Pavement Demonstration Program Project Finalization Full-Depth Reconstructed Perpetual Hot Mix Asphalt Pavement –
M-84 & I-96
(MDOT Job Numbers 31804 & 52803)

Final Technical Report

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16. Abstract

Pavement demonstration projects are used to evaluate their long-term performance and applicability as a Michigan Department of Transportation (MDOT) standard practice. This document provides a comprehensive report on the “Full-Depth Reconstructed Perpetual HMA Pavement” on M-84 southbound (SB) (MDOT job number 31804) and I-96 westbound (WB) (MDOT job number 52803). These projects were both completed in the fall of 2005. The pavement structures are comprised of hot mix asphalt (HMA) layers with total thickness of 6.5- and 14-inches for M-84 SB and I-96 WB, respectively. The design life for both projects was 40 years, designed so that the strain at the bottom of the HMA layer is lower than its endurance limit to prevent fatigue cracking. Typically, MDOT HMA reconstruction is designed with a 20-year design life with no specific emphasis on the endurance limit. M-84 SB exhibits acceptable pavement condition, with minor longitudinal cracking and IRI showing a stable annual increase rate. Coring and Falling Weight Deflectometer (FWD) data confirm adequate construction quality, and the perpetual section performs better in preventing bottom-up cracking than the standard section in NB. Despite the higher incidence of recorded transverse cracking in the M-84 SB perpetual section compared with the NB standard section in recent years, the transverse cracking appears to be limited to the surface. I-96 WB displays excellent overall performance, with both local and express lanes showing low incidences of cracking and potholes. However, it is important to note that certain deterioration related to construction quality was observed, such as cracks around the longitudinal joints between lanes and shoulders. Furthermore, Ground Penetrating Radar (GPR) tests revealed that thickness is insufficient at some locations. These issues emphasize the importance of construction quality control. The data derived from these projects provide cost and performance insights. These findings serve as valuable guides for future perpetual pavement projects.

17. Key Words
Perpetual pavement; full-depth reconstruction; HMA overlay; distress; performance analysis, cost analysis; maintenance

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Introduction

Public Act 457 of 2016, MCL 247.651h, contains what is referred to as the pavement life-cycle law. This law requires the Michigan Department of Transportation (MDOT) to conduct a life-cycle cost analysis (LCCA) on projects with pavement costs of $1.5 million or more. The LCCA process is a tool to select the lowest-cost pavement design over the expected service life of the pavement. By law, the LCCA process must include historical information for initial construction and maintenance costs and performance (service life). This information is unavailable for new pavement design types and technologies. Thus, it cannot be used in the pavement selection process until substantial information has been obtained. Accordingly, Public Act 457 of 2016, MCL 247.651i, the pavement demonstration law provides a means for trying new and innovative ideas through demonstration projects. These demonstration projects are not subject to an LCCA process. Pavement demonstration outcomes are intended to increase service life, improve pavement condition, improve ride quality, and/or lower service life costs. Future LCCAs may utilize the cost, performance, and maintenance information from the demonstration projects. Selection of candidate projects is collaborative among MDOT Construction Field Services pavement personnel, MDOT region personnel, and paving industry groups. Once the demonstration project is identified, it goes to MDOT's Engineering Operations Committee for formal approval. Once approved, the project becomes part of the Pavement Demonstration Program. All costs for the demonstration project are funded by the respective MDOT region's rehabilitation and reconstruction template budget. These projects are monitored until a final decision is made regarding the suitability of adopting them as MDOT standard practice. This report evaluates two projects for the “Full-Depth Reconstructed Perpetual Hot Mix Asphalt Pavement” pavement demonstration fix type on the M-84 southbound (SB) in Bay/Saginaw County, MDOT job number 31804, and the I-96 westbound (WB) in Wayne County, MDOT job number 52803.

Project Description

This report covers two full-depth reconstructed perpetual Hot Mix Asphalt (HMA) pavement projects: (1) the M-84 SB reconstruction project and (2) the I-96 WB reconstruction project. The M-84 SB project is a non-freeway, low-traffic-volume route, while the I-96 WB project is a high-traffic-volume route consisting of freeway express and local lane sections. The pavement construction plans for the two projects are shown in Appendix A, Figures 43-47. The two projects were designed using the “perpetual pavement” concept, intended to prohibit bottom-up cracking and constrain distress to the surface so that only surface repairs are needed, and subsequent full-depth major fixes (rehabilitation or reconstruction) are delayed. Accordingly, both projects utilized a design life of 40 years to achieve a service life of at least 50 years. In contrast, MDOT standard practice is to use a 20-year design life for full-depth HMA reconstruction with a current service life estimated at 37 years. The design life of a pavement refers to the theoretical duration until a subsequent major reconstruction or rehabilitation is required, excluding any maintenance, serving as the basis for pavement design. Conversely, the service life pertains to the life cycle of the pavement, encompassing the estimated duration until a major reconstruction or rehabilitation is needed, including maintenance events. A component of the service life is its initial fix life projection, which is the duration until a subsequent major reconstruction or rehabilitation would be required, excluding any maintenance. However, unlike design life, service and fix life are estimated per the measured data of in-service pavements.

The M-84 project was constructed over three years from 2003 to 2005, consisting of both the northbound (NB) and SB directions, where the SB lanes were designed as perpetual HMA reconstruction and the NB lanes as standard HMA reconstruction. The SB lanes were completed in the fall of 2005, whereas the NB lanes were completed in 2004. This project spans approximately 3 miles from Pierce Road to 1000 feet south of Delta Road in Saginaw County as shown in Figure 1. Note that the subsections shown in Figure 1 are for location milepoint identifiers and were not monitored separately or uniquely constructed. The existing two-lane M-84 road was converted into a four-lane boulevard section (two lanes in each direction), featuring a 5-lane configuration (two lanes in each direction and a middle lane) at the starting and ending locations. The SB cross-section consisted of 6.5 inches of HMA over 12 inches of dense-graded aggregate base (DGAB) over 13.5 inches of sand subbase. This design incorporated polymer-modified asphalt binder and a thicker unbound aggregate base for enhanced durability and reduced maintenance needs. In comparison, NB M-84 utilized a standard pavement cross-section, consisting of 6.5 inches of HMA over 6 inches of DGAB over 18 inches of sand subbase. Table 1 details the pavement cross-section for both bounds on M-84.

The I-96 project completed construction in the fall of 2005, where the WB was designed as perpetual HMA reconstruction. This project includes the local and express lanes over approximately 2 miles from Schaefer Road to M-39/Southfield Freeway in Wayne County as shown in Figure 2. Both the local and express sections consist of three lanes each. Both WB sections consist of 14 inches of HMA over 16 inches of open-graded drainage course (OGDC) over 8 inches of sand subbase. The existing clay subgrade was stabilized with lime to a depth of 12 inches. Apart from the increased pavement thickness compared with standard HMA pavement, this project included Gap Graded Superpave (GGSP) (currently known as Stone Matrix Asphalt (SMA)) with polymer modified binder to improve cracking and rutting resistance. Additionally, to improve longitudinal joint density, the middle and right lanes were paved simultaneously with echelon paving, where two pavers placed asphalt pavement side-by-side. Table 2 details the pavement cross-section on WB I-96.

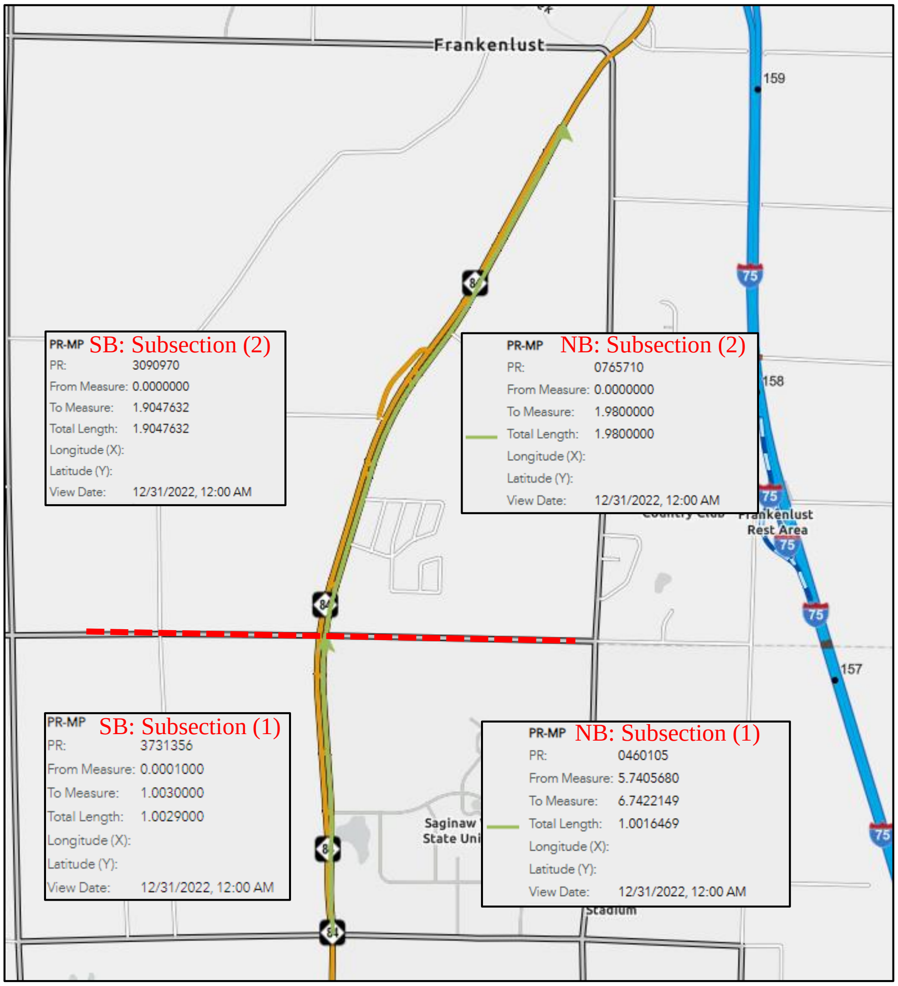
Table 1. M-84 pavement cross-section

Layer	**M-84 SB (perpetual)**			**M-84 NB (standard)**		
	Thickness (inch)	**Material Type**	**Binder PG**	**Thickness (inch)**	**Material Type**	**Binder PG**
Top HMA course	1.5	5E3	70-28P*	1.5	5E3	70-28
Leveling HMA course	2	4E3	70-28P*	2	4E3	70-28
Base HMA course	3	3E3	70-28P*	3	3E3	58-22
Base	12	DGAB	-	6	DGAB	-
Subbase	13.5	Sand	-	18	Sand	-
Subgrade	-	Existing Clay Soils	-	-	Existing Clay Soils	-

* “P” refers to polymer-modified.

Table 2. I-96 WB pavement cross-section

Layer	I-96 WB (local and express lanes)		
	Thickness (inch)	Material Type	Binder PG
Top HMA course	1.5	GGSP	76-22P*
Leveling HMA course	2.5	4E30	76-22P*
Base HMA course	10	3E30	70-22P*
Base	16	OGDC	-
Separator	-	Geotextile separator-fabric	-
Subbase	8	Sand	-
Subgrade	12	Clay stabilized with lime	-



PR-MP SB: Subsection (2)
PR: 3090970
From Measure: 0.0000000
To Measure: 1.9047632
Total Length: 1.9047632
Longitude (X):
Latitude (Y):
View Date: 12/31/2022, 12:00 AM

PR-MP NB: Subsection (2)
PR: 0765710
From Measure: 0.0000000
To Measure: 1.9800000
Total Length: 1.9800000
Longitude (X):
Latitude (Y):
View Date: 12/31/2022, 12:00 AM

PR-MP SB: Subsection (1)
PR: 3731356
From Measure: 0.0001000
To Measure: 1.0030000
Total Length: 1.0029000
Longitude (X):
Latitude (Y):
View Date: 12/31/2022, 12:00 AM

PR-MP NB: Subsection (1)
PR: 0460105
From Measure: 5.7405680
To Measure: 6.7422149
Total Length: 1.0016469
Longitude (X):
Latitude (Y):
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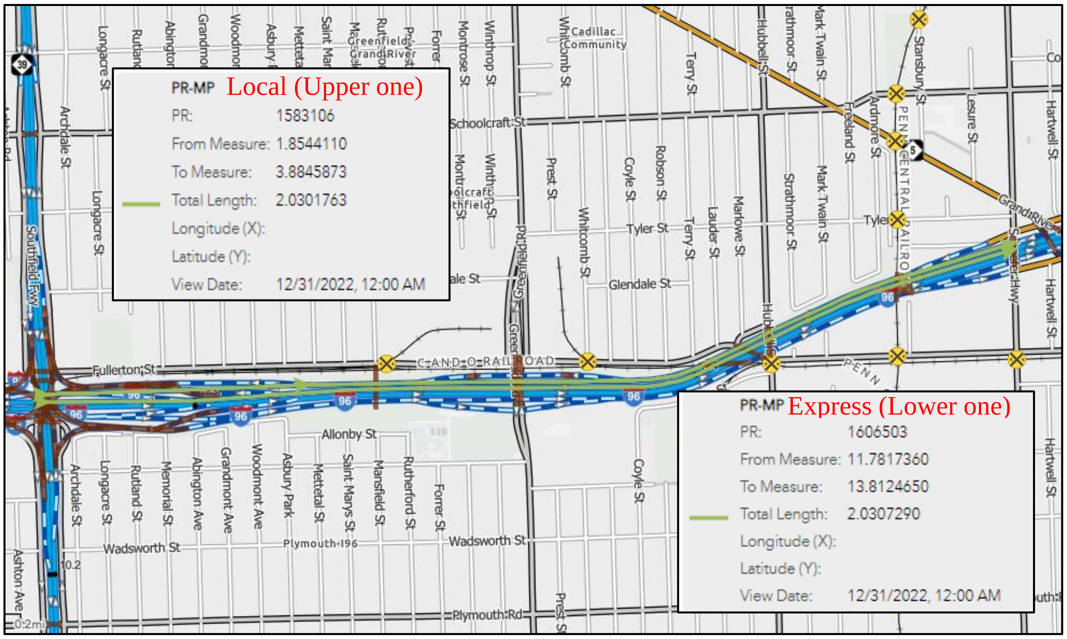
Note: Using Version 23 of the PR (Physical Road) framework

Figure 1. M-84 project location



PR-MP Local (Upper one)
PR: 1583106
From Measure: 1.8544110
To Measure: 3.8845873
Total Length: 2.0301763
Longitude (X):
Latitude (Y):
View Date: 12/31/2022, 12:00 AM

PR-MP Express (Lower one)
PR: 1606503
From Measure: 11.7817360
To Measure: 13.8124650
Total Length: 2.0307290
Longitude (X):
Latitude (Y):
View Date: 12/31/2022, 12:00 AM

Note: Using Version 23 of the PR framework

Figure 2. I-96 WB project location

Traffic Data Assessment and ESAL Estimation

Pavement structure design heavily relies on traffic data, given its significant role in determining pavement performance and durability. This section will summarize the traffic data used for the original pavement designs as detailed in the 2003 MDOT report, *Pavement Structural Design Recommendations for Reconstruction and Widening of M-84* [1] and 2004 MDOT report, *Pavement Structural Analysis of the Design Recommendations for Reconstructing I-96 (M-39 to Schaeffer Road)* [2]. Both demonstration projects utilized and compared mechanistic-empirical (ME) based pavement design and the 1993 AASHTO empirical pavement design method. The design methods and their required traffic type parameters are listed in Table 3. The traffic data used for all pavement design methods is listed in Table 4.

Table 3. Traffic parameters for different pavement design methods

Design Method	Traffic Parameter	Design Method Used in Original Analysis
1993 AASHTO pavement design	ESAL, calculated using typical truck factor	M-84 and I-96
Simplistic ME method	ESAL, calculated using typical truck factor or traffic and load distribution	M-84 and I-96
MEPDG	CAADT, traffic, and axle load distribution	I-96

* ESAL: Equivalent Single Axle Load,
CAADT: Commercial Average Annual Daily Traffic,
MEPDG: Mechanistic-Empirical Pavement Design Guide

Table 4. Traffic data for the M-84 and I-96 original pavement designs

Parameter	M-84	I-96
Annual Average Daily Traffic (AADT), both directions (Year Collected)	12,900 (2003)	191,800 (2005)
CAADT, both directions (Year Collected)	451 (2003)	9,600 (2005)
Traffic growth rate, compound	1.3%	2.0%

The estimated ESAL for the 1993 AASHTO design method was calculated using the equation below:

$$ESAL_{Estimated} = CAADT \ \times 365 \times DD \times LD \times TF \times GF$$

Where:
TF = Truck factor; DD = Directional Distribution Factor; LD = Lane Distribution Factor;
GF = growth factor, $[(1+g)^n - 1]/g$
g = growth rate expressed as a decimal
n = number of years

Table 5 show the resulting $ESAL_{Estimated}$ for the 1993 AASHTO pavement design method for the two projects. Note that the 40-year design ESAL for M-84 is estimated because there is no record of this value, and it was not specifically used as part of the report for the original pavement design [1]. Details of the calculation are shown in Appendix B, Figures 48 to 55 for M-84, Figures 56-60 for I-96.

Table 5. M-84 and I-96 ESAL for 1993 AASHTO pavement design method

Project	TF	DD	LD	Initial Annual ESAL (two-way)	ESAL (20 years)	ESAL (40 years)
M-84	0.77	0.50	0.80	126,870	1,150,650	2,640,000
I-96	0.68	0.56	0.70	2,382,720	22,694,400	56,400,000

Figures 3 and 4 depict the results of per-year ESAL calculations using the 1993 AASHTO pavement design method for M-84 and I-96, respectively.

