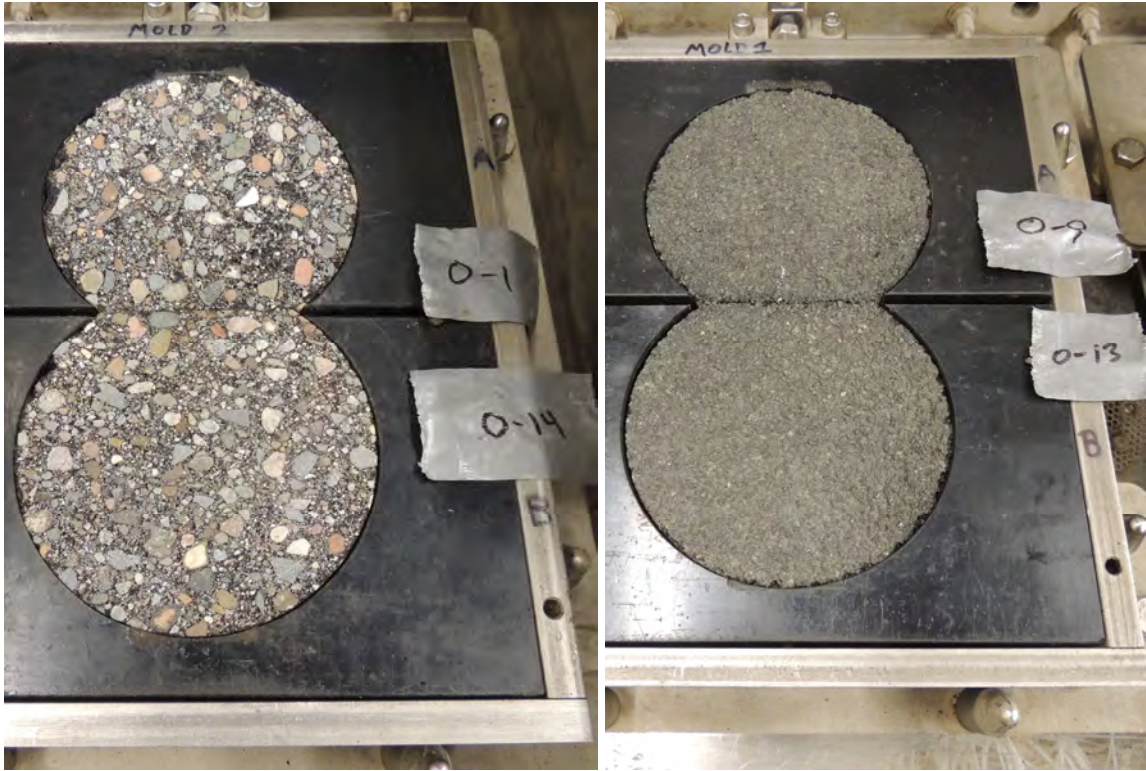


Figure J-7. Paired specimens from Osseo, MN, before Hamburg test

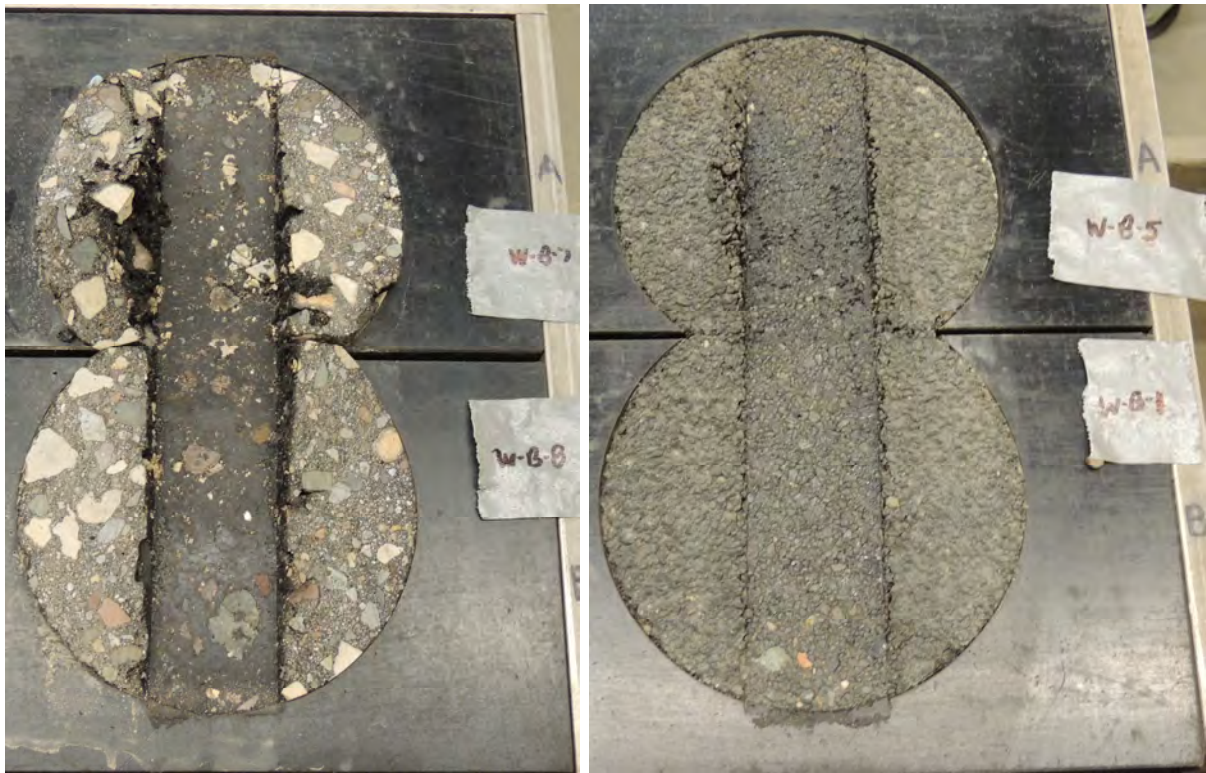


Figure J-8. Paired specimens from Bridgewater