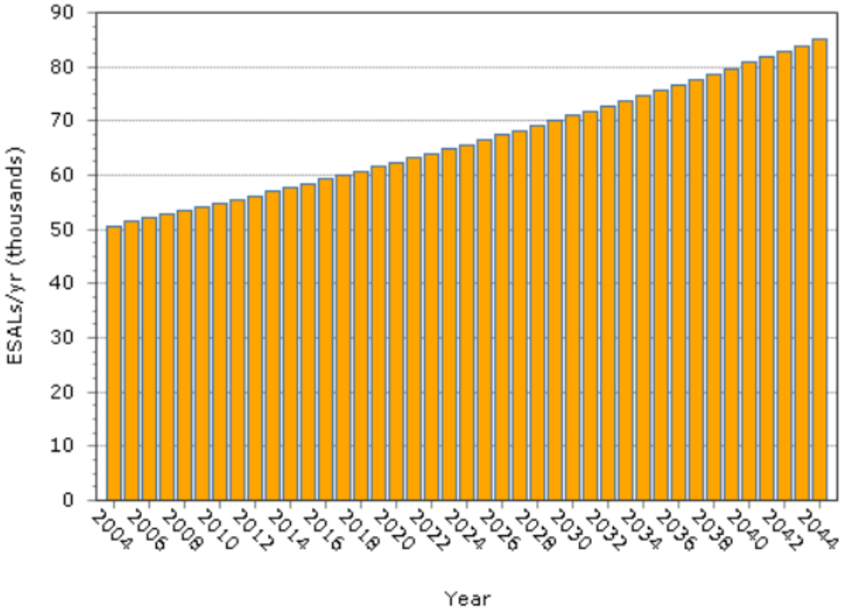


Figure 3. 2004 to 2044 per year ESAL for the M-84 project using 1993 AASHTO design

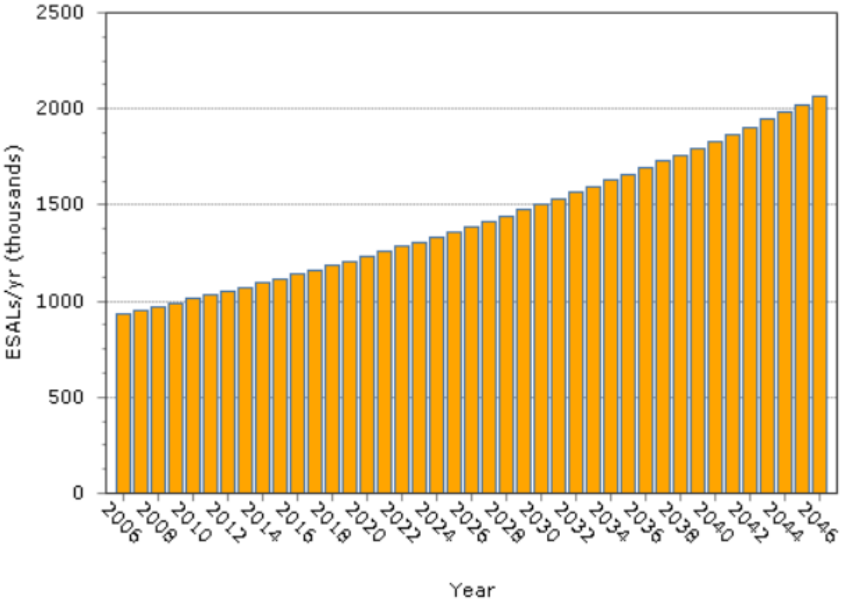


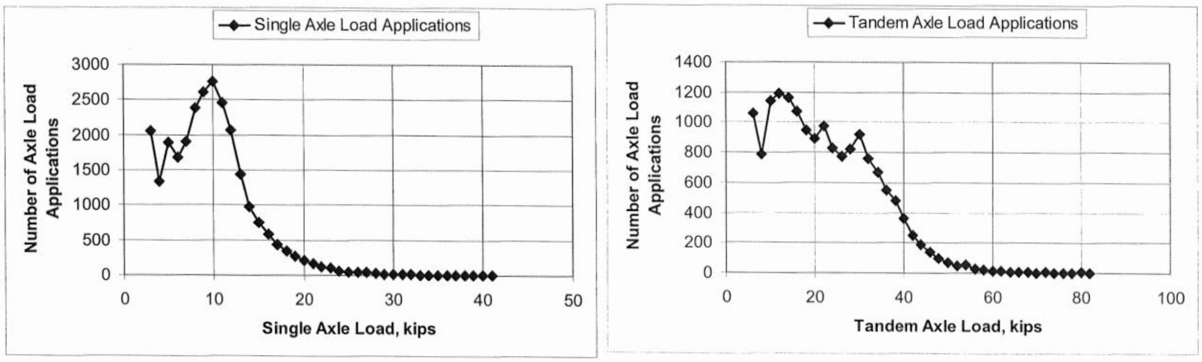
Figure 4. 2006 to 2046 per year ESAL for the I-96 project using 1993 AASHTO design

For the ME design methods, the truck class and axle load distributions are needed in addition to the traffic data shown in Table 4. Table 6 shows the truck vehicle classification normalized volume distribution for the M-84 project in 2003 and the I-96 project in 2005. For the M-84 project, the original analysis utilized estimated values from MDOT and adjusted them relative to the MEPDG global default values for Truck Traffic Classification (TTC) group 16 (as derived from the Long-Term Pavement Performance (LTPP) pavement sections). This group is described as predominantly single-unit trucks. While for the I-96 project, the TTC group 3 was assumed for this roadway, which is described as predominantly single-trailer trucks.

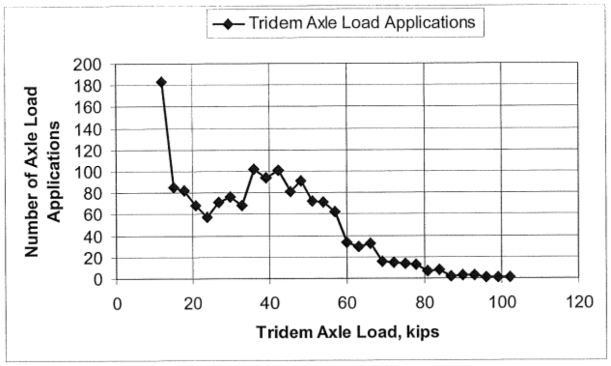
Table 6. Truck vehicle classification normalized volume distribution for the M-84 and I-96 projects

Truck Vehicle Classification	Normalized Volume Distribution, %	
	M-84 (in 2003)	I-96 (in 2005)
4	10.0	0.90
5	17.2	11.6
6	13.6	3.6
7	1.0	0.2
8	18.3	6.7
9	17.0	62.0
10	2.8	4.8
11	0.6	2.6
12	0.1	1.4
13	19.4	6.2

Figure 5 shows the load distribution of single, tandem, and tridem axles for the M-84 project. Figure 6 shows the corresponding distribution for the I-96 project.

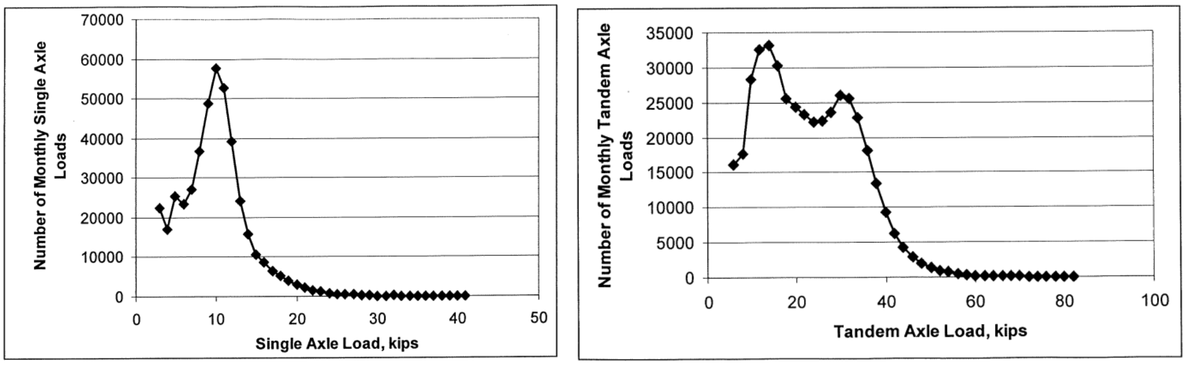


(a) Single axle load (b) Tandem axle load

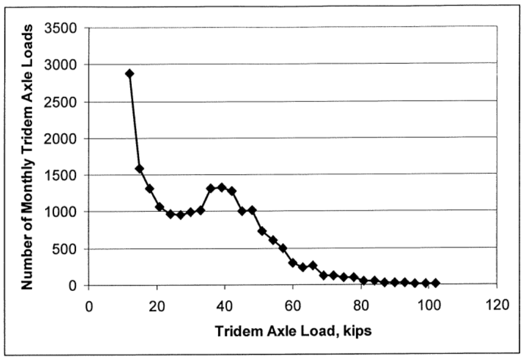


(c) Tridem axle load

Figure 5. Axle load weight distribution for the M-84 project



(a) Single axle load (b) Tandem axle load



(c) Tridem axle load

Figure 6. Axle load weight distribution for the I-96 project

In addition to the MEPDG load and distribution data, the simplistic ME procedure requires a unique ESAL calculated per the load and distribution data (as shown in Table 6, Figures 5 and 6). For the M-84 project, the ME initial year ESAL in both directions ($ESAL_{InitialY}$) was estimated to be 220,602, while for the I-96 project, this was estimated to be 4,411,425. The calculations for $ESAL_{InitialY}$ are shown in Appendix B, Figures 61-63. Note that the detailed calculation process for the M-84 $ESAL_{InitialY}$ were not provided in the original pavement designs so M-84 calculations are estimated for this report. Accordingly, the TF for the M-84 and I-96 projects was separately computed as 1.340 and 1.259 using the $ESAL_{InitialY}$. The TF calculation process is presented in the equation below. Table 7 provides a summary of the $ESAL_{InitialY}$ and TF values for M-84 and I-96 projects.

$$TF = ESAL_{InitialY}/(CAADT \times 365)$$

Table 7. TF calculation process using ME traffic and load distribution

Project	CAADT	Initial year ESALs ($ESAL_{InitialY}$)	TF
M-84	451	220,602	1.340
I-96	9600	4,411,425	1.259

The ME ESAL values per 20- and 40-year design periods were calculated for the M-84 and I-96 projects using the equation below. The results are shown in Table 8. It should be noted that the DD and LD percentages match those used for the 1993 AASHTO pavement design (as shown in

Table 5), except for the M-84 design, where it was increased from 0.50 to 0.55. Notably, the ME ESAL values are nearly twice those employed in the 1993 AASHTO pavement design. This may be due to the different truck types in Michigan compared to those from the global database, or because a different TTC may have been better suited to represent the traffic. As a result, the ME ESAL values were not used for the I-96 simplistic ME design likely due to this difference. Instead, the I-96 simplistic ME design used the AASHTO 1993 ESAL values. While the M-84 pavement design continued to use the ME ESAL values, it did not use the 40-year value as part of the report for the original pavement design [1]. Therefore, in Table 8, the values not used in the original pavement design reports are estimated for informational purposes.

$$ESAL = ESAL_{InitialY} \times DD \times LD \times GF$$

Table 8. Calculated ESAL for simplistic ME method

Project	**DD**	**LD**	$ESAL_{InitialY}$	**Growth rate (g)**	**ESAL (20 years)**	**ESAL (40 years)**
M-84	0.55	0.80	220,602	1.3%	2,230,000	5,113,000*
I-96	0.56	0.70	4,411,425	2.0%	42,017,000*	104,452,000*

* Estimated since these were not used for original pavement designs

Since the future projections of traffic data used for the original designs were estimated for the pavement design period, assumptions such as growth rate may be inconsistent with actual conditions, potentially leading to inaccurate traffic predictions. Therefore, the actual measured traffic data will be compared with these traffic estimations and predictions. The actual measured traffic data was obtained from the MDOT Transportation Data Management System (TDMS) within the project limits, specifically TDMS location number 73-0585, located north of Pierce Road (around the south end of the project) for M-84, and TDMS location number 82-5577, located 0.5 mile west of Schaefer/Grand River Ave for I-96. Note that the I-96 TDMS measurements include traffic data for both express and local lanes. The traffic information for the two projects is shown in Tables 9 and 10. The TDMS data measurement positions are on the project routes. The comparison between the TDMS recorded traffic data and the traffic for design is shown in Figures 7 and 8.

The results show that the traffic estimates for both M-84 and I-96 projects were overestimated in the design period. Accordingly, if the future TDMS traffic continues to be lower relative to the estimated prediction, then there is a decreased risk of unanticipated pavement distress and potential improvement in the anticipated service life. It is worth noting that there has been a notable decrease in recorded CAADT in the year 2020, likely due to the COVID-19 pandemic. Since that time, a gradually increasing trend has been observed for both projects. Still, it should be noted that commercial traffic is largely estimated since it is not measured as frequently as the total AADT, so it is typically an assumed percentage of the total AADT. For M-84, the initial design estimated that commercial traffic was 3.5% of AADT, whereas for I-96, it is estimated to be 5%. Whereas, for the actual percentage of commercial traffic, this is estimated to be between 1.6% to 2.1% for M-84 and 3.5% to 6.7% for I-96. If the highest rate of commercial traffic percentage is used, then the measured values, while still lower for most years, are much closer to the estimated design values.

Table 9. Traffic data for the M-84 project from TDMS

Year	2-Way		SB	
	AADT	CAADT (FHWA Class 4 and above)	AADT	CAADT (FHWA Class 4 and above)
2023	14,885	312	7,528	159
2022	14,508	306	7,337	156
2021	18,210	309	N/A	N/A
2020	16,002	272	N/A	N/A
2019	20,027	340	N/A	N/A
2018	20,128	342	N/A	N/A
2017	20,128	337	N/A	N/A
2016	19,909	328	N/A	N/A
2015	19,292	N/A	N/A	N/A
2014	17,388	326	N/A	N/A
2013	16,980	318	N/A	N/A
2012	16,762	311	N/A	N/A
2011	17,277	307	N/A	N/A

Table 10. Traffic data for the I-96 project from TDMS

Year	2-Way		WB	
	AADT	CAADT (FHWA Class 4 and above)	AADT	CAADT (FHWA Class 4 and above)
2023	131,193	8,134	69,208	4,291
2022	117,215	7,267	64,918	4,025
2021	111,396	6,907	54,253	N/A
2020	128,168	7,946	66,331	N/A
2019	147,945	9,912	73,437	N/A
2018	148,688	9,962	73,806	N/A
2017	162,406	9,852	81,241	N/A
2016	146,000	7,931	N/A	N/A
2015	N/A	N/A	N/A	N/A
2014	135,680	7,683	N/A	N/A
2013	132,500	5,553	N/A	N/A
2012	115,800	5,428	N/A	N/A
2011	112,400	5,306	N/A	N/A
2010	137,500	5,295	N/A	N/A
2009	144,700	5,091	N/A	N/A
2008	160,800	6,690	N/A	N/A

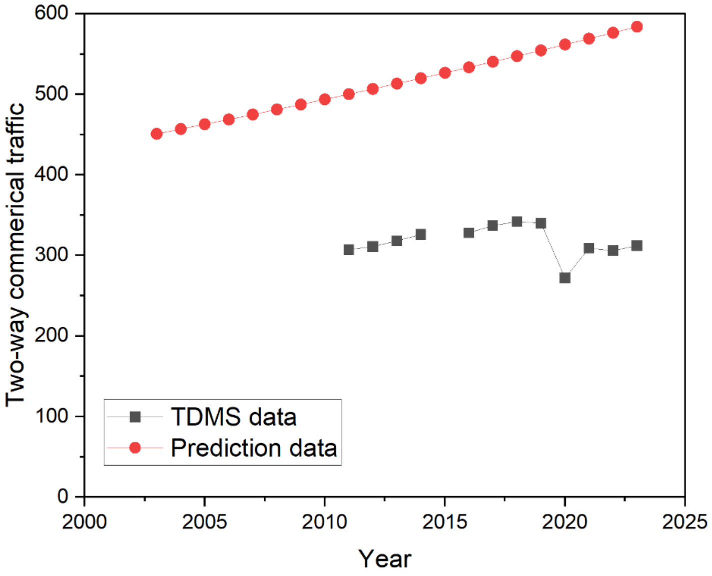


Figure 7. Comparison between TDMS measurements versus predicted two-way CAADT for the M-84 project

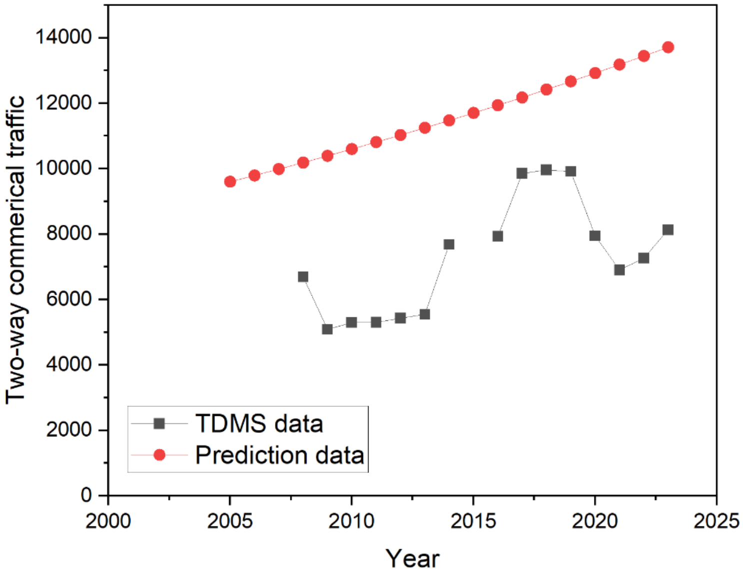


Figure 8. Comparison between TDMS measurements versus predicted two-way CAADT for the I-96 project

Pavement Design and Distress Prediction

As introduced in the previous section, the AASHTO 1993 and ME-based pavement design methods were employed to evaluate the original HMA perpetual pavement design for the M-84 and I-96 projects per the MDOT pavement design development reports [1-2]. Therefore, the traffic-related parameters for pavement design will not be repeated in this section; instead, it will detail the remaining design aspects. M-84 pavement design aspects will be described first, followed by I-96.

The result of the 1993 AASHTO pavement design for the M-84 project using a 20-year design life (per ESAL of 1,150,650) is 6-inches of HMA over 6-inches of aggregate base over 18-inches of sand subbase, See Appendix C, Figure 64 for more details. This design utilizes the MDOT standards of that time for structural and drainage coefficients.

The layer and general design parameters used for the ME-based, simplistic design for the M-84 HMA perpetual pavement are shown in Table 11. These values were estimated per test results of typical HMA and unbound materials of LTPP projects at that time. Accordingly, the model and associated design criteria limits are shown in Table 12 and Figure 9. The figure shows the graph used to determine the modulus ratio between two adjacent unbound pavement layers. This assumes that the long-term in-place modulus of unbound base and subbase layers are dependent on the modulus of the supporting layer due to potential loss of compaction. This is based on each layer's thickness and the supporting layer's modulus.

Table 11. Simplistic ME method design parameters for the M-84 project

Layer/Property	Value/Estimation
Tire pressure	120 psi (827 kPa)
Tire load	4,500 lbs (20kN) per tire
Sand subbase	Resilient modulus = 12,000 psi; Poisson’s ratio = 0.40
Aggregate base	Resilient modulus = 25,000 psi; Poisson’s ratio = 0.35
HMA	Combined equivalent annual elastic layer modulus = 400,000 psi; Poisson’s ratio = 0.30
Subgrade soil	Resilient modulus = 6,000 psi (41,368 kPa)

Table 12. Simplistic ME method design limiting criteria for the M-84 project

Criteria/Property		Value/Estimation
Response model		EVERSTRESS
Design life / ESAL		20 years / 2,230,000 ESAL
Tensile strain at the bottom of the HMA layers, in./in.		0.000174
Vertical compressive strain, in./in.	Top of sand subbase	0.000536
	Top of subgrade	0.000455
Maximum deflection, in.	Full-depth/deep strength HMA	0.028
Unbound layer modulus ratios		Thickness dependent per Figure 9
Alligator cracking (bottom-up fatigue), %		10
Subgrade distortion (rutting), in.		0.5

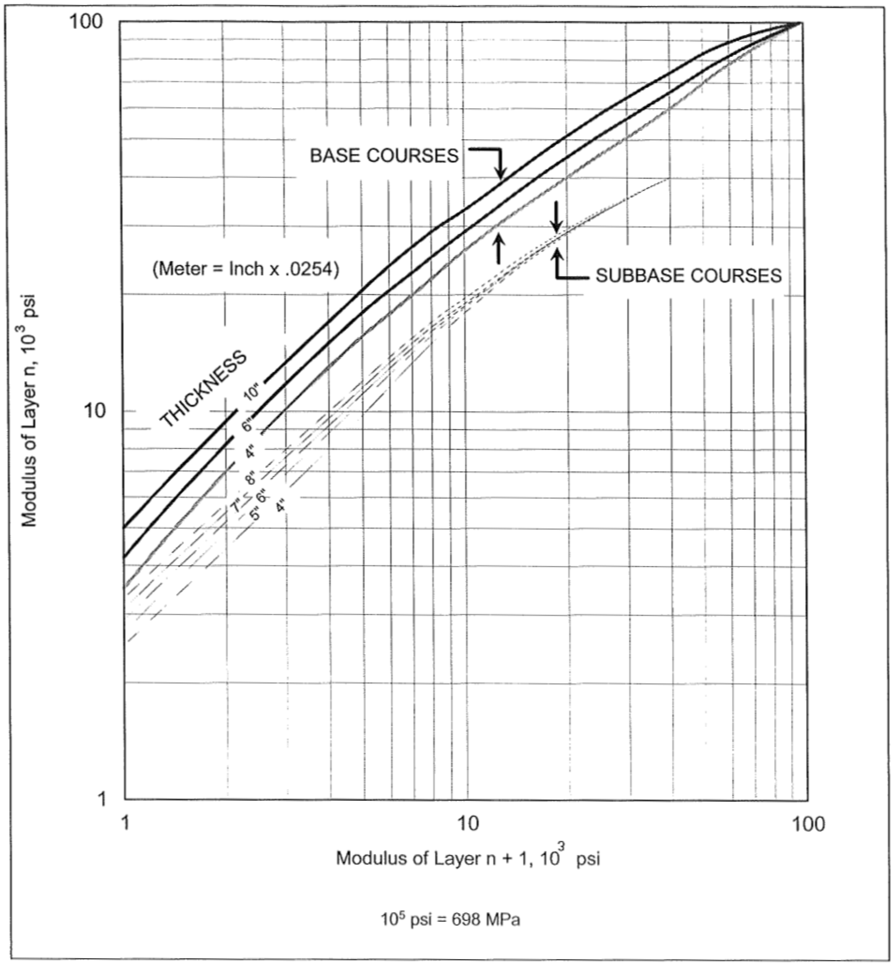


Figure 9. Limiting modulus criteria of unbound aggregate base and subbase layers

Per the design layer inputs and design criteria using the EVERSTRESS response model, the results of the simplistic ME pavement design for the M-84 project are shown in Table 13. Note that recommended mixes and material types as presented in this table are per MDOT standards and best practices known at that time to reduce the potential for cracking and rutting and were not specifically evaluated as part of the ME-based design procedure. As shown, the simplistic ME design method results in a total HMA thickness of 7.5 inches. However, it is important to note that this thickness was not ultimately adopted. Instead, the 6.5-inch HMA structure with the polymer-modified binder as shown in Table 1 was used for this HMA perpetual design. It is likely that the ME-based design result was used in support of AASHTO 1993 design, HMA binder selections, and aggregate base thickness. As previously explained, the ESAL traffic estimation for this ME-based 20-year design (2,230,000) was nearly the same as the estimated AASHTO 1993 ESAL at 40 years (2,640,000). Therefore, as shown in Appendix C, Figure 65, using current MDOT design standards with the estimated AASHTO 1993 40-year ESAL (2,640,000) and thicknesses as per the final design used in the construction plans, the 6.5-inch HMA structure would meet AASHTO 1993 design requirements. Accordingly, for the purposes of this report, the 40-year design life will serve as a reference for the following assessments.

Table 13. Simplistic ME method design results for the M-84 project

Layer	Material Type	Asphalt Binder	Thickness (in.)
Top course	HMA 5-Superpave, Gap-Graded	PG 70-28	2.0
Leveling course	HMA 4-Superpave	PG 70-28	2.5
Base course	HMA 3-Superpave	PG 70-28	3.0
Base	21AA; Crushed Aggregate	-	12.0
Subbase	Non-frost Susceptible Sand	-	16.5
Separator	Geotextile	-	-
Subgrade	Sandy Clay Soil	-	-

The result of the 1993 AASHTO pavement design for the I-96 project using a 20-year design life (per ESAL of 22.7 million) is 11.5-inches of HMA over 16-inches of aggregate base over 8-inches of sand subbase. See Appendix C, Figure 66 for details. MDOT estimated a 40-year design life (per ESAL 56 million) pavement section using the 1993 AASHTO pavement design to be used for the ME-based analyses. This design result was 14-inches of HMA over 16-inches of aggregate base over 8-inches of sand subbase as shown in Figure 10. Records of the original 40-year design calculations could not be located, so it was recreated for the purpose of this reporting. See Appendix C, Figure 67 for details.

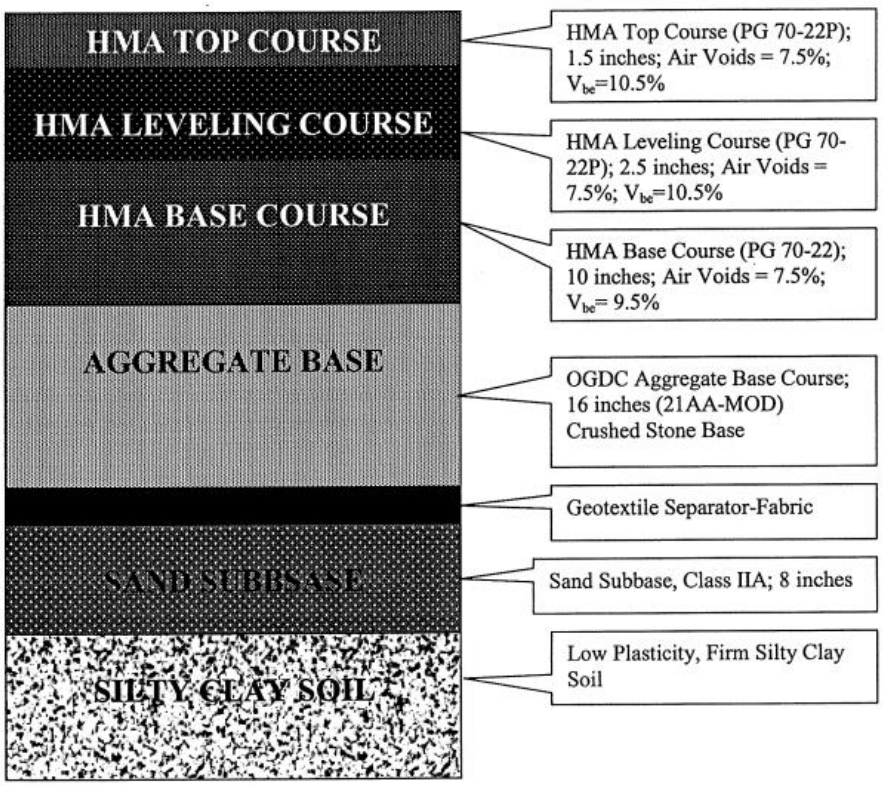


Figure 10. I-96 Original AASHTO 1993 pavement design, 40 years Cross-Section

As per the layers and thicknesses in Figure 10, the layer and general design parameters used for the simplistic ME design method for the I-96 HMA perpetual pavement are shown in Table 14. These values were estimated per test results of typical HMA and unbound materials of LTPP projects at that time. See Appendix C, Figures 68 to 71 for details. Note that subgrade stabilization was not considered or specifically included as part of any of the ME-based design procedures. In addition, trial iterations were used to verify the unbound layer modulus values to ensure that the theoretical and laboratory values provide consistent results. Accordingly, the theoretical modulus values to be used in the ME-based designs were adjusted according to these trial iterations and consideration for consistency. The simplistic ME design criteria limits are shown in Table 15.

Table 14. Simplistic ME method design parameters for the I-96 project

Layer/Property	Value/Estimation
Tire pressure	120 psi (827 kPa)
Tire load	4,500 lbs (20kN) per tire
Sand subbase	Resilient modulus = 7,000 psi; Poisson's ratio = 0.35
Aggregate base	Resilient modulus = 7,500 psi; Poisson's ratio = 0.35
HMA	Combined equivalent annual elastic layer modulus = 892,000 psi; Poisson’s ratio = 0.30
Subgrade soil	Resilient modulus = 5,200 psi, Poisson’s ratio = 0.45

Table 15. Simplistic ME method design limiting criteria for the I-96 project

Criteria/Property		Value/Estimation	
Response model		EVERSTRESS	
Design life / ESAL		20 years / 22,694,400 ESAL	40 years / 56,000,000 ESAL
Tensile strain at bottom of the HMA layers, in./in.	20% Cracking	0.000100	0.000075
	10% Cracking	0.000070	0.000053
Vertical compressive strain (for rutting), in./in.	In HMA layers	0.000091	0.000068
	Top of sand subbase	0.000284	0.000227
	Top of subgrade	0.000235	0.000187
Maximum deflection, in.	Full-depth HMA	0.017500	0.015800
Unbound layer modulus ratios		Thickness dependent per Figure 9	
Damage Index		1.0	
Alligator cracking (bottom-up fatigue), %		20	
Subgrade distortion (rutting), in.		0.5	
HMA distortion (rutting), in.		0.4	

The layer and design parameters used for the MEPDG design method for the I-96 HMA perpetual pavement are shown in Table 16. As shown, the MEPDG method requires several more inputs than those used in the simplistic ME method. Where inputs are similar, the MEPDG inputs mostly match those used for the simplistic ME method. Global default values for ME of that time were used when insufficient data was available. Accordingly, the associated design criteria limits are shown in Table 17. It should be noted that a 30-year analysis period was used instead of 40 years because the results were found to be “unstable” beyond 30 years.

Table 16. MEPDG method design parameters for the I-96 project

<table>
<tr><th>Layer/Property</th><th colspan="2">Value/Estimation</th></tr>
<tr><td>Initial IRI</td><td colspan="2">65 in/mi</td></tr>
<tr><td>Sand subbase</td><td colspan="2">Resilient modulus = 7,000 psi
Poisson’s ratio = 0.35
Plasticity Index = 0
Passing #200 Sieve = 10%
Passing #4 Sieve = 72%
Max Dry Unit Weight = 135 pcf
(all other parameters calculated or default)</td></tr>
<tr><td>Aggregate base</td><td colspan="2">Resilient modulus = 7,500 psi
Poisson’s ratio = 0.35
Plasticity Index = 0
Passing #200 Sieve = 7%
Passing #4 Sieve = 30%
Max Dry Unit Weight = 130 pcf
Optimum Water Content = 7%
(all other parameters calculated or default)</td></tr>
<tr><td rowspan="6">HMA</td><td>Binder parameters (per ASTM D2493)</td><td>A = 10.299; VTS = -3.426
(Default ME Superpave, PG 70-22)</td></tr>
<tr><td rowspan="4">Volumetrics</td><td>Poisson’s ratio = 0.35</td></tr>
<tr><td>Effective Binder Content = 10.5% Top/Level; 9.5% Base</td></tr>
<tr><td>Air Voids = 7.5 %</td></tr>
<tr><td>Total Unit Weight = 148 pcf</td></tr>
<tr><td>Mix Aggregates
% Passing</td><td>3/4-inch sieve = 100 Top; 100 Level; 90 Base
3/8-inch sieve = 80 Top; 70 Level; 60 Base
#4 sieve = 65 Top; 60 Level; 50 Base
#200 sieve = 6.5 Top; 6.0 Level; 5.5 Base</td></tr>
<tr><td>Subgrade soil</td><td colspan="2">Resilient modulus = 5,200 psi
Poisson’s ratio = 0.45
Plasticity Index = 15
Passing #200 Sieve = 65%
Passing #4 Sieve = 93%
Max Dry Unit Weight = 116 pcf
Optimum Water Content = 13%
(all other parameters calculated or default)</td></tr>
</table>

Table 17. MEPDG design limiting criteria for the I-96 project

Layer/Property	Value/Estimation
Design life	30 years
Damage Index	1.0
Reliability (for all criteria), %	90
Terminal IRI, in./mi.	170
Top-Down Cracking, ft/500	2500
Bottom-Up Cracking (alligator fatigue), %	10
HMA Permanent Deformation (rutting), in.	0.35
Total Permanent Deformation (rutting), in.	0.60

Tables 18 and 19 provide distress prediction results from the two ME-based analysis methods (simplistic ME and MEPDG) for the proposed 14-inch HMA structure (as initially estimated per 1993 AASHTO pavement design). It should be noted that the simplistic ME distress predictions were converted to match the distress types of the MEPDG method for comparison in Table 19. According to the predicted distress results, the cross-sectional structure of the pavement design from the 40-year, 1993 AASHTO pavement design is suitable for addressing cracking since the highest predicted value for bottom-up fatigue cracking remains below 20 percent (which is the threshold criteria for simplistic ME as shown in Table 15). However, the results indicate potential excessive rutting. The MEPDG method anticipates rutting mainly in unbound layers and foundation soil, while the simplistic ME analysis method predicts rutting predominantly in the HMA layers. It is more likely that rutting is predominantly in the HMA layers because the resilient modulus values used for the unbound layers are lower than what were used for designs that use the global MEPDG default calibration coefficients. Therefore, the MEPDG method may be overestimating potential rutting in these unbound sub-layers.

To address the concern of potential HMA rutting, an additional design iteration using the simplistic ME method was used with assumptions for top and leveling HMA to use PG 76-22P, instead of PG 70-22P. As shown in Table 19, this reduces the predicted rutting to a value below the desired design criteria (as shown in Table 17), so it was recommended that top and leveling courses use this increased binder grade. As a result, the 14-inch HMA design with increased binder grades for top and leveling courses was adopted for the plans used for construction (per Table 2).

Table 18. Simplistic ME method design prediction results for the I-96 project

Criteria/Property		Predicted Value
Tensile strain at the bottom of the HMA layers, in./in.		0.000050
Vertical compressive Strain (for rutting), in./in.	In HMA layers	0.000092*
	Top of sand subbase	0.000099
	Top of subgrade	0.000089
Maximum deflection, in.	Full-depth HMA	0.010800

* This value exceeds the 20- and 40-year design criteria values as shown in Table 15.

Table 19. Summary of distress predictions using ME-based methods for the I-96 project

Predicted Distress		Simplistic ME Method		MEPDG Method	
		20-Year	40-Year	20-Year	30-Year
Fatigue Cracking	Damage Index	0.324	0.801	0.028	0.047
	Area cracking, %	2.0	6.0	8.4	11.9*
Top-down cracking, ft./mi.		N/A	N/A	267	274
Thermal cracking, ft./mi.		N/A	N/A	40	211
Total rutting, in.	Per PG 70-22 design	0.48	0.70*	0.77*	0.86*
	Per PG 76-22 design	0.36	0.54	N/A	N/A
Layer rutting or distortion, in.	Per PG 70-22 design	0.48	0.70	0.21	0.26
	Unbound layers	0.00	0.00	0.56	0.60
IRI, in./mi.		N/A	N/A	120	134

* This value exceeds the design criteria values as shown in Table 17.

Construction and Quality Control

This section provides a summary of the construction conditions and initial construction results. It includes records of tests conducted before and after construction, encompassing parameters of the cross-section material classifications, moisture levels, densities, thicknesses, and strength characteristics. It should be noted that the information presented in this section was not necessarily used for construction acceptance. Instead, this data was collected for informational purposes of the demonstration projects.

For M-84 SB, moisture and density tests were conducted on HMA layers (top, leveling, and base), aggregate base, sand subbase, and subgrade (embankment) using the nuclear method during construction in 2005. Adequate density of compacted materials is important to ensure their long-term performance and structural support. For M-84 SB, measurements were taken on both outside and inside lanes. Note that these measurements were taken independently of those used for construction acceptance, solely to characterize the material properties of the pavement demonstration. The percent of compaction was calculated based on the measured density and the maximum dry density. The percent of compaction and moisture results for different M-84 SB pavement layers are listed in Figures 11 and 12. Note that these results are presented in the original sequential order from the recording files, not by specific locations. Detailed station and lane location information can be found in Appendix D, Figures 72-89.

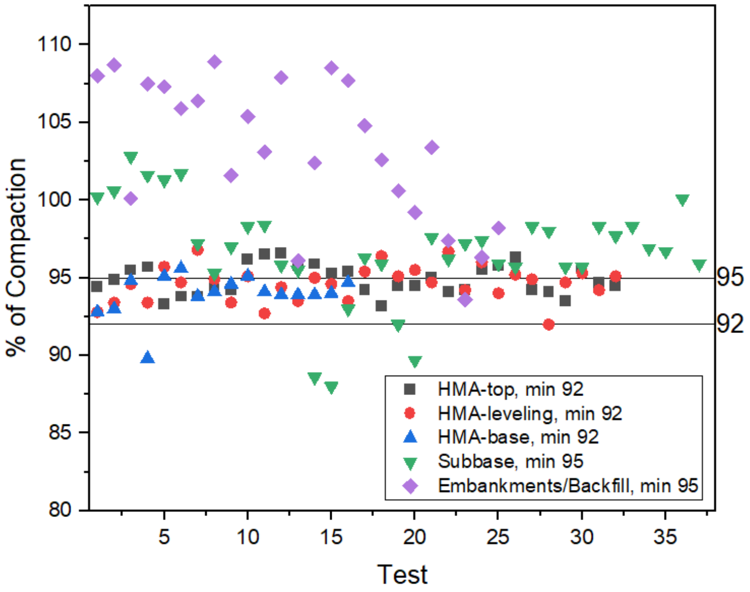


Figure 11. Percent of compaction for different M-84 SB pavement layers

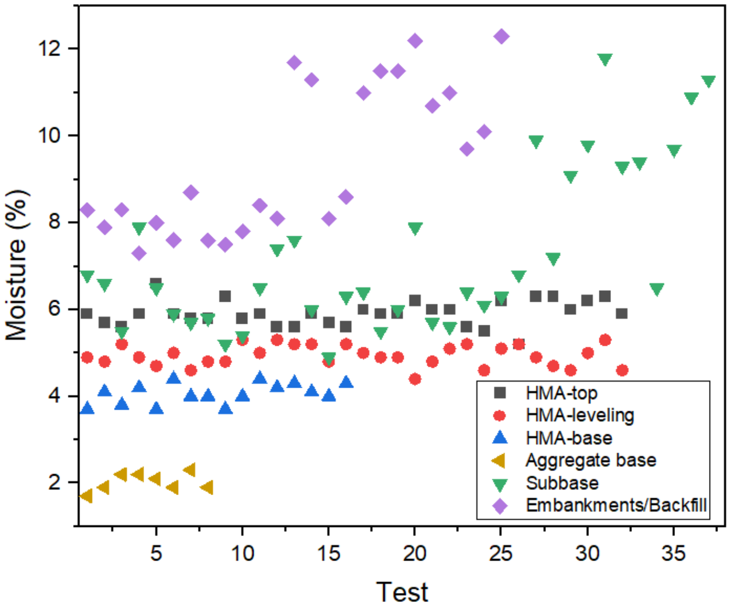


Figure 12. Moisture for different M-84 SB pavement layers

According to the testing results on the percent of compaction of different M-84 SB pavement layers, the compaction of the tested HMA layers almost all meets the 92% minimal requirement. Only one test point of the tested HMA-base layer is slightly lower than the 92% criterion. The variance in compaction of HMA layers is small, indicating that the compaction process on M-84 SB HMA is uniform and well controlled. The tested subbase compaction range is larger than that of the HMA layers, with 5 out of 37 total test points falling below the 95% criterion. The compaction for tested subgrade (embankment/backfill) is slightly better than that for the subbase, with only one test point below the 95% criterion. Note that aggregate base max dry density was not obtained which was likely due to density testing challenges as according to the original test records.

Accordingly, the percent compaction could not be determined. However, conservatively, at least half of the 8 tests appear to achieve 98% compaction. Therefore, the density requirements for all M-84 SB layers appear to be largely achieved with very few exceptions.