Road in Woodbury, MN, after Hamburg test

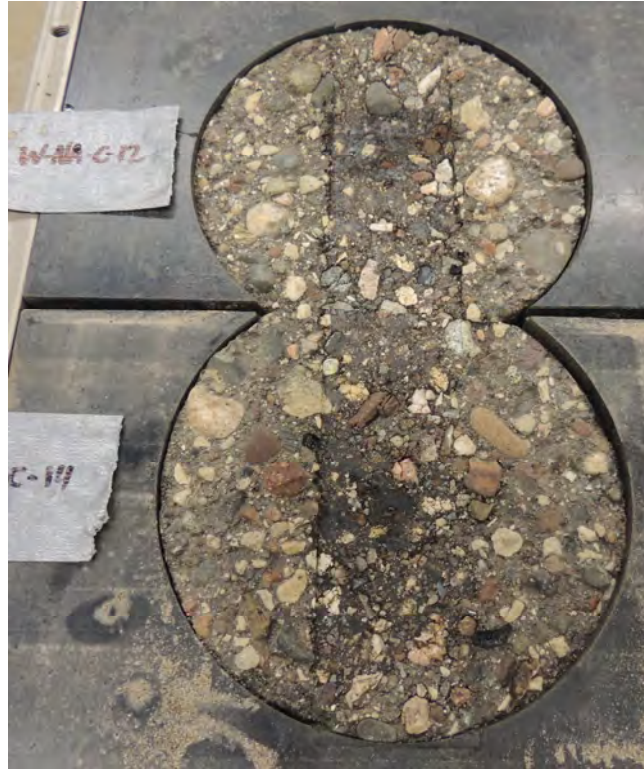


Figure J-9. Specimen without chip seal from Newbury Alcove Cul de Sac in Woodbury, MN, after Hamburg test

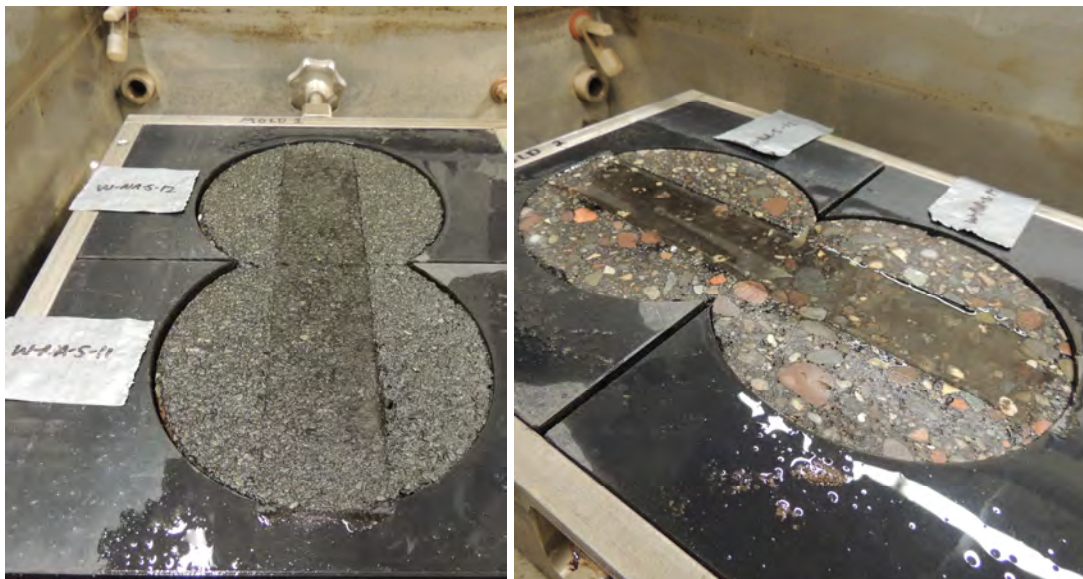


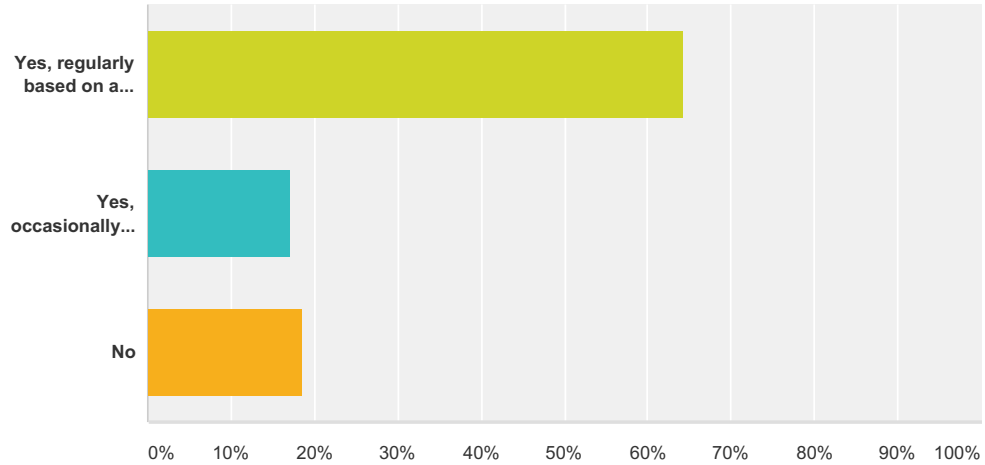
Figure J-10. Paired specimen from Newbury Alcove Straightaway in Woodbury, MN, after Hamburg test

APPENDIX K

CITY/COUNTY SURVEY AND RESPONSES

Q1 Are you currently using chipseals as part of your pavement maintenance program?