The moisture levels for tested M-84 SB pavement layers indicate that the tested subbase and subgrade (embankments/backfill) areas exhibit similar higher moisture levels compared to other layers. The tested aggregate base material shows the lowest moisture content. The order of moisture levels for HMA layers is HMA-top course, followed by the HMA-leveling course, and HMA-base course with the lowest moisture level.

In addition to the density testing, stiffness and Young's modulus were tested for the aggregate base using GeoGauge testing, as shown in Figure 13. The original record with the test location information is shown in Appendix D, Figure 90. The results indicate that the average Young's modulus for the M-84 SB aggregate base layer is approximately 28.5 ksi, with a minimum of 16.85 ksi. Considering that the resilient modulus used for the aggregate base in the design process is 25 ksi, the base material generally meets the requirement. It should be noted that GeoGauge is not currently used by MDOT to measure strength parameters, so this data is for informational purposes only.

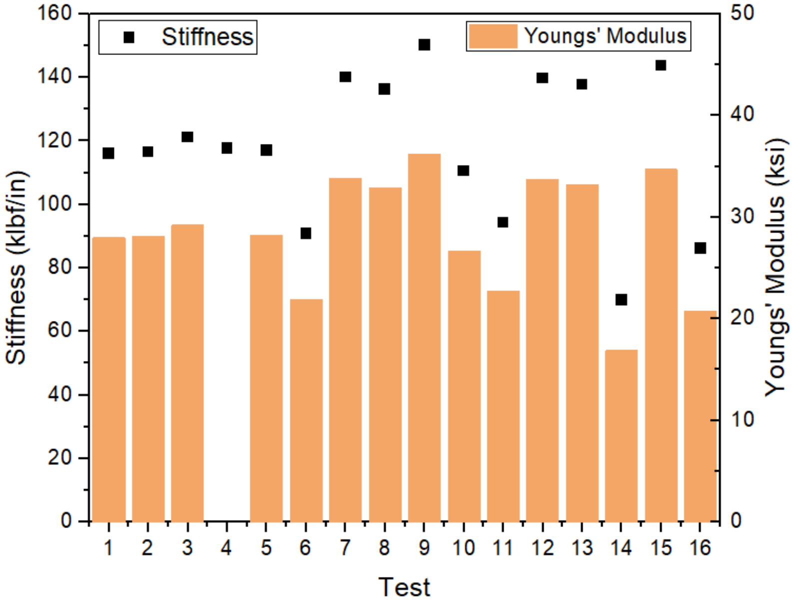


Figure 13. Stiffness and modulus for M-84 SB aggregate base layer

For I-96 WB, moisture and density tests for the reclaimed (existing) subbase were conducted during construction in 2005 using the nuclear method, as depicted in Appendix D, Figures 94-96. According to the tests, compaction of the tested subbase all exceed the 95% minimum requirement. The in-place moisture content was 6.0 to 8.0 percent. In addition to the density testing, the associated aggregate inspection for soil classification of the material was conducted as shown in Appendix D, Figure 97. Accordingly, the subbase meets acceptable MDOT Class IIA subbase material. Additional soil classification testing was conducted for the sand subbase, as shown in Appendix D, Figures 102-104. This tested subbase material is consistent with the samples taken for density testing as it also meets the MDOT specifications for Class IIA subbase. Further soil classification testing was conducted for the non-stabilized and lime stabilized subgrade samples, with the results displayed in Appendix D, Figures 98-101. The soil classification test results are summarized in Table 20. As shown, the subgrade stabilization appears to have improved the material quality such that it is classified as an improved material type with less fines (as expressed by the percent passing the #200 sieve).

Table 20. Soil classification summary of the I-96 WB samples

Material	Station	Offset	Percent Passing #100 Sieve	Loss by Wash Percent Passing #200 Sieve	Liquid Limit	Plasticity Index	Natural Moisture Percentage by Weight	Classification
Subgrade	314+25	Center of middle lane	83	78	39	22	19.1	Lean Clay with Sand (CL)
Subgrade	317+00	Center of rightmost lane	83	77	40	22	20.0	Lean Clay with Sand (CL)
Stabilized Subgrade	314+25	18-feet left of centerline	58	49	38	16	20.0	Sandy Silt (ML)
Stabilized Subgrade	317+00	42-feet left of centerline	57	50	38	10	22.9	Clayey Sand (SC)
Reclaimed (existing) Subbase	314+00 to 315+66	-	25	9.7	-	-	-	Meets MDOT Class IIA
Reclaimed (existing) Subbase	315+66 to 317+33	-	25	10.3	-	-	-	Meets MDOT Class IIA
Reclaimed (existing) Subbase	317+33 to 319+00	-	18	8.9	-	-	-	Meets MDOT Class IIA

To further evaluate these materials and to assess the initial pavement construction and subgrade strength characteristics on NB M-84, Falling Weight Deflectometer (FWD) testing was conducted on M-84 NB in May 2005, encompassing both the outside and inside lanes. The results shown in Figures 14 and 15 depict the measured deflections along the length of the project for both the NB inside and outside lanes. Note that station length measurements are in metric and begin near College Drive. The maximum deflection at 0 inches (load plate) is indicative of the strength of the entire pavement structure, while the maximum deflection at 60 inches is used to estimate the strength of the subgrade. Analysis of the FWD data unveiled varying deflection patterns along the project's length, with notably high deflections observed near specific locations such as the Contractor Yard (1,300-feet south of Freeland Road), Box Culvert (350-feet south of Kara Drive), Kara Drive, and Amelith Road areas. These notable areas could indicate potential issues, but these are relative to the project itself and do not necessarily indicate poor strength, so as discussed in the following condition sections, these areas were not found to exhibit uniquely different performance. Generally, even those areas with the highest deflection are fair for both the pavement structure and its subgrade.

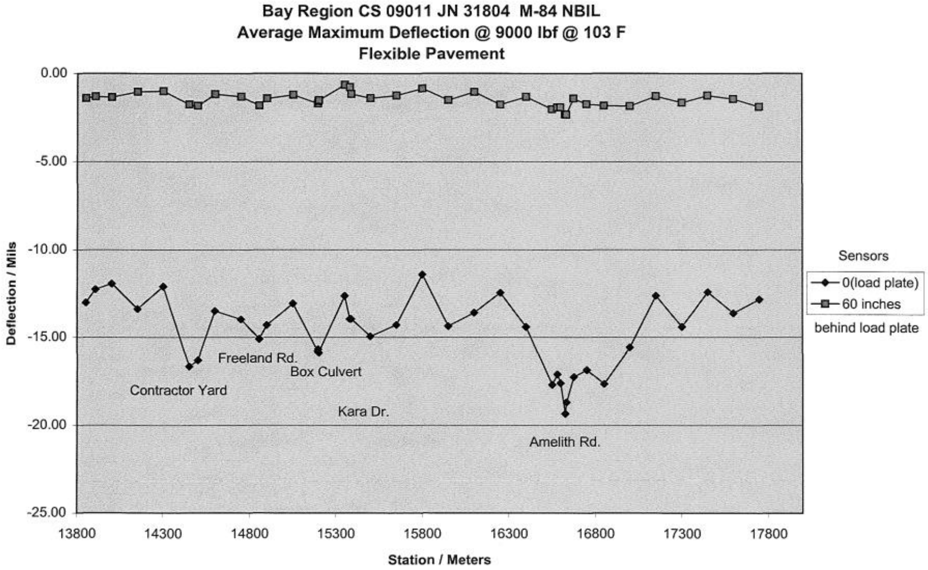


Figure 14. Average maximum deflection data for the M-84 NB inside lane

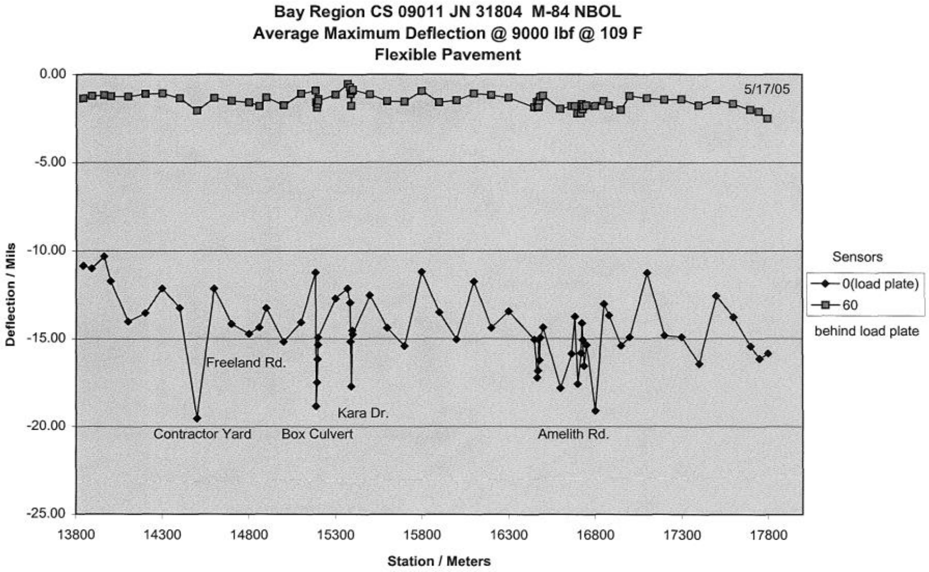


Figure 15. Average maximum deflection data for the M-84 NB outside lane

For the I-96 project, FWD at construction was not available, but according to the office memorandum in 2001 to describe soil conditions, the in-situ subgrade soil classification is 72% Firm Silty Clay, 18% Plastic Silty Clay, and 9% Soft Silty Clay, with 3,000 psi estimated resilient modulus for 1993 AASHTO pavement design. See Appendix D, Figures 91-93 for more details. This is lower quality subgrade material, but serviceable as a construction platform. Still, given its low quality, stabilizing was warranted. As a result, the subgrade support and its consistency are significantly improved from these initial estimations. This is confirmed by the soil classification tests conducted during construction as previously noted.

In addition to the material properties, a crucial structural component for performance of the constructed perpetual pavement is the thickness of HMA. Adequate pavement thickness will reduce fatigue cracking and avoid functional maintenance within the design period. Ground

Penetrating Radar (GPR) tests were conducted on the M-84 and I-96 WB (local and express) pavement projects to measure the thickness of the HMA layers. It should be noted that GPR measurements are estimates since core data is not available to confirm them. However, M-84 cores taken in 2020 show that average thicknesses correlate with the GPR measurements.

For the M-84 project, thickness data for an approximately 15,700-foot (2.97-mile) pavement section, measured at 10-foot intervals, was collected in both NB and SB directions. The scatter and distribution of HMA thickness for the M-84 NB standard pavement are presented in Figures 16 and 17, while Figures 18 and 19 show the M-84 SB perpetual pavement thicknesses. The distance of 0 feet refers to the starting point at the southern end, with the distance increasing towards the northern endpoint.

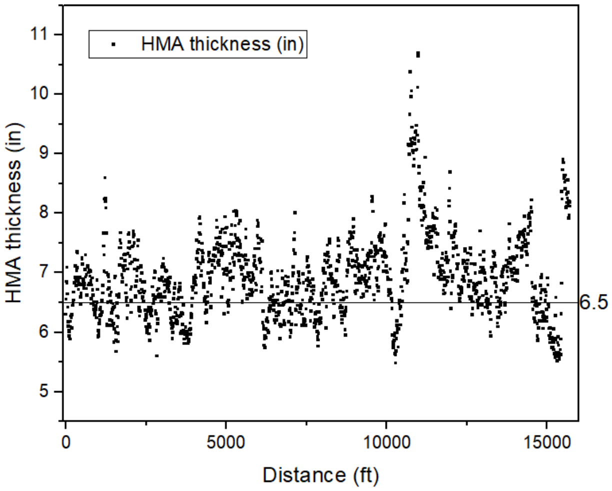


Figure 16. HMA thickness along the distance for the M-84 NB standard pavement

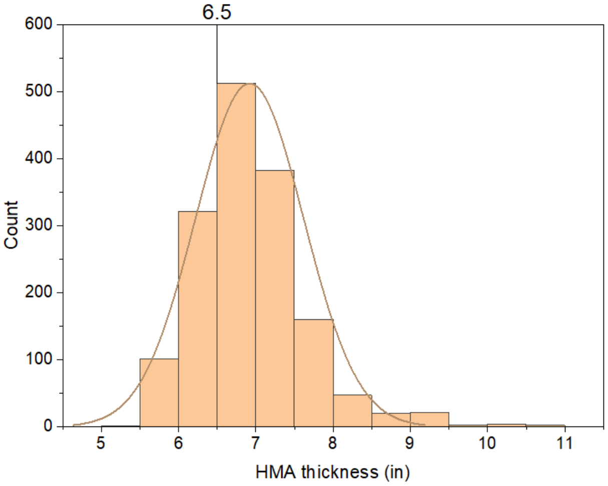


Figure 17. HMA thickness distribution for the M-84 NB standard pavement

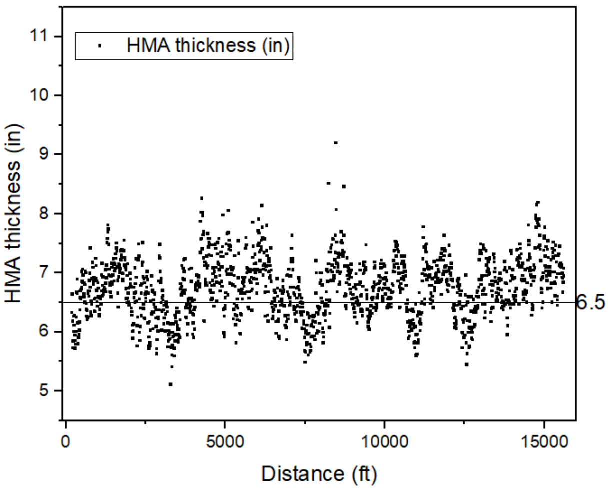


Figure 18. HMA thickness along the distance for the M-84 SB perpetual pavement

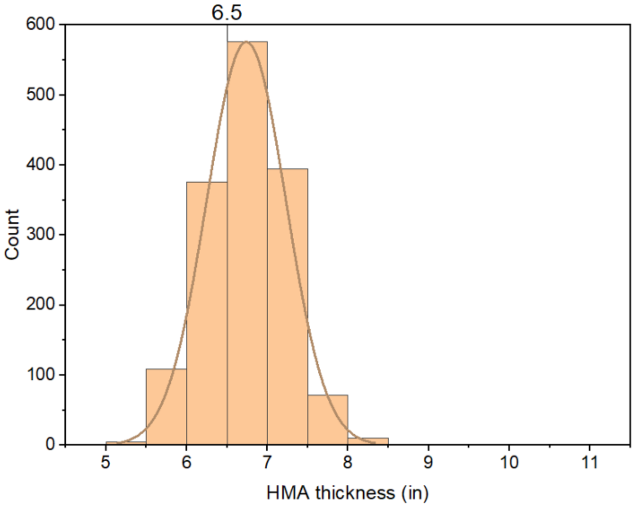


Figure 19. HMA thickness distribution for the M-84 SB perpetual pavement

According to the thickness data for M-84, most of the pavement on both bounds meet or exceed the designed 6.5-inch thickness. The NB standard pavement has an average thickness of 6.92-inches, while the SB perpetual pavement has an average thickness of 6.74-inches. Of the tested pavement locations, 73% and 68% are at least 6.5-inches thick for the NB standard pavement and SB perpetual pavement, respectively. For the SB perpetual pavement, 32% of tested locations are less than 6.5-inches, most of these are still at least 6-inches thick with only 7% of tested locations less than 6-inches. For the SB perpetual pavement, thinnest paved areas are north of College Dr. to 500-feet north of the first turnaround north of College Dr. and 500-feet north and south of Matthew Dr. For the NB standard pavement, thinnest paved areas are from the northernmost turnaround to 500-feet north and 1000-feet south of Amelith Rd. to 500-feet south of Amelith Rd. However, as will be further discussed int the following sections, it should be noted that there was no discernable difference in pavement performance at these locations.

For the I-96 project, thickness data for a 10,240-foot (1.94-mile) pavement section, measured at 10-foot intervals, were collected starting at the east endpoint, near Schaefer Rd (0-feet) and ending at the west endpoint, near the bridge for M-39 (10,240-feet). The scatter and distribution of HMA thickness for the express lane are presented in Figures 20 and 21, while those for the local lane are presented in Figures 22 and 23.

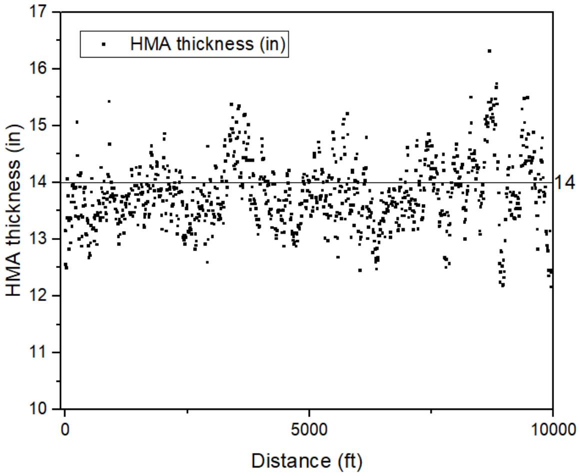


Figure 20. HMA thickness along the distance for the I-96 WB express lane section

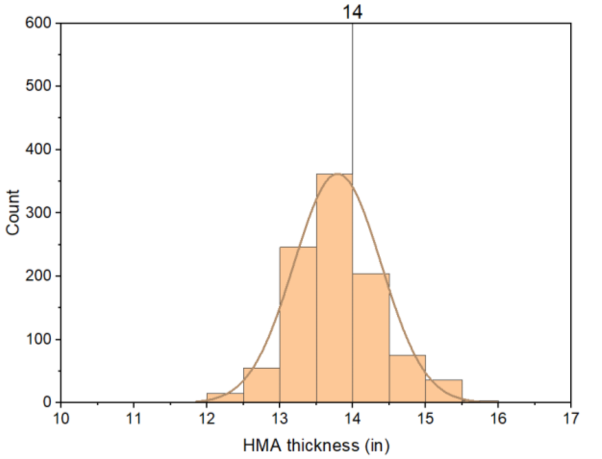


Figure 21. HMA thickness distribution for the I-96 WB express lane section

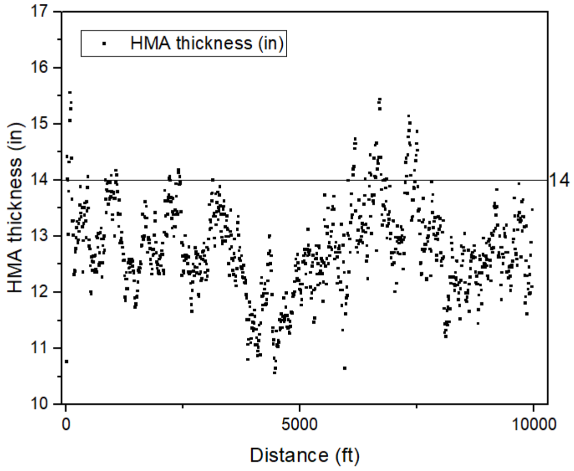


Figure 22. HMA thickness along the distance for the I-96 WB local lane section

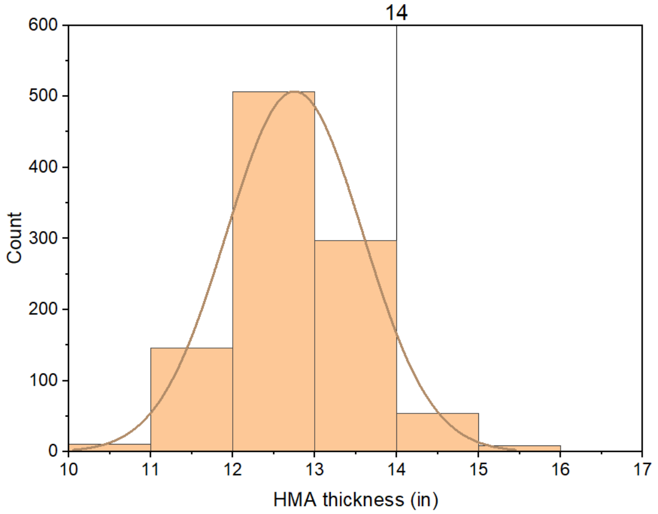


Figure 23. HMA thickness distribution for the I-96 WB local lane section

The thickness data for the I-96 project reveals that most pavement sections do not meet the designed 14-inch thickness, especially for the local lanes. The express lane pavement has an average thickness of 13.79-inches, while local lane pavement has an average thickness of 12.76-inches. Of the tested pavement locations, 32% and 6% are at least 14-inches thick for the express and local pavement, respectively. For the express pavement, thinnest paved areas from the start of the most west off ramp for the local lanes (to Evergreen Rd.) to its 22-foot point. For the local pavement, the thinnest paved areas from the start of the off ramp for Greenfield Road to the Greenfield Road overpass. It's important to note that there may be some variability in the GPR measurements as these can be influenced by the equipment and data processing. Nevertheless, insufficient thicknesses for I-96 WB may accelerate the development of pavement distress, most notably for the local lanes.