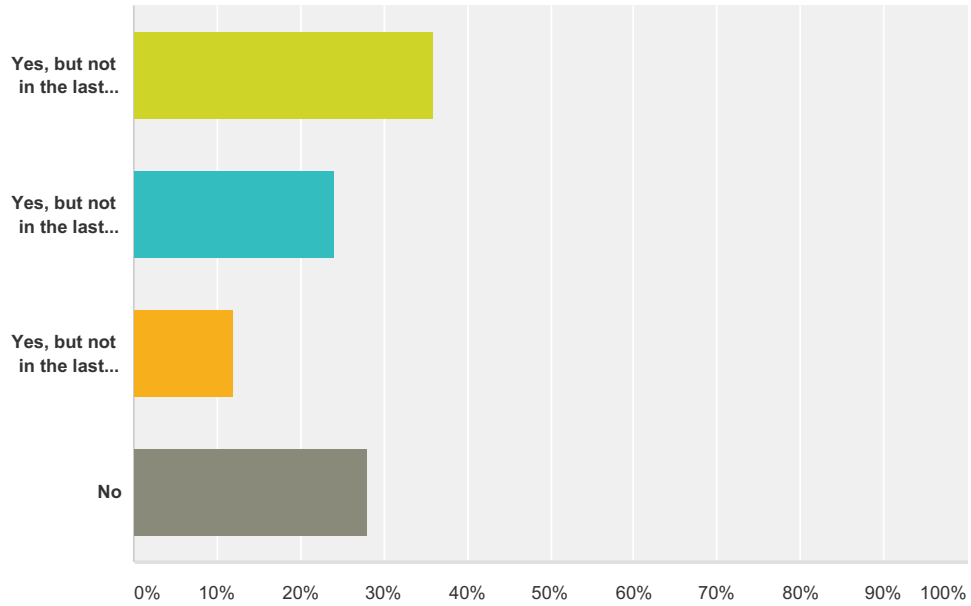
Answered: 129 Skipped: 0



Answer Choices	Responses
Yes, regularly based on a schedule for most roadways	64.34% 83
Yes, occasionally depending on pavement and traffic conditions	17.05% 22
No	18.60% 24
Total	129

Q2 Has your organization used chipseals in the past?

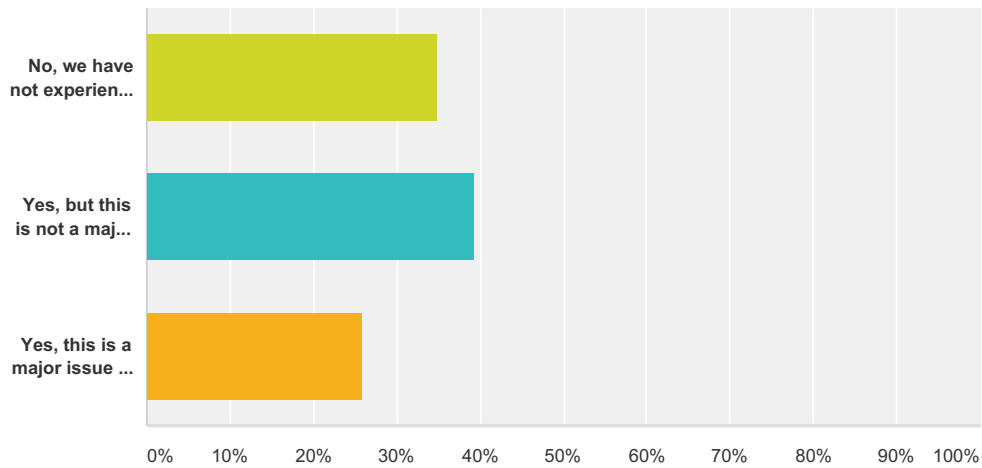
Answered: 25 Skipped: 104



Answer Choices	Responses
Yes, but not in the last approximately 5 years	36.00% 9
Yes, but not in the last approximately 10 years	24.00% 6
Yes, but not in the last approximately 20 years	12.00% 3
No	28.00% 7
Total	25

Q3 On roads where chipseals have been used, have you experienced any problems with stripping or or delamination of the chipseal with the underlying layer of asphalt?Stripping is defined as a loss in the asphalt/aggregate bond resulting in raveling, a shallow surface pothole, or delamination of the chipseal surface.