In summary, almost all construction-related sampled materials for both the M-84 and I-96 meet or exceed the requirements for material classifications, moisture levels, densities, and strength characteristics. Additionally, M-84 meets the design requirements for pavement thickness. However, test results for I-96 reveal a notable deficiency in its pavement thicknesses. As a result, there are no notable construction concerns for M-84, whereas I-96 findings suggest that its pavement thicknesses may not adequately resist bottom-up fatigue cracking and could experience accelerated distress. It is important to note that this summary does not consider the construction density of the HMA longitudinal joints since these were not measured or documented in the construction records. This is notable since these joints were found to be a performance issue for I-96. Since the construction of I-96, MDOT has implemented changes to its construction requirements to ensure the density of the longitudinal construction joints, aiming to prevent long-term performance issues.

Pavement Condition Data Analysis

For MDOT roadways, pavement condition (used for performance assessment) for each project is measured by a variety of methods, including rutting, MDOT's Distress Index (DI), and International Roughness Index (IRI). Rutting is the difference in elevation across the pavement surface plane defined by its transverse cross slope, measured in each wheel path separately in inches. The DI measurement is the total accumulated distress point value for a given pavement section normalized to a 0.1-mile length, collected per a sampling of the 0.1-mile length. It is a unitless value that indicates a pavement's 2-dimensional surface distress condition (so faulting and rutting are not included). The IRI measurement is the roughness of the road profile in inches/mile (so that physical distresses such as faulting and rutting can impact its measurement).

Condition data measurements are to be taken in the rightmost lane (outside lane) unless this lane was unavailable due to construction or other lane obstruction. Lane configurations for the M-84 and I-96 projects are presented in Figures 24 and 25, respectively.

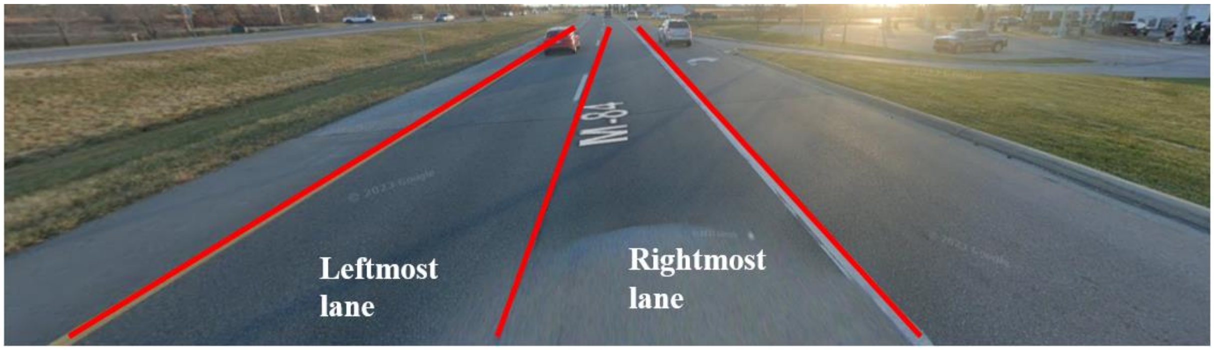


Figure 24. Lane configuration for M-84 SB, Google Maps Image, 2023

(a) Express lanes

(b) Local lanes

Figure 25. Lane configuration for I-96 WB, Google Maps Image, 2023

Note that historically through 2019, MDOT network-level data collection for DI, IRI, and rut-or-fault was intended to be obtained every other year for any given route segment (including both directions of divided routes). However, the following is a list of exceptions to that biennial schedule:

- Starting in 2009, the annual IRI collection began in at least one direction of all National Highway System (NHS) routes.
- Starting in 2018, the annual IRI collection on at least one direction of all NHS routes was reduced to only Interstate routes.
- Also, starting in 2018, the annual collection of DI and rut-or-fault began (in addition to IRI) on one direction of the Interstate routes.
- Schedules for data collection are subject to roadway availability, so construction or similar operations may prevent data collection for that anticipated year.

A summary of yearly IRI, rutting, and DI data for both bounds of the M-84 project are presented in Table 21 and Figures 26 to 28. Note that the data is separated into two subsections due to location milepoint identifiers that separate how the data is organized and output. The limits of subsections (1) and (2) are shown in Figure 1. As shown, subsection (1) is from Pierce Rd to approximately 1 mile north while subsection (2) begins where (1) ends to approximately 2 miles north (to the end). It is worth noting that the project area has experienced 3 crack treatment projects and occasional minor repair events that have been isolated to spot repairs, typically spanning less than 50 feet in length. Since this work is relatively minor, the overall pavement condition data is minimally impacted by these events.

The IRI data in Table 21 and Figure 26 indicates a consistent increase in roughness with pavement age for both the M-84 SB perpetual pavement and NB standard HMA sections. All subsections of the pavement have remained reasonably smooth, with the IRI consistently well below 170 inches/mile, which is the FHWA threshold for fair condition (per FHWA 23 CFR 490.313). Still, the IRI values in the SB sections are slightly lower than those in the NB sections, suggesting a smoother surface for the demonstration project. According to the FHWA threshold for good IRI condition, below 95 inches/mile (per FHWA 23 CFR 490.313), the SB perpetual pavement subsection (1) still remains within the good range and subsection (2) has remained good until age of 13 years. In comparison, the IRI values for the NB standard subsections (1) and (2) were considered good until 10 years and 12 years, respectively.

The data in Figure 27 shows that the overall average rutting is low for all M-84 subsections, remaining below 0.2 inches, which meets the FHWA threshold for good condition (per FHWA 23 CFR 490.313). Although early rutting values were relatively higher than later ones, this may be attributed to factors such as traffic compaction after construction and/or data noise. Both bounds indicate a strong structure as average rutting values have remained low. There are minimal discernable trends or differences between the two bounds.

As shown in Figure 28, all subsection DI values remain low, far below 50 DI, which is the value used in the *MDOT Pavement Selection Manual* [3] to approximate the end of service life. This indicates that both bounds of the project have been in good to fair condition. Comparing the sections, before year 9, the DI between the SB perpetual sections and NB standard sections are quite similar. However, thereafter, the SB subsections DI values begin to exhibit slightly higher

DI values than the NB subsections. Still, the NB subsections show steeper slopes in DI increase, which may indicate a more rapid rate of deterioration of the NB standard HMA pavement in the future years. As a result, the M-84 SB perpetual pavement seemingly exhibits more favorable long-term DI values compared to the NB standard pavement. Nonetheless, the most recent DI values for all subsections are quite similar, suggesting comparable DI for both bounds.

Table 21. Yearly progression of IRI, rutting, and DI for the M-84 project

Data Year (Pavement Age of SB) *	**Pavement section**											
	SB (Perpetual) Subsection (1)			**SB (Perpetual) Subsection (2)**			**NB (Standard) Subsection (1)**			**NB (Standard) Subsection (2)**		
	IRI	**Rutting**	**DI**	**IRI**	**Rutting**	**DI**	**IRI**	**Rutting**	**DI**	**IRI**	**Rutting**	**DI**
2006 (1)	57	0.13	0	-	-	-	73	0.12	0.01	79	0.09	0.04
2007 (2)	-	-	-	65	0.11	0.18	-	-	-	63	0.09	0.01
2008 (3)	58	0.14	0.01	-	-	-	73	0.12	0.26	-	-	-
2009 (4)	-	-	-	-	-	-	76	0.14	-	63	0.12	-
2010 (5)	63	0.16	3.17	66	0.15	3.39	75	0.15	2.06	65	0.13	-
2011 (6)	-	-	-	-	-	-	79	0.17	-	70	0.14	-
2012 (7)	62	0.06	1.25	71	0.05	1.65	79	0.07	3.06	69	0.06	1.85
2013 (8)	-	-	-	-	-	-	82	-	-	71	-	-
2014 (9)	77	0.09	3.57	80	0.07	5.64	94	0.08	3.57	82	0.06	4.42
2015 (10)	-	-	-	-	-	-	99	-	-	88	-	-
2016 (11)	82	0.09	13.07	88	0.07	13.17	103	0.09	6.21	94	0.07	9.32
2017 (12)	-	-	-	-	-	-	108	-	-	97	-	-
2018 (13)	88	0.07	22.22	102	0.05	22.66	115	0.06	22.92	106	0.04	25.31
2019 (14)	-	-	-	-	-	-	-	-	-	-	-	-
2020 (15)	-	-	-	-	-	-	-	-	-	-	-	-
2021 (16)	94	0.13	-	107	0.10	-	126	0.09	-	115	0.07	-
2022 (17)	-	-	-	-	-	-	-	-	-	-	-	-

* The pavement age corresponds to the SB perpetual pavement section. For the NB standard pavement, the age should be adjusted by adding 1 year since it was completed one year earlier.

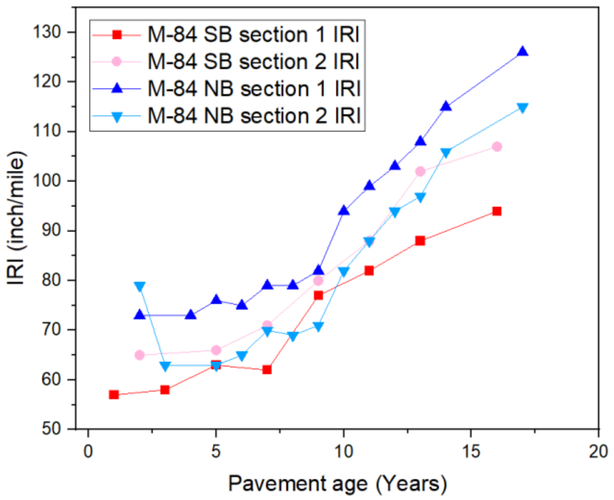


Figure 26. Yearly IRI data for the M-84 project

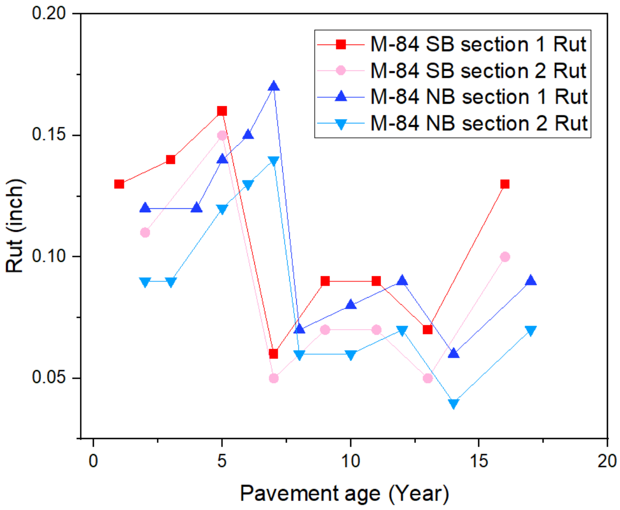


Figure 27. Yearly rutting data for the M-84 project

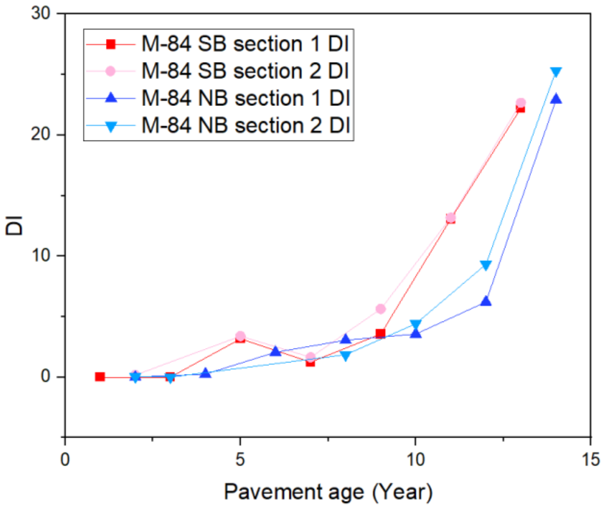


Figure 28. Yearly DI data for the M-84 project

To identify distinct areas of pavement performance, detailed breakdown of the latest pavement DI (in 2018) per tenth mile along the M-84 project length is shown in Table 22 and visually shown in Figure 29. Accordingly, the DI along the M-84 SB perpetual pavement project is shown to be mostly evenly distributed, with standard deviations of 6.6 for SB and 7.1 for NB. This mostly even distribution in DI data indicates that the performance of the M-84 project is relatively uniform along the entire distance. Overall, the NB standard HMA section generally shows a higher DI compared to the SB perpetual section at the same milepoint. This suggests that SB may be outperforming NB. However, it is important to consider that SB is one year younger than NB, so this may change when SB reaches the same age as NB.

Table 22. M-84 pavement DI per 0.1 mile in 2018

Pavement Length (Mile, South to North Direction) *	M-84 SB (Perpetual)	M-84 NB (Standard)
0.1	11.025	22.09
0.2	21.275	26.34
0.3	19.48	20.37
0.4	31.22	35.185
0.5	19.96	23.835
0.6	17.585	21.875
0.7	21.465	28.57
0.8	17.815	19.275
0.9	29.48	14.215
1.0	32.182	18.423
1.1	27.49	35.265
1.2	31.185	37.795
1.3	33.765	21.56
1.4	19.05	24.4
1.5	14.695	24.885
1.6	15.51	29.3
1.7	21.16	23.785
1.8	23.835	15.525
1.9	11.36	35.21
2.0	21.51	25.07
2.1	17.655	26.33
2.2	17.685	24.215
2.3	21.29	24.46
2.4	35.025	13.595
2.5	30.695	15.805
2.6	17.69	15.4
2.7	24.945	16.48
2.8	21.335	23.63
2.9	26.74	38.9
Average	22.6	24.2

* 0 to 1.0 miles are per subsection (1) and 1.1 to 2.9 miles are per subsection (2).

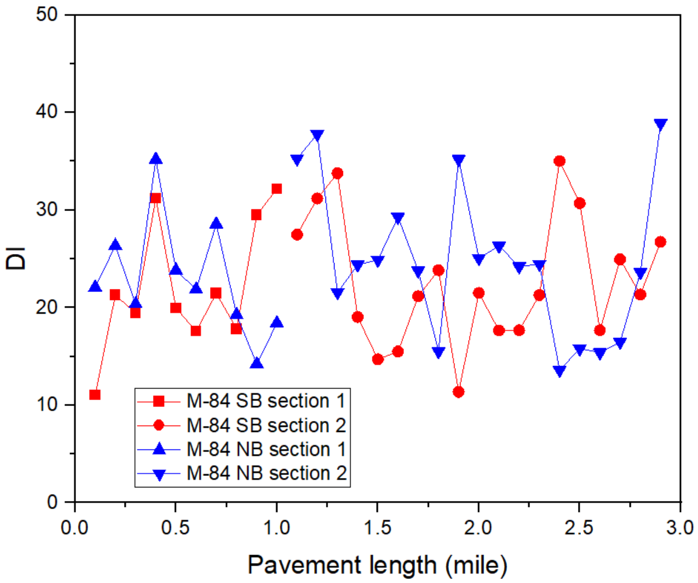


Figure 29. DI per 0.1 mile along the M-84 project

A summary of yearly IRI, rutting, and DI data for the I-96 project are presented in Table 23 and Figures 30 to 32. Condition data is separated by the local and express lane sections. It is worth noting that the project area has experienced repair events in 2020 and 2021 to repair segregation and raveling at the longitudinal construction joints between some of the lanes and shoulders. Since most of this work was not within the vehicle wheel paths, the pavement condition data for these two years are largely unaffected by these events.

As shown in Table 23 and Figure 30, both the local and express lane sections exhibit low IRI values as both sections consistently remained below the threshold for good condition of 95 inches/mile. The express section demonstrates a slightly lower IRI than the local lane.

Both the local and express sections demonstrate low rutting, measuring less than 0.2 inches, as shown in Figure 31. The express section exhibits slightly more rutting than the local lanes, but this is minimal. Overall, both sections indicate adequate structure as average rutting values have remained low.

Figure 32 shows that the DI remained very low for both sections throughout the first 12 years after construction. However, the last recorded DI for the express lane at age 14 shows a dramatic increase. Still, the DI for that year (13.11) still indicates satisfactory conditions as this value is well below 50 DI. This single year DI increase could be attributed to the development of segregation and raveling at the longitudinal construction joints that were observed in field condition survey reviews as is discussed in the following section of this report. These types of excessive distress within the longitudinal construction joints will be included in DI measurements, but some of this may have been overly captured, even in areas with fair construction joints. Therefore, additional DI after 2019 would be beneficial to verify the accuracy of the DI increase found in 2019.