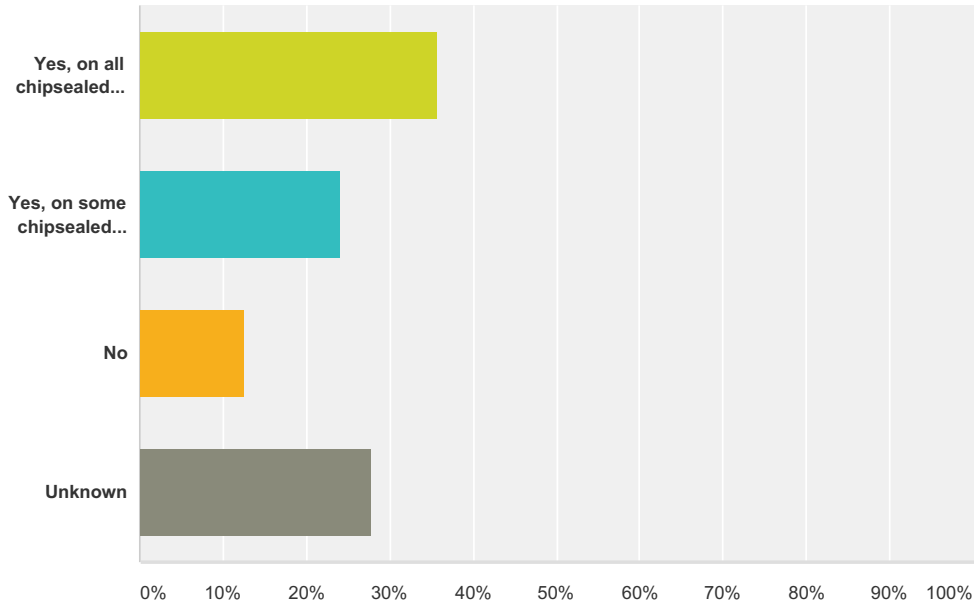
Answered: 112 Skipped: 17



Answer Choices	Responses
No, we have not experienced this issue	34.82% 39
Yes, but this is not a major issue on our roadway network	39.29% 44
Yes, this is a major issue on our roadway network	25.89% 29
Total	112

Q4 Do you use a polymer modified emulsion with your chipseals?

Answered: 112 Skipped: 17



Answer Choices	Responses
Yes, on all chipsealed roadways	35.71% 40
Yes, on some chipsealed roadways	24.11% 27
No	12.50% 14
Unknown	27.68% 31
Total	112

Q5 When did you start specifying the polymer modified emulsion?

Answered: 51 Skipped: 78

#	Responses	Date
1	2005	10/28/2015 10:31 PM
2	Started doing cul-de-sacs a number of years ago. All streets this past year.	10/27/2015 12:41 PM
3	2000	10/26/2015 3:46 PM
4	?	10/24/2015 6:07 PM
5	unknown - at least 5 years	10/24/2015 10:06 AM
6	We reference MNDOT Spec 3151 & bid item is CRS-2. Not sure when MNDOT spec changed.	10/23/2015 2:26 PM
7	2008	10/22/2015 1:35 PM
8	2008	10/22/2015 10:46 AM
9	2008	10/22/2015 7:05 AM
10	2008	10/21/2015 10:26 PM
11	2014	10/21/2015 5:36 PM
12	2014	10/21/2015 4:38 PM
13	not known	10/21/2015 4:34 PM
14	5 to 10 years ago	10/21/2015 4:21 PM
15	2010	10/21/2015 2:51 PM
16	2010	10/21/2015 2:39 PM
17	2014	10/21/2015 12:01 PM
18	We have been using CRS2P for several years	10/21/2015 11:55 AM
19	2005	10/21/2015 11:35 AM
20	prior to my tenure	10/21/2015 11:30 AM
21	3 years ago	10/21/2015 11:25 AM
22	We use st. Louis County's Spec. They bid out our work	10/21/2015 11:05 AM
23	2005	10/21/2015 10:56 AM
24	2008	10/21/2015 10:53 AM
25	Not sure - likely more than 10 years ago. Used on cul-de-sac ends.	10/21/2015 10:51 AM
26	2014	10/21/2015 10:41 AM
27	2008	10/21/2015 10:30 AM
28	2010	10/21/2015 10:18 AM
29	2008	10/21/2015 10:14 AM
30	2004, for FA-3 chip seals only	10/21/2015 10:09 AM
31	Stopped chip sealing all together	10/21/2015 10:04 AM
32	On cul-de-sacs & High Volume Roads 2008	10/21/2015 10:02 AM
33	unknown	10/21/2015 9:36 AM
34	2012	10/21/2015 9:24 AM

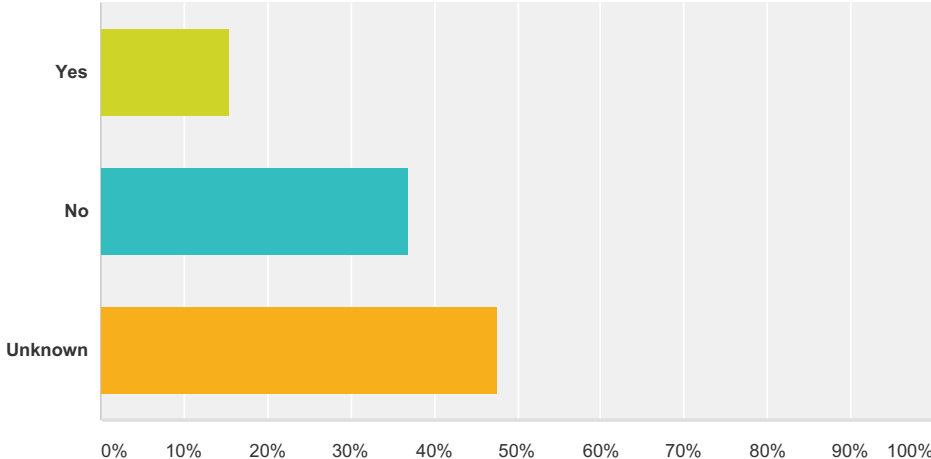
Chip Seal Usage

SurveyMonkey

35	2000	10/21/2015 9:22 AM
36	6 years ago.	10/21/2015 9:19 AM
37	we bid it every year, but typically don't use it because of the price difference. We use the cheaper oil with a cheaper chip. On a few occasions we've used a higher quality chip and have used the polymer emulsion. But not usually.	10/21/2015 9:14 AM
38	2012	10/21/2015 9:14 AM
39	2012	10/21/2015 9:12 AM
40	The City of Hastings has used CRS-2P oil since 2004.	10/21/2015 9:09 AM
41	2004	10/21/2015 9:08 AM
42	2014	10/21/2015 9:04 AM
43	2010	10/21/2015 9:03 AM
44	2009 or so	10/21/2015 9:02 AM
45	Don't know	10/21/2015 9:02 AM
46	over 10 years ago	10/21/2015 9:01 AM
47	yes, we used emulsion -but are not currently chip sealing	10/21/2015 9:00 AM
48	2014	10/21/2015 8:58 AM
49	2013	10/21/2015 8:57 AM
50	7-10 years ago maybe?	10/21/2015 8:55 AM
51	2015	10/21/2015 8:53 AM

Q6 Have you noticed any difference in the incidence of stripping/delamination on roads with polymer modified emulsion?