Table 23. Yearly Progression of IRI, rutting, and DI for the I-96 WB project

Data Year (Pavement Age)	I-96 WB (Local)			I-96 WB (Express)		
	IRI	Rutting	DI	IRI	Rutting	DI
2006 (1)	-	-	-	-	-	-
2007 (2)	77	0.12	0.20	77	0.14	0.01
2008 (3)	-	-	-	-	-	-
2009 (4)	81	-	2.73	80	0.16	0.05
2010 (5)	-	-	-	-	-	-
2011 (6)	87	-	4.25	79	0.18	5.53
2012 (7)	-	-	-	-	-	-
2013 (8)	87	0.08	0.14	82	0.10	3.27
2014 (9)	-	-	-	-	-	-
2015 (10)	89	0.08	0.69	84	0.10	0.11
2016 (11)	-	-	-	-	-	-
2017 (12)	87	0.11	0.46	84	0.11	1.67
2018 (13)	-	-	-	-	-	-
2019 (14)	93	0.06	-	87	0.08	13.11
2020 (15)	-	-	-	-	-	-
2021 (16)	-	-	-	79	0.09	-
2022 (17)	92	0.11	-	-	-	-

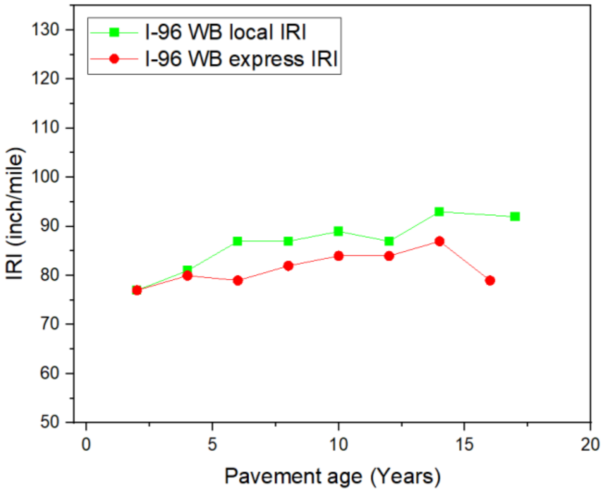


Figure 30. Yearly IRI data for the I-96 WB project

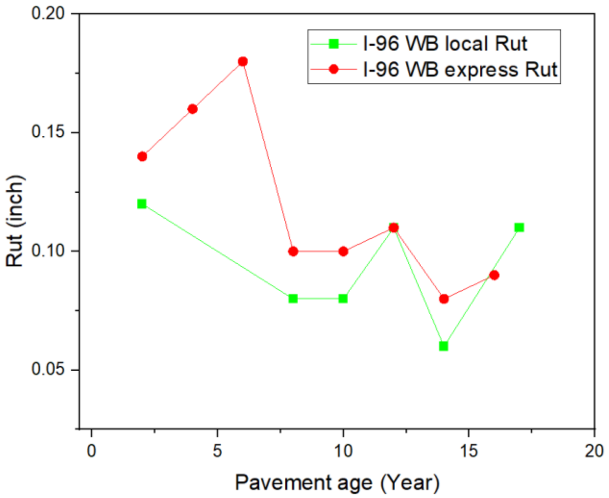


Figure 31. Yearly rutting data for the I-96 WB project

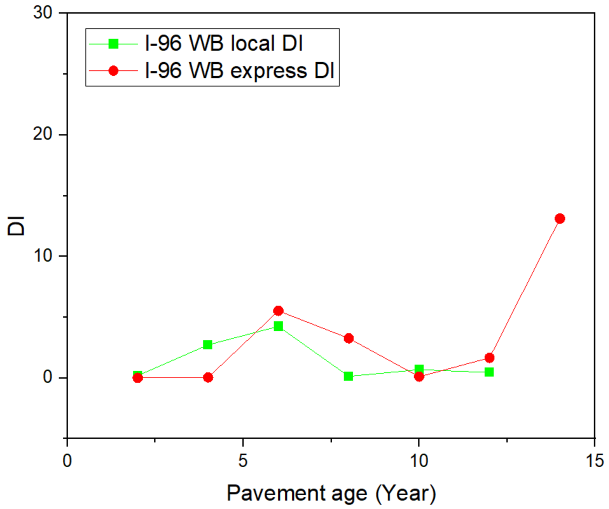


Figure 32. Yearly DI data for the I-96 WB project

To identify distinct areas of pavement performance, detailed breakdown of the latest pavement DI (in 2019) per tenth mile along the I-96 project length is shown in Table 24, with corresponding visual representation in Figure 33. Note that the local lane section is not shown because DI data was not measured in 2019 and due to its very low values in 2017, its relative differences are low and would not show identifying differences along the route. As shown, the DI along the I-96 WB express section tends to be relatively high near M-39 and its off ramps but decreases as it progresses to the east. This could be attributed to variations in traffic control measures and/or constructability issues near this transition area of the project.

Table 24. I-96 WB pavement DI per 0.1 mile in 2019

Pavement Length (Mile, West to East Direction)	I-96 WB Express Section
0.1	5.625
0.2	14.005
0.3	22.62
0.4	17.64
0.5	26.3
0.6	38.84
0.7	14.88
0.8	7.4
0.9	7.065
1.0	6.8
1.1	8.28
1.2	7.56
1.3	7.46
1.4	11.485
1.5	7.12
1.6	7.18
1.7	15.06
1.8	11.16
1.9	9.5
2.0	16.89
Average	13.1

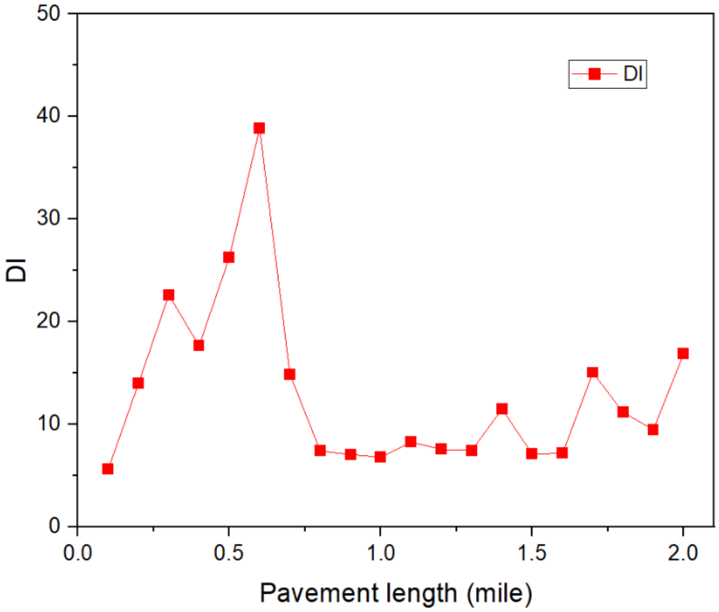


Figure 33. DI per 0.1 mile along the I-96 WB express section

Pavement Condition Survey Findings

Annual pavement condition field assessments of all MDOT demonstration projects are documented in the MDOT Pavement Demonstration Program Legislative Status Report, *Pavement Demonstration Program Status Report Public Act 457 of 2016* [4]. Typically, this annual report includes a summary of visual distress conditions, including cracking and repairs. These reports are derived from the field survey notes. As an example, the 2022 field evaluation notes are shown in Appendix E. Survey pictures are shown in Appendix F. Annual surveys collected data in all mainline through lanes (excluding ramps and turn lanes) of the two projects, so the pavement condition data measurements (used for performance assessments) may not be directly comparable to the annual site surveys since condition data measurements are taken in one lane. Note that observed crack lengths exclude those at the longitudinal construction joint since this is a common crack occurrence due to construction operations and may not indicate the pavement's structural characteristics. The survey on the M-84 project includes both the NB standard and SB perpetual sections from 2007 to 2022 for comparison. Key survey observations for both directions in each survey year are summarized in Table 25.

Table 25. Summary of the M-84 perpetual demonstration program status reports

Report Date	Key Observations
Jan. 2007	Both Directions: Pavement in as-constructed condition with no distress.
Jan. 2008	Both Directions: Several short areas, in both directions, were milled and resurfaced during construction, to improve ride quality. NB: 1 minor transverse crack observed. SB: No distresses was noted.
Feb. 2009	Both Directions: Construction related longitudinal cracking observed at the paving joints. NB: 15 transverse cracks observed (previously filled in 2008). SB: No distresses was noted.
Mar. 2010	NB: 29 transverse cracks observed, 337-feet total length. SB: 3 minor transverse cracks observed, 16-feet total length.
Feb. 2011	NB: Minimal increase in transverse cracking from 2010. SB: No change from 2010.
Jan. 2012	NB: Significant increase in transverse cracking to 848-feet total length. SB: Significant increase in transverse cracking to 218-feet total length. However, many of these cracks are short.
Feb. 2013	Both Directions: Note that this year's crack counts included turn lanes. NB: Transverse cracking was 959-feet in total length. SB: Transverse cracking was 388-feet in total length. Most of this cracking is at and near turnaround left lanes.
Jan. 2014	NB: Transverse cracking increased to 1,782-feet total length with less than 200 feet of longitudinal cracking observed. SB: Transverse cracking increased to 514-feet total length with less than 30 feet of longitudinal cracking observed.
Jan. 2015	Both Directions: Note that this year's crack counts focused on unsealed cracking because this was representative of the new cracking from the previous year. NB: Unsealed transverse cracking increased to 2,710-feet total length. SB: Unsealed transverse cracking increased to 1,318-feet total length.

Jan. 2016	NB: Transverse cracking increased by 3,054-feet to 7,512-feet in total length. Longitudinal cracking was 75-feet total length. SB: Transverse cracking significantly increased by 6,336-feet to 8,216 total length. This is an increase of 336 percent. Longitudinal cracking was 24-feet total length.
Jan. 2017	NB: Transverse cracking increased by 2,911-feet. Longitudinal cracking was 126-feet total length. SB: Transverse cracking increased by 4,900-feet. Longitudinal cracking was 165-feet total length.
Jun. 2018	NB: Transverse cracking increased by 2,990-feet. Longitudinal cracking was minimal. SB: Transverse cracking increased by 600-feet. Longitudinal cracking was minimal.
Jun. 2019	NB: Transverse cracking increased by 269 feet/lane-mile. Transverse cracks are widening. Longitudinal cracking was minimal. SB: Transverse cracking increased by 1,029 feet/lane-mile. While this increase is higher than NB, the cracks are consistently narrower. Longitudinal cracking was minimal.
Jun. 2020	NB: Transverse cracking increased by 217 feet/lane-mile. Transverse cracks continue widen with some faulting at these cracks. Longitudinal cracking was minimal. SB: Transverse cracking increased by 351 feet/lane-mile. Cracks continue to remain narrow. Longitudinal cracking was minimal.
Jun. 2021	NB: Transverse cracking increased by 126 feet/lane-mile. Transverse cracks continue widen with some faulting at these cracks. Longitudinal cracking remains low. SB: Transverse cracking increased by 513 feet/lane-mile. Cracks continue to remain narrow. Longitudinal cracking remains low.
Jun. 2022	NB: Transverse cracking increased by 71 feet/lane-mile to 2,534 feet/lane-mile in total. Transverse cracks are wider than SB with some faulting at these cracks. Longitudinal cracking remains low. SB: Transverse cracking increased by 699 feet/lane-mile to 4,654 feet/lane-mile in total. Cracks continue to remain narrow. Longitudinal cracking remains low.

For further details, Table 26 provides comprehensive data on pavement cracking (including transverse and longitudinal types) per lane-mile, as well as pothole distresses observed on both bounds of M-84 since 2014 (age of 9 years), (with exception of 2018 since its raw data could not be confirmed). This table highlights recent-year data, particularly showing the inflection of crack propagation. As shown, longitudinal cracking is minimal and stable in both directions of M-84 project, so both sections seem to be resisting fatigue cracking. However, as shown in Figure 34, transverse cracking per lane-mile since 2017 (age of 12 years) has been very high for both sections. Transverse cracking on the M-84 SB perpetual section was lower than that on the NB standard prior to 2016, but has remained higher than NB after 2016. According to the survey reports, despite the SB perpetual pavement having a greater increase in transverse cracking after the year 2016, most of its cracks remain narrow (approximately 1/16th of an inch) and short (approximately 2’), while cracks on NB are much wider (approximately 1 inch) and longer (full width – 12’). Therefore, the observed transverse cracking in SB is likely limited to the surface, preserving the HMA sublayers, so the surface layer can be milled and resurfaced to eliminate most of this cracking. Yet, for NB, since these cracks are much wider, milling with resurface will be less effective, so cracks are likely to reemerge faster, lowering the overall pavement service life. Therefore, overall, while both bounds are performing poorly in thermal cracking, the latest field survey annual reporting has described the SB perpetual pavement overall structural performance as good. It should be noted that annual reporting condition ratings of good, fair, and/or poor are assigned to each project based on a subjective evaluation of the condition at the time of the latest field visit and are only intended to provide a general sense of the performance (in terms of anticipated distress and ride quality per the design type), so this qualifier may not reflect the final recommendation of this pavement after all relevant information is obtained to make a final determination.

Table 26. Yearly cracking and pothole distress for the M-84 project

Year	Pavement Age*	NB (Standard)			SB (Perpetual)		
		Transverse Cracks (feet/ lane-mile)	Longitudinal Cracks (feet/ lane-mile)	Potholes (total number)	Transverse Cracks (feet/ lane-mile)	Longitudinal Cracks (feet/ lane-mile)	Potholes (total number)
2014	9	298	-	-	86	-	-
2015	10	746	-	-	313	-	-
2016	11	1,257	13	-	1,369	4	-
2017	12	1,744	21	-	2,185	27	-
2018	13	-	-	-	-	-	-
2019	14	2,119	-	-	3,092	-	-
2020	15	2,337	28	3	3,442	27	3
2021	16	2,463	157	2	3,955	48	8
2022	17	2,534	104	4	4,654	63	3

* The pavement age corresponds to the SB perpetual pavement section. For the NB standard pavement, the age should be adjusted by adding 1 year since it was completed one year earlier.

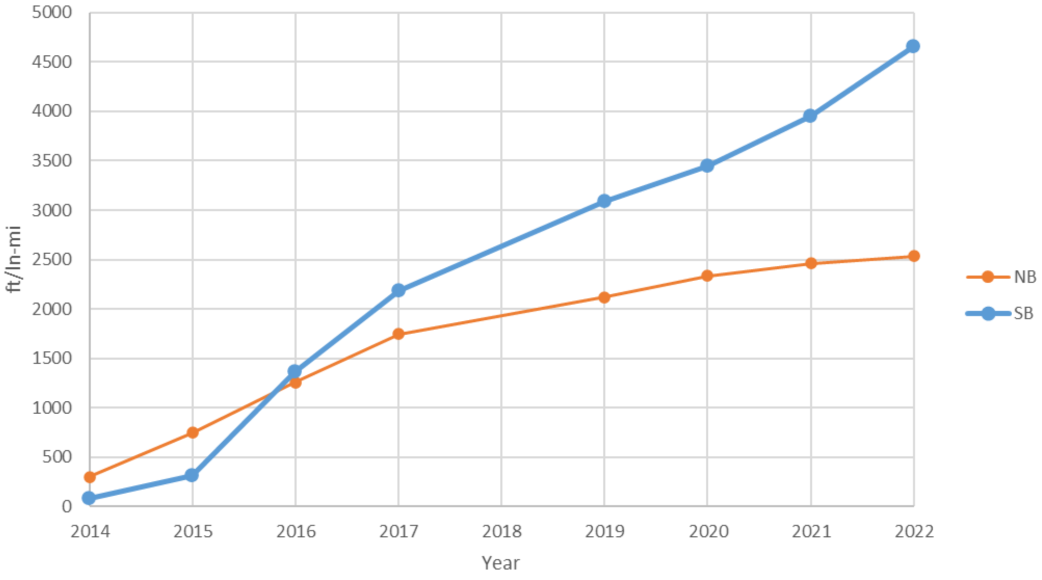


Figure 34. Yearly transverse cracking per lane-mile of the M-84 project

During April and May of 2020, in addition to the annual visual survey, additional assessments of the M-84 project were conducted through pavement coring and falling weight deflectometer (FWD) testing. Specifically, to confirm that transverse cracking was within the surface of the perpetual HMA pavement, 22 cores with 11 cores per direction were randomly extracted from evenly distributed transverse cracks within the outer lanes. The focus was on cracks with varying lengths and widths, excluding those exceeding a width of ¼ inch since these were assumed to be full depth. The coring locations along M-84 are shown in Figure 35.

The M-84 sampled core average results are presented in Table 27. An example of coring location and sample condition is illustrated in Figure 36. Per the cores, the mean pavement depth measured 6.73 inches for the NB samples and 6.77 inches for the SB samples. Notably, the NB lanes exhibited generally longer and broader cracks, with an average crack length of 7.6 feet and a width of 0.094 inches, compared with the SB lanes' averages of 6.2 feet and 0.075 inches, respectively. The average crack depth was similar for both directions, but SB was less than NB with a 5.4-inch average depth for SB versus 5.6-inches for NB. This result is expected since the distribution of all sampled cracks were those that were less than ¼-inches in width. Full-depth cracks were on average, 8.7-feet long whereas those of partial depth were 4.8-feet long. Since most of the cracks on SB are short (2' length) and narrow, this further suggests that most cracks on SB are partial depth and constrained to the surface course layer.

(a) NB (b) SB

Figure 35. 2020 coring locations for the M-84 project

(a) Location (b) core top view (c) core side view

Figure 36. Example of coring location and sample condition in M-84 SB coring

Table 27. Core cracking average results of the M-84 project

Direction	Crack Length (ft)	Crack Surface Width (in)	Pavement Thickness (in)	Crack Depth (in)
NB (standard)	7.6	0.094	6.73	5.58
SB (perpetual)	6.2	0.075	6.77	5.43

The FWD test covered 15,700 feet (2.97 miles) in the NB standard HMA pavement and 15,730 feet (2.97 miles) in the SB perpetual pavement sections. Figure 37 illustrates the M-84 corrected subgrade resilient modulus derived from the FWD tests, indicating similar modulus values at corresponding locations along both bounds of the M-84 project. On average, subgrade support slightly decreases from Pierce Road north to the Point of Ending (POE) in both directions. Notably, the SB direction exhibits marginally higher subgrade support than the NB direction, with average subgrade resilient modulus values of 7,387 psi and 7,064 psi, respectively. Despite the FWD tests being conducted under spring conditions, which typically lead to lower modulus values due to wet and softer conditions, the calculated values are relatively high. Minimum values remain fair (above 3,000 psi) and occur intermittently, indicating the absence of poor locations or lengths. The FWD subgrade resilient modulus values at the sampled crack locations reveal no discernible trends, suggesting that subgrade conditions are not impacting cracking or its propagation. Overall, the subgrade demonstrates good performance, and it is likely that cracking and its propagation are being most significantly influenced by the pavement material and is unrelated to subgrade conditions.

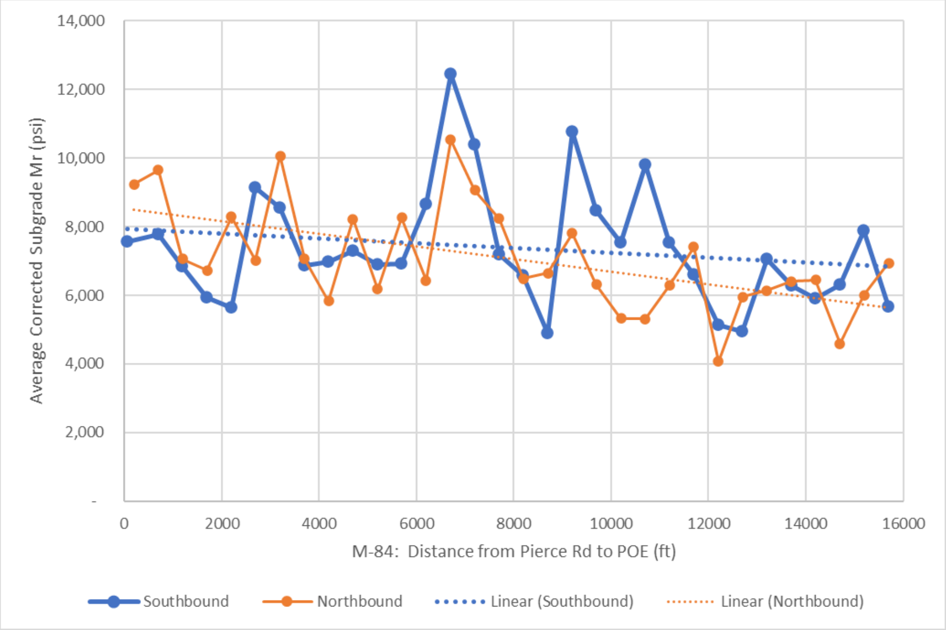


Figure 37. M-84 corrected subgrade resilient modulus

For the I-96 project, annual surveys were conducted on WB local and express lanes. Accordingly, observations on local and express sections were tracked separately. The key survey observations for each survey year are summarized in Table 28.