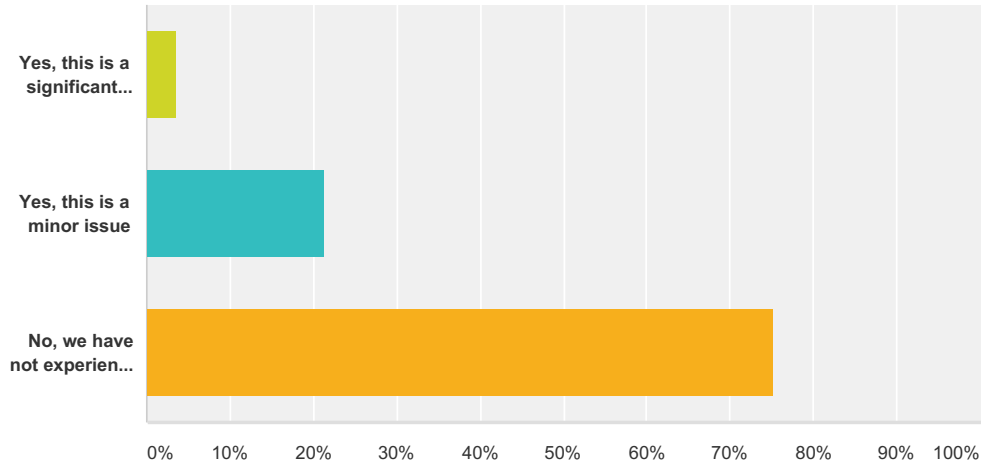
Answered: 65 Skipped: 64



Answer Choices	Responses
Yes	15.38% 10
No	36.92% 24
Unknown	47.69% 31
Total	65

Q7 Do you have any pavements which are not chipsealed that are experiencing stripping failures? Stripping is defined as a loss in the asphalt/aggregate bond resulting in raveling, a shallow surface pothole, or delamination of the chipsealed surface.

Answered: 113 Skipped: 16



Answer Choices	Responses
Yes, this is a significant issue	3.54% 4
Yes, this is a minor issue	21.24% 24
No, we have not experienced stripping on non-chipsealed surfaces.	75.22% 85
Total	113

Q8 Is there anything else you'd like to share about your use or non-use of chipseals?

Answered: 34 Skipped: 95

RespondentID	StartDate	Is there anything else you'd like to share about your use or non-use of chipseals?
4273372900	10/21/2015	Almost appears to be worse on roads with multiple chip seals. Maybe something to do with moisture getting trapped between the chip seal and the wear course.
4273395006	10/21/2015	Based on analysis done on our streets by Tom Wood @ MnDOT, the failure seems to be due to high air voids in the wearing course (possibly due to poor compaction).
4273399156	10/21/2015	Chip seal stripping, from our experience, has been late in the chip seal's life (year 5-7). Our specification on tack material is for a CRS-2P/CRS-2 (MnDOT Spec 3151) with an FA-2 Modified 1/8" aggregate. Not entirely sure if the CRS-2P/CRS-2 material is a polymer modified emulsion or not.
4278472353	10/23/2015	I have observed that the quantity of road salt that is placed on the road in the winter, affects the amount and area where stripping failure occurs. Please contact me if you would like to discuss. By Paul Pearson, PE, Sambatek, Inc. (ppearson@sambatek.com)
4274077158	10/21/2015	I have told our City Council for last 2 years that we no longer should do seal coating. No plans to start it up again.
4273391423	10/21/2015	I'm torn between answering number 6 as "unknown" instead of "no." Most of our roads built since the 90s have been chip sealed. The roads which haven't been chip sealed are really old roads built in the 80s (or earlier) that are now dilapidated in more ways than one.
4274626934	10/21/2015	In general, Albert Lea has not experienced a problem with this.
4273379811	10/21/2015	In regard to 6, we have limited number of non seal coated streets thus no answer. We have experienced striping below seal coat on streets paved around 1997 which is prior to us specifying anti strip additives in the bit pavement mix. The seal coats on those streets appeared to do little to prevent stripping in the mix.
4273428867	10/21/2015	Lakeville has gone away from the use of chip seals primarily because of the raveling issue, but also because we have we have started using c-oil with our bituminous mix designs, and have seen less thermal cracking, and therefore can better manage surface failures with crack filling alone.
4273512769	10/21/2015	Lots of info about non-use that I would love to share! However, the use of chip seals should all come down to a simple question: did the use extend the life of a street and save money. In most cases and in my opinion, it cost cities millions more to use a chip seal vs. not using them. Even if there was just minor stripping and potholes, that cost still negates the benefits of using a chip seal. There are many cities that have not used chip seals and instead put the same money into crack filling and overlays. Their streets look great and they are not looking at spending millions to correct a problem that nobody can with 100% certainty tell us how to correct. If this answer to this question was known, Klayton would not have had to send this survey out.
4274195066	10/21/2015	Not finding chipseals indicated for the distresses associated with local roads. Our focus is on routing and sealing cracks and reserving resources for thin overlays to extend pavement life when patching/ride/visuals prompt complaints. There is discussion from time to time whether some sort of surface treatment is desired by the community for aesthetic purposes.
4276394004	10/22/2015	Only 3 projects done-2008, 2014 & 2015. These are thin sealcoats with a fine FA-2 trap rock.
4273380854	10/21/2015	Our focus is now on mill and overlay as we are dedicating more money to addressing the chip seal issue.
4273393443	10/21/2015	Past practice was to chipseal to the amount budgeted, which resulted in a 50 year rotation on bit streets. We now budget based on a goal of 7 year rotation, with a budget reality of about 12.
4273378017	10/21/2015	Since chip seals have not been used in over 20 years, streets that were sealed have since been overlaid or reconstructed. Not able to give condition related to stripping as a result.

RespondentID	StartDate	Is there anything else you'd like to share about your use or non-use of chipseals?
4273459913	10/21/2015	Spring Lake Park is considering using polymer modified emulsion with our future chipseals.
4273638348	10/21/2015	The answer to question 6 is because we seal coat all of our roads. On question 2, I characterized the problem as "not a major issue" only because we are seeing the failures on roads that were constructed in the 1990's (give or take). Older roads are not showing signs of this type of failure, nor are newer roads.
4273401330	10/21/2015	The City did not have a proactive Pavement Management program until 2002. As a result, we did not have many paving projects in the 1990s. Also, we used to perform sealcoats using our own crews until 2000.
4276855573	10/22/2015	There has not been any stripping issues on our new pavements where we chose not to chip seal.
4273482462	10/21/2015	This is not scientific - the correlation between stripping and seal coating seems to be more associated with pavements in the late 80's and 90's. Previous to that there seems to be less of an issue. Again - not carefully documented or analyzed.
4276693172	10/22/2015	Typically this is bid as part of the City's material bids in the spring and administered and managed by the public works director. I have little say in which roads get treated and the frequency. The public works director does this on an as needed basis as funds are available.
4274773816	10/21/2015	Using the underbelly plows seems to have an effect on removing chip seals on the high spots of the road. We started using the polymer based oil last year and have not had enough time to see if it is better.
4273395125	10/21/2015	Very minor amount of stripping observed. Seemed to be in a few isolated, heavily shaded, flat grad sections. These observations are from WI
4273383483	10/21/2015	we are actually exploring using chip seals again.
4274663236	10/21/2015	We chip seal all newly constructed roadway surfaces within one year of completion.
4273573011	10/21/2015	We continue to chipseal roads that have previously been chipseal but will no long chipseal new pavements due to major issues. Feel free to contact me for more discussion.
4274407207	10/21/2015	We have decided to forgo second round of sealcoat between overlays (or between construction and first overlay) as of 2015.
4291598661	10/29/2015	We have greatly reduced the amount of chip sealing in the last 7 years due to the issues associated with stripping of the chip seal.
4273380373	10/21/2015	We have had success extending the life of our roads by using seal coating.
4273847397	10/21/2015	we have not experienced any stripping problems with our chipseals
4275194344	10/22/2015	We have stopped chipsealing because of the stripping failures. Very frustrating.
4275713929	10/22/2015	We heard about the stripping issues and decided not to use it. We are concerned about all forms of sealcoating.
4273775103	10/21/2015	We just started chip seals this year, so we don't have much history of failures.
4273454365	10/21/2015	We quit chip sealing when the failures occurred on the chip sealed roads and there were no failures on non-chip sealed roads of the same age.