Table 28. Summary of the I-96 perpetual demonstration program status reports

Report Date	Key Observations
Jan. 2007	All lanes: Pavement in as-constructed condition with no distress.
Jan. 2008	All lanes: Pavement still in as-constructed condition with no distress.
Feb. 2009	All lanes: Pavement still in as-constructed condition with no distress.
Mar. 2010	Local: Possibly 3 faint cracks observed within a 15-foot section.
Feb. 2011	All lanes: No change from previous year.
Jan. 2012	All lanes: Construction related longitudinal cracking starting to appear at the paving joints.
Feb. 2013	All lanes: No change from previous year.
Jan. 2014	All lanes: Construction related longitudinal cracking increasing at the paving joints, specifically between the right lane and right shoulder. Local: Two straight transverse cracks, approximately 6 feet apart observed with settlement between them. It is unclear if this is due to recent utility work or loss of support over a utility trench.
Jan. 2015	All lanes: Construction related longitudinal cracking continues to increase at the paving joints, specifically between the right lane and right shoulder. Where echelon paving was used between the middle and right lanes, these longitudinal joints are still performing well. Express: The longitudinal construction joint between the left and middle lanes has intermittent locations with significant segregation.
Jan. 2016	All lanes: Construction related longitudinal cracking continues to increase at the paving joints. The longitudinal joints have been sealed with overband crack sealant. Express: Possibly two sealed longitudinal cracks observed in the leftmost lane.
Jan. 2017	All lanes: Mostly unchanged from previous year with the longitudinal construction joints exhibiting the most distress.
Jun. 2018	All lanes: Mostly unchanged from previous year. The longitudinal construction joints continue to show widening, specifically, the joint between the outside lane and the on/off ramps have significant segregation.
Jun. 2019	All lanes: Mostly unchanged from previous year with the longitudinal construction joints exhibiting the most distress. The observed pavement distress is very low for both sections.
Jun. 2020	All lanes: Overall, the observed pavement distress is very low for both sections. Local: Segregation and raveling of the longitudinal construction joint between the outside lane and the on/off ramps along the project length remains mostly stable, but there are some infrequent random longitudinal joint pop-outs between lanes. Express: Longitudinal joint separation and raveling observed between the leftmost and middle lanes. Also observed between the rightmost lane and right shoulder. Significant separation observed at two separate locations approximately 1,000-feet in length.
Jun. 2021	All lanes: The longitudinal construction joints continue to exhibit the most distress. Otherwise, the overall observed pavement distress is very low for both sections. Local: Segregation and raveling of the longitudinal construction joint between the outside lane and ramps are notably increasing, up to 2-feet wide. Other longitudinal joints between lanes are starting to separate. Express: A minor amount of intermittent repair patches was conducted prior to this year's review. This comprises about 0.5 percent of the surface area.
Jun. 2022	All lanes: A large amount of intermittent repair patches was conducted in both the local and express lane sections prior to this year's review. This comprises about 7.6 and 10.6 percent of the surface area of the local and express sections, respectively. Almost all patching was within the longitudinal joints (between lanes and the shoulders) to repair joint raveling and segregation. Overall, the observed pavement distress remains very low for both sections.

Detailed pavement cracking (transverse, longitudinal) per lane-mile and pothole distresses for both sections of I-96 since 2019 (age of 14 years) are shown in Table 29. As shown in this table and summarized by the key observations in Table 28, other than the construction related longitudinal joint segregation, both local and express lanes have exhibited very low amounts of cracking and potholes throughout its life. The express lane appears to have slightly more cracking than the local lanes, which could be attributed to differences in traffic and/or construction.

Table 29. Yearly cracking and pothole distress for the I-96 project

Year	Pavement Age	Local Lanes			Express Lanes		
		Transverse Cracks (feet/ lane-mile)	Longitudinal Cracks (feet/ lane-mile)	Potholes (total number)	Transverse Cracks (feet/ lane-mile)	Longitudinal Cracks (feet/ lane-mile)	Potholes (total number)
2019	14	0	0	2	6	0	10
2020	15	0	6	8	6	3	11
2021	16	0	7	18	21	30	27
2022	17	12	21	29	41	110	35

As of the most recent Demonstration Program Status Reports in both 2021 and 2022, the general condition of the pavement has largely remained stable, with some noteworthy developments. For all lanes, the longitudinal construction joints continue to separate and ravel. However, patching repairs at poor longitudinal joint areas have mitigated these issues. Otherwise, areas with limited sunlight beneath bridges, hindering water evaporation and leading to prolonged water exposure, have been found to have the most potholes. Despite these localized challenges, the overall performance of both pavement sections is classified as good. As previously noted, annual reporting condition ratings of good, fair, and/or poor are assigned to each project based on a subjective evaluation of the condition at the time of the latest field visit and are only intended to provide a general sense of the performance (in terms of anticipated distress and ride quality per the design type), so this qualifier may not reflect the final recommendation of this pavement after all relevant information is obtained to make a final determination.

Performance Comparison and Evaluation

A performance comparison was conducted to evaluate the relative pavement performance of the two full-depth reconstructed perpetual pavement demonstration projects against MDOT standard reconstructed HMA pavement as per data in the *MDOT Pavement Selection Manual* [3]. For comparison, the estimated fix life (estimated pavement life without maintenance per 50 DI) of the M-84 and I-96 pavement sections with standard pavement are shown in Figures 38 and 40, respectively. Note that the M-84 subsection annual DI values have been grouped together per each direction using the weighted average of their milepoint lengths. The service life (estimated pavement life with maintenance per 50 DI) of the standard pavement with the M-84 and I-96 DI values are shown on Figures 39 and 41, respectively. It should be noted that the demonstration project DI values may exhibit more variability than the statewide project values since its data is derived from a few project sections rather than a broad set of values.

As shown in Figure 38, the M-84 project has recorded enough data points to show a reasonable DI data trend with pavement ages, indicating fix lives of about 16 years for both bounds, which is approximately 2 years less than the standard alternative. The DI for the M-84 SB and NB sections remained relatively low within the first 10 years post-construction. However, the DI noticeably increased thereafter. It is noteworthy that limited structural distress in terms of longitudinal cracking was observed in both sections. However, the development of transverse cracking in both the SB and NB sections have likely contributed to the rapid increase in DI, as revealed in the condition field survey results. Despite the faster increase of transverse cracking in the SB perpetual pavement as compared to the NB standard section, the shorter and narrower width of cracks in the SB perpetual section indicates that most of its cracks are isolated to the top layer of HMA and do not penetrate the full depth. Thus, the upgraded materials in the M-84 SB perpetual pavement have been seemingly effective in reducing the severity of its cracking. Still, the DI values in the SB section may be overestimated, as the reduced severity of its transverse cracks may not be effectively accounted for within the calculation of its DI. Nevertheless, while the initial fix life projections of NB and SB are very similar, the subsequent maintenance events for SB should provide more years of service life beyond that of NB and result in lower long term DI values.

To date, M-84 has had 3 maintenance events over the last 18 years of service, which is the same as the standard alternative over that same timeframe. However, these have all consisted of crack treatments, which are relatively minor, so, the first substantial maintenance event (i.e. HMA overlay) has not yet occurred as is expected for standard HMA reconstruction. Nevertheless, per the projected fix life and raw number of maintenance events, the data indicates that the demonstration has about the same service life as that of the standard version, which would be 37 years. This is significantly less than the anticipated 50 years of service life, but as noted, the first substantial maintenance event has not yet occurred and it should be more effective, so 37 years is likely underestimated.

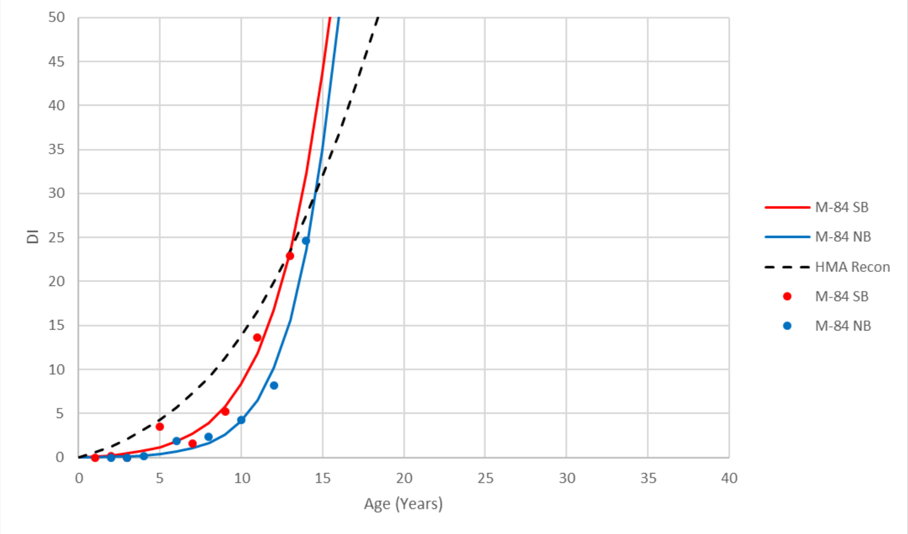


Figure 38. Comparison on M-84 DI trends with fix life of standard pavement

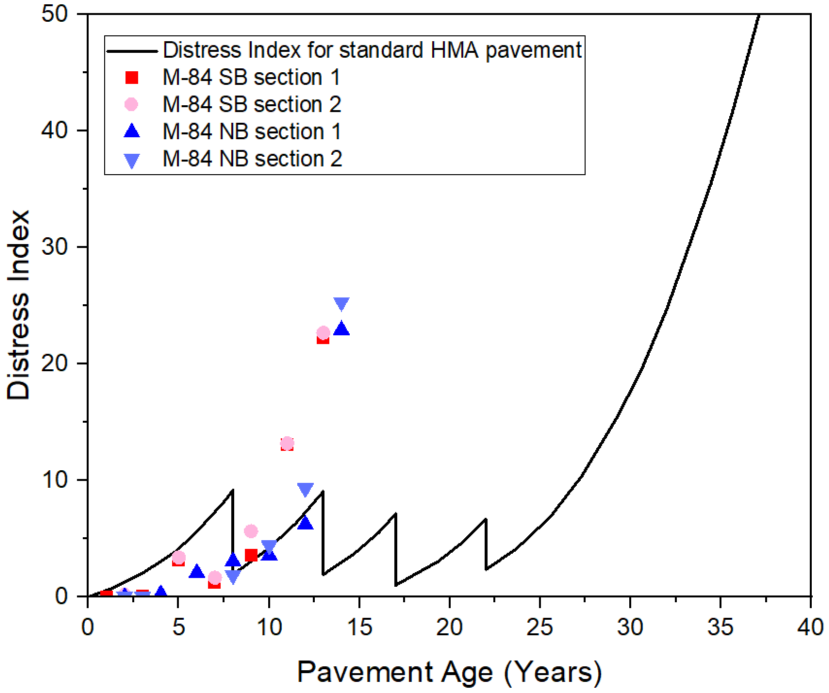


Figure 39. Comparison on M-84 DI trend with service life of standard pavement

According to Figure 40, the I-96 WB project express lane section has similar fix life as standard HMA reconstruction, but the local section is nearly infinite due to its consistent DI values and no inflection point. As a result, its single projection does not yet appear to reasonably estimate its initial fix life performance curve. Regardless, both the local and express lane sections of I-96 WB maintained a very low level of DI within its initial 12 years after construction without major maintenance. However, the most recent DI data in the express section at 14 years (year 2019) demonstrates a noticeable increase, though it remains relatively low. Since there was no available DI data after the year 2019, it is unclear if the local section also increases in DI. However, combining with the condition survey findings in 2019 and 2020 in Table 29, potholes and cracking started to show up around year 2019, which may contribute to increased DI. Additionally, as previously observed, increased DI may be attributed to the development of segregation and raveling at the longitudinal construction joints that were observed in field condition survey reviews. Some of this may have been overly accounted for within the express section DI measurement for 2019 as it may have included areas with fair construction joints. This was found to be an issue primarily for DI measurements in 2018 and 2019 as technology automation was incorporated to aid in DI calculation for these years. Nevertheless, this distress is largely a construction-related issue due to inadequate density at construction joints and are not representative of the integrity of the pavement structure. Therefore, the improved structural performance of the I-96 WB project is seemingly being limited by its construction conditions and distress found in the longitudinal joints.

In consideration of estimated service life, if the first maintenance event is assumed to be at the pavement age of 15 years in 2020 (despite primarily being repairs for longitudinal construction joints), this would be is 7 years after the first maintenance event for the standard alternative. As shown in Figure 41, if we assume the same number of maintenance events, timing between each, and similar improvements to DI as estimated for the standard alternative, then the I-96 express section could be estimated to have a service life of approximately 44 years. While this estimation is slightly lower than the anticipated 50 years of service life, if longitudinal construction joint issues can be constrained by the repairs that have taken place, then this service life will likely increase and reach the anticipated life.

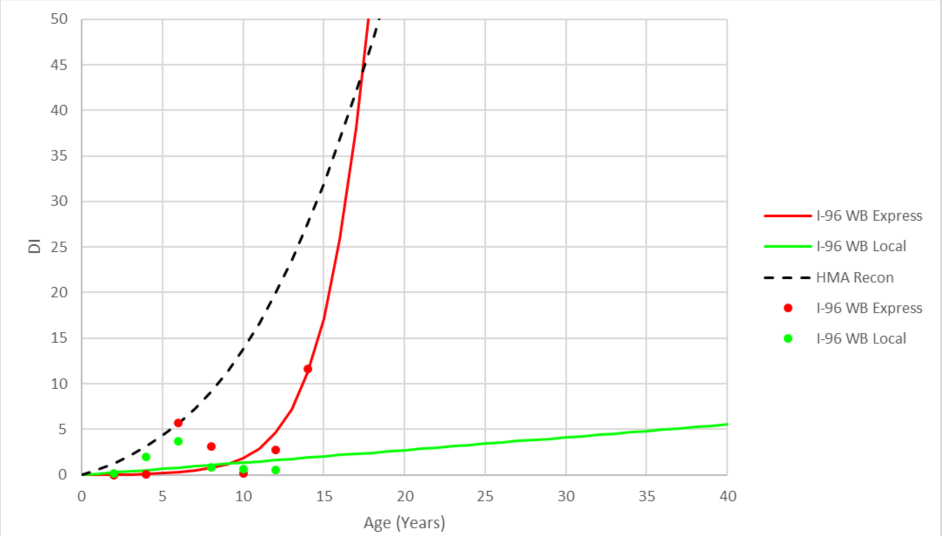


Figure 40. Comparison on I-96 DI trends with fix life of standard pavement

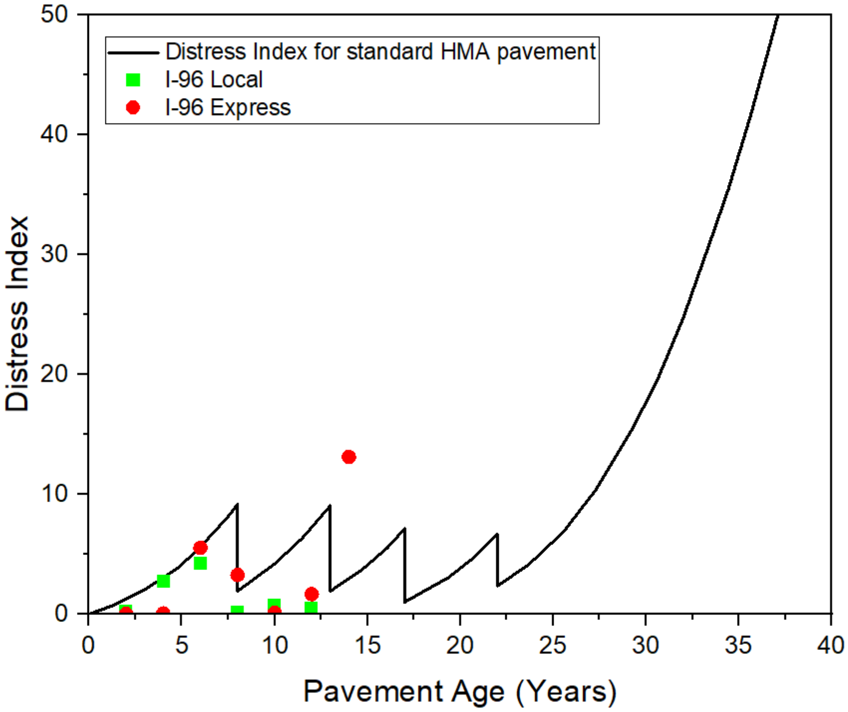


Figure 41. Comparison on I-96 DI trend with service life of standard pavement

Figure 42 shows the composite fix life curve derived from the perpetual full-depth reconstruction project sections on M-84 SB and I-96 WB as compared to the standard alternative. As shown, the perpetual reconstruction projects exhibit a significantly lower increase in the DI within the first 10 years post-construction. However, the overall DI progression of the perpetual HMA reconstruction demonstration project is slightly worse than that of standard HMA reconstruction. Specifically, the estimated resulting fix life for the demonstration sections is estimated to be 16 years, whereas it is projected to be 18 years for the standard alternative. As previously noted, several factors may be contributing to this, including the transverse cracking issues on M-84 and longitudinal construction joint issues on I-96. Moreover, the absence of subsequent DI datapoints and limited sample size as compared to the standard dataset may be impacting the accuracy of the curve projections. Consequently, the fix life projection may be underestimated. To enhance the reliability of these results, additional DI datapoints and/or future demonstration projects may be needed to verify or improve the accuracy of the demonstration performance curve.

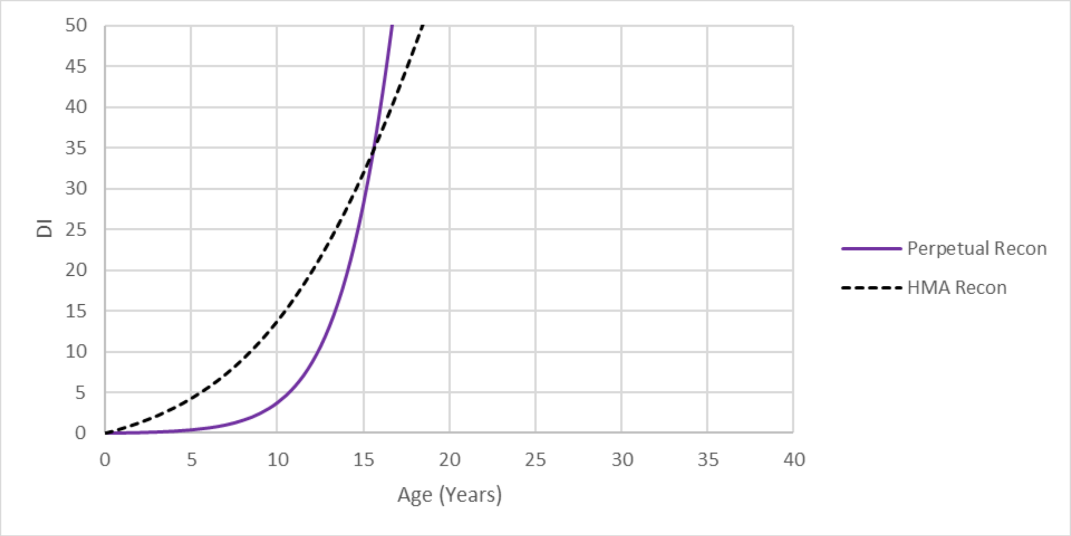


Figure 42. Comparison between perpetual and standard HMA pavement

Cost Comparison and Evaluation

The estimated initial and long-term costs of the pavement demonstration projects will be compared with the estimated costs of MDOT standard reconstructed HMA pavement. Costs included in this report were adjusted to 2019 dollars for comparison with the standard costs included in the *MDOT Pavement Selection Manual* [3] by using the procedure as denoted in Chapter 6, Section F of that manual. This manual explains the Life Cycle Cost Analysis (LCCA) procedure and MDOT’s guidelines for pavement selection. The initial cost for construction was approximated by using MDOT LCCA unit prices and the estimation method for the pavement costs as described in Chapter 2, Section A of the *MDOT Pavement Selection Manual*.

Since both M-84 SB and I-96 WB demonstration projects were finished construction in year 2005, the historical unit price from August 2006 will be used to estimate the initial construction cost of the two demonstration projects, since these prices captured construction in 2005 (cost will be inflated to 2019 dollars). The actual project bid prices will not be used since these can be highly variable due to the project quantities and do not provide costs for other mix types needed for comparison. Additionally, it is not clear if binder grade adjustments alone have significant cost impacts, so this will not be included in the cost analysis. However, since mix types and layer thicknesses have a significant impact on overall cost, the cost comparison will use these parameters. Note that I-96 WB included subgrade stabilization, but since this was not directly considered as part of any of the design procedures which could have impacted the design recommendation of other layers, it will not be included in the cost analysis. However, since unbound base thicknesses were considered and are variable per the design, these will be included.

The estimated perpetual HMA pavement, 40-year design life initial cost for the M-84 SB and the I-96 WB projects are estimated to be approximately $283,000 and $454,000 per lane-mile, respectively, as shown in Tables 30 and 32. In contrast, to estimate the initial cost of the standard alternatives, the standard 1993 AASHTO pavement designs using 20-year design life as shown in Appendix C will be used. Accordingly, as shown in Tables 31 and 33, this is estimated to be approximately $227,000 and $401,000 per lane-mile for M-84 and I-96, respectively. Therefore, the M-84 perpetual reconstruction initial cost is about $56,000 per lane-mile or 1.25 times the initial pavement cost more than its standard HMA reconstruction alternative. Similarly, the I-96 perpetual reconstruction initial cost is about $53,000 per lane-mile or 1.13 times the initial pavement cost more than its standard HMA reconstruction alternative. As a result, it appears that the high-volume traffic route of I-96 may be more effective for perpetual pavement application since its relative cost increase was less than the low volume route of M-84.

Table 30. Estimated initial cost for the M-84 SB perpetual pavement, 40-year design life per unit prices

Layer	Type	Thickness (inch)	Application Rate (lbs/syd)	Total Tons	Unit Price in 2006	Cost per Lane-Mile
HMA - Top	5E3	1.5	165	581 ton	$44.31	$25,735.25
HMA - Level	4E3	2	220	774 ton	$45.19	$34,995.14
HMA - Base	3E3	3	330	1,162 ton	$42.33	$49,170.53
Base	DGAB	12	-	7,040 syd	$10.44	$73,497.60
Subbase	Sand	13.5	-	2,640 cyd	$8.20	$21,648.00
Total Cost per Lane-Mile (Using price in 2006)						$205,046.51
Total Cost per Lane-Mile (Adjust to 2019)						**$282,604.69**

Table 31. Estimated initial cost for the M-84 standard pavement, 20-year design life per unit prices

Layer	Type	Thickness (inch)	Application Rate (lbs/syd)	Total Tons	Unit Price in 2006	Cost per Lane-Mile
HMA - Top	5E3	1.5	165	581 ton	$44.31	$25,735.25
HMA - Level	4E3	2	220	774 ton	$45.19	$34,995.14
HMA - Base	3E3	3	330	1,162 ton	$42.33	$49,170.53
Base	DGAB	6	-	7,040 syd	$3.71	$26,118.40
Subbase	Sand	18	-	3,520 cyd	$8.20	$28,864.00
Total Cost per Lane-Mile (Using price in 2006)						$164,883.31
Total Cost per Lane-Mile (Adjust to 2019)						**$227,249.89**

Table 32. Estimated initial cost for the I-96 WB perpetual pavement, 40-year design life per unit prices

Layer	Type	Thickness (inch)	Application Rate (lbs/syd)	Total	Unit Price in 2006	Cost per Lane-Mile
HMA - Top	GGSP	1.5	165	581 ton	$53.80	$31,247.04
HMA - Level	4E30	2.5	275	968 ton	$46.04	$44,566.72
HMA - Base	3E30	10	1100	3872 ton	$42.07	$162,895.04
Base	OGDC	16	-	7,040 syd	$11.36	$79,974.40
Subbase	Subbase	8	-	1,564 cyd	$6.73	$10,528.71
Total Cost per Lane-Mile (Using price in 2006)						$329,211.91
Total Cost per Lane-Mile (Adjust to 2019)						**$453,735.25**

Table 33. Estimated initial cost for the I-96 standard pavement, 20-year design life per unit prices

Layer	Type	Thickness (inch)	Application Rate (lbs/syd)	Total	Unit Price in 2006	Cost per Lane-Mile
HMA - Top	GGSP	2	220	774 ton	$53.80	$41,662.72
HMA - Level	4E30	2.5	275	968 ton	$46.04	$44,566.72
HMA - Base	3E30	7	770	2710 ton	$42.07	$114,026.53
Base	OGDC	16	-	7,040 syd	$11.36	$79,974.40
Subbase	Subbase	8	-	1,564 cyd	$6.73	$10,528.71
Total Cost per Lane-Mile (Using price in 2006)						$290,759.08
Total Cost per Lane-Mile (Adjust to 2019)						**$400,737.76**

While the initial paving costs for perpetual pavement projects are higher than the standard HMA reconstruction project, the service life for both are anticipated to be longer than its standard alternative. Per the *MDOT Pavement Section Manual*, the standard HMA reconstruction pavement service life is 37 years, while the anticipated service life of the perpetual alternative is at least 50 years. However, as observed in the previous section, both projects currently suggest lower service lives of roughly 37 and 44 years for M-84 and I-96, respectively. Therefore, as shown in Table 34, the M-84 perpetual alternative initial cost per year of its service life may range from $5,660 to $7,650 per lane-mile, while its standard alternative is $6,135 per lane-mile. For I-96, this is $9,080 to $10,320 per lane-mile with standard alternative being $10,840 per lane-mile. It is important to note that this per year cost does not include the benefit of delayed major rehabilitation or reconstruction, which becomes more significant with longer service life. Still, in terms of the initial paving cost, the perpetual alternative is more cost-effective than the standard if at least 47 and 41 years of service life are achieved for the M-84 and I-96 projects, respectively. Based on current rough estimates of their service lives, I-96 is on track to achieve this, but M-84 may not be. This seems to further support that the high-volume traffic route of I-96 may be more suitable for perpetual pavement applications as it appears to already be more cost effective and would require fewer years of service life in order to achieve this.

Table 34. Initial paving cost per year of service life

Type	Initial Pavement Cost	Service life (years)	Yearly average cost
M-84 perpetual HMA reconstruction	$283,000	37	$7,650
		50	$5,660
M-84 standard HMA reconstruction	$227,000	37	$6,135
I-96 perpetual HMA reconstruction	$454,000	44	$10,320
		50	$9,080
I-96 standard HMA reconstruction	$401,000	37	$10,840

In addition to the pavement's initial cost, maintenance considerations play a crucial role in influencing costs. According to the *MDOT Pavement Selection Manual*, for the MDOT standard HMA reconstruction pavement, preventive maintenance cycles occur on average after 8, 13, 17, and 22 years, with rehabilitation or reconstruction estimated to occur after 37 years. Accordingly, the maintenance cost per lane-mile of these maintenance fixes is estimated at $28,071, $41,342, $44,005, and $32,411, respectively, so their total cost is $145,829 per lane-mile.

Records show that the M-84 project underwent three maintenance projects since its initial construction. These were conducted on both directions and all involving crack treatment. The maintenance costs per lane-mile of these were $2,315 for cycle 1 in 2008 (age 3), $3,429 for cycle 2 in 2013 (age 8), and $3,596 for cycle 3 in 2016 (age 11), bringing their total cost to $9,340 per lane-mile (as adjusted to 2019 cost). Considering that the pavement life is 18 years in 2023, the number of maintenance events is the same as the standard HMA reconstruction projects over that same period but is $104,078 less in total cost. This seems to indicate that the M-84 maintenance events have been less extensive than what is typically seen on standard pavements.

For I-96 WB, one programmed maintenance project is scheduled for 2024, containing cold milling with a HMA single-course overlay. Prior to this, no contracted maintenance activities have occurred. Still, as previously noted, minor repairs were observed during field surveys to have been performed in 2020 and 2021. This type of non-contracted minor repair work is commonly conducted on various routes throughout the state, but it isn't easy to compare or assess the relative amount of this work per route because this type of minor repair work is not fully tracked for every roadway segment. Still, to assess the maximum potential cost of maintenance work, considering the total number of repairs observed, it can be approximated that the minor repair work is roughly equal to a single contracted maintenance cycle. Therefore, the I-96 WB maintenance events will be estimated as 2 cycles, occurring at ages 15 and 19. The costs of these maintenance activities can be roughly assumed to be similar to that of standard HMA reconstruction. However, the number of maintenance events is 1 less than that of the standard HMA reconstruction projects over that same time period, so that the overall cost of I-96 WB maintenance has been less than the standard alternative.

Therefore, to date, the maintenance costs of both perpetual HMA reconstruction projects on M-84 and I-96 are lower than standard HMA reconstruction projects. While their initial costs are higher, the potential increased service life would reduce the overall long-term cost of the pavement.

Therefore, considering the increased service life and reduced maintenance costs, this demonstration fix type should provide a cost-effective option based on current service life estimates. Specifically, its advantages may be more pronounced for high-volume traffic routes, where the initial cost increase may be relatively less than the added cost on low-volume routes.

Conclusions and Recommendations

This report presents the finalization evaluation of the "Full-Depth Reconstructed Perpetual HMA" pavement demonstration projects on M-84 SB, MDOT Job Number 31804 and I-96 WB, MDOT Job Number 52803. It includes summary and evaluation of each project and its pavement design, construction quality control, condition, performance, costs, and comparisons. Conclusions and recommendations are presented as follows.

For M-84, both bounds were found to be consistently constructed and consistent with design plans as per GPR results. Furthermore, FWD results show that both bounds have relatively uniform subgrade offering fair to good support. This project location has accumulated sufficient condition data since its construction in 2005. While transverse cracking continues to increase, more so in SB than NB, the severity of these cracks for SB are lower as the width of transverse cracking in the SB perpetual sections is lower than that in the NB standard sections. This is confirmed by the coring results, showing that the perpetual section in SB has performed better in preventing full-depth transverse cracking than the standard HMA section in NB. Longitudinal cracking has remained steady and minor throughout the pavement life of both bounds, with SB performing slightly better than NB. However, according to the DI analysis, the SB perpetual did not show a distinct advantage compared to the NB standard sections. This is likely due to the higher count of transverse cracks in SB than NB. Still, the reduced severity of these cracks may not be fully demonstrated by the DI alone. As a result, while the initial fix life projections of NB and SB are very similar, the subsequent maintenance events for SB should provide more years of service life beyond that of NB.

For I-96, analysis of thickness data from GPR tests revealed that a significant portion of the pavement sections are less than the designed 14-inch thickness, achieving 12.8- and 13.8-inches in average thickness for the local and express lane sections, respectively. In addition, notable longitudinal construction joint failure attributable to insufficient density and/or inadequate bonding was found intermittently throughout the project for both sections. This highlights the need to ensure the success of perpetual HMA reconstruction by addressing construction quality control for similar future projects. Nevertheless, the I-96 WB project has demonstrated excellent performance in both local and express lanes since completion in 2005. However, the express lane section, while still relatively low, had a relatively noticeable increase in DI and observed cracking in 2019 (at age 14). This increased cracking in recent years may be partially contributing to the DI increase as shown in that year. However, due to the intermittent longitudinal construction joint raveling and segregation, DI may be overstated and not fully represent the performance of the perpetual design as this distress is largely a construction-related issue and not representative of the integrity of the pavement structure. It should be noted that since the construction of I-96, MDOT has implemented changes to its construction requirements to ensure the density of the longitudinal construction joints, aiming to prevent long-term performance issues. Interestingly, despite being mostly thicker than the local lane section, the express lane section has shown slightly more cracking and potholes than the local section. This may be attributed to differences in traffic and/or construction. Despite the initial high cost of the I-96 WB project due to the increased HMA thickness, the long-term maintenance costs have been significantly reduced. If the longitudinal construction joint issues can be constrained by the repairs that have taken place, then this service life will likely increase leading to overall cost savings.

The full-depth reconstructed perpetual HMA demonstration pavements have generally collected a sufficient amount of condition data. Still, there is some uncertainty about the forecasted fix life of these pavements due to the currently available DI measurements. Factors contributing to this uncertainty include the observed high quantity but low severity transverse cracking on M-84 and longitudinal construction joint issues on I-96 that may be overly influencing current DI values. Moreover, the absence of recent (2020 and newer) DI datapoints and limited sample size as compared to the standard dataset may be impacting the accuracy of performance curve projections. Consequently, the fix life and/or service life projections may be currently underestimated.

Nevertheless, since an adequate amount of time has passed and enough data is available to fully evaluate these projects, it is recommended that MDOT consider standardization and implementation of full-depth reconstructed perpetual HMA pavement. Per the findings and conclusions of this report, as compared to standard HMA reconstruction, perpetual pavement offers potential advantages in terms of longer service life and lower overall cost due to reduced long-term maintenance needs. Consequently, less frequent maintenance and reconstruction events will lead to reduced disruptions to traffic. This highlights its promise as a sustainable and cost-effective pavement solution.

However, if the service life projection does not reasonably accommodate practical use as compared to standard alternatives or as necessary for MDOT life cycle procedures, then MDOT may consider the construction of additional projects using this demonstration fix type or continue to wait for additional data on the existing sections prior to standardizing. If more projects are to be constructed, then construction quality standards should be ensured to uphold the integrity of the design. Furthermore, high-volume traffic routes should be prioritized as the high-volume traffic route of I-96 has shown more overall cost savings due to the lower relative increased cost from standard design. These pavements may also benefit more as this provides less traffic interruption due to anticipated pavement maintenance.

Regardless, since the primary issue is that of establishing and validating the performance curve and because additional detailed annual reviews would not enhance the conclusions from these projects, it is recommended that the MDOT end its annual monitoring and status reporting of the M-84 SB and I-96 WB demonstration projects. If needed, future data collection for fix type evaluation can be solely facilitated by the standard networkwide MDOT condition data measurements and standard MDOT project tracking.

References

1. Harold Von Quintus. Pavement Structural Design Recommendations for Reconstruction and Widening of M-84. Michigan Department of Transportation. April 2003.
2. Harold Von Quintus. Pavement Structural Analysis of the Design Recommendations for Reconstructing I-96 (M-39 to Schaeffer Road). Michigan Department of Transportation. August 2004.
3. Michigan Department of Transportation Pavement Selection Manual. Pavement selection. 2021.
4. Schenkel J. Pavement Demonstration Program Status Report Public Act 457 of 2016 [Internet]. 2022. Available from: https://www.michigan.gov/mdot/about/governmental-affairs

Appendix A: Proposed Pavement Construction Plans

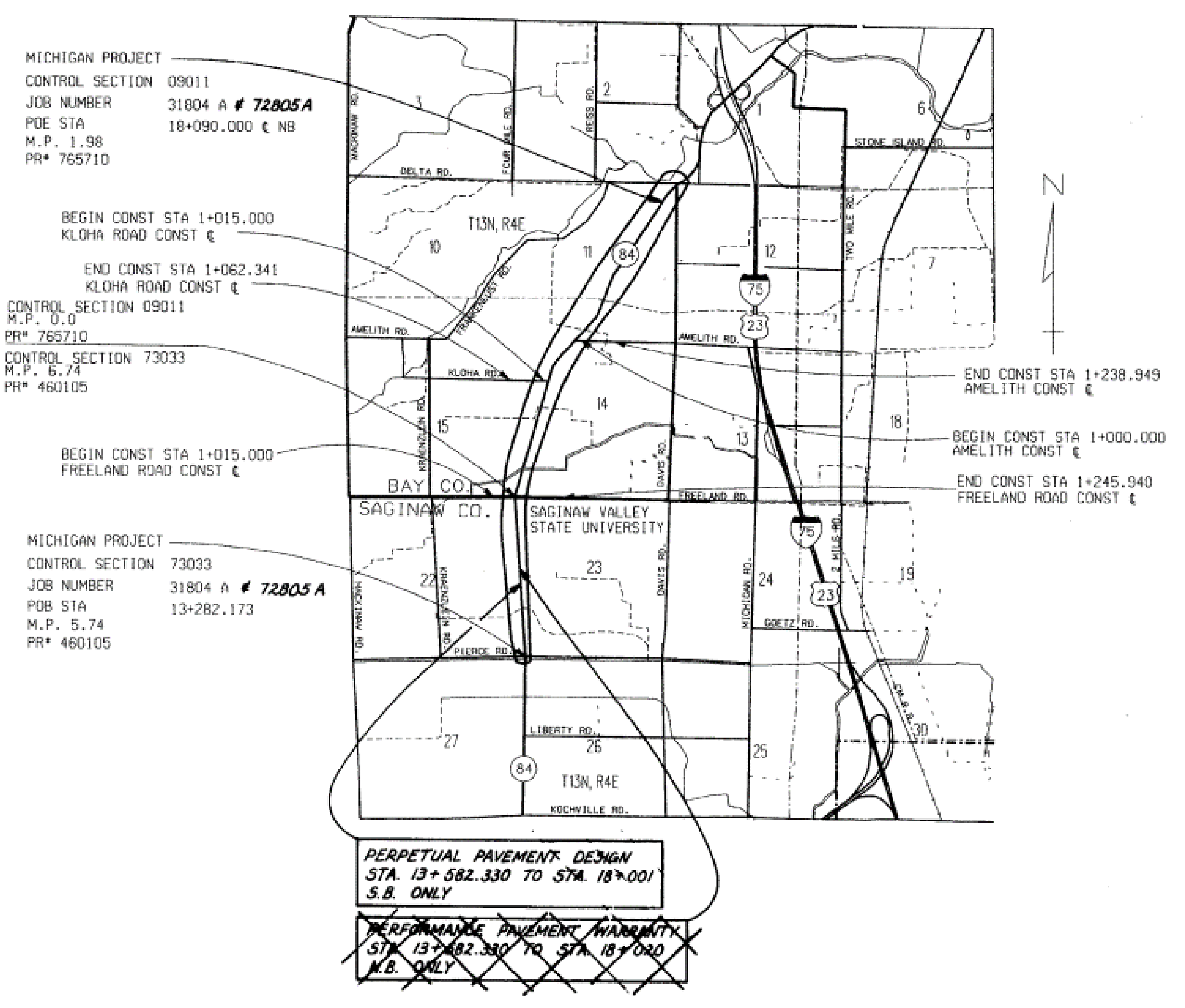


Figure 43. JN 31804A project location for the M-84 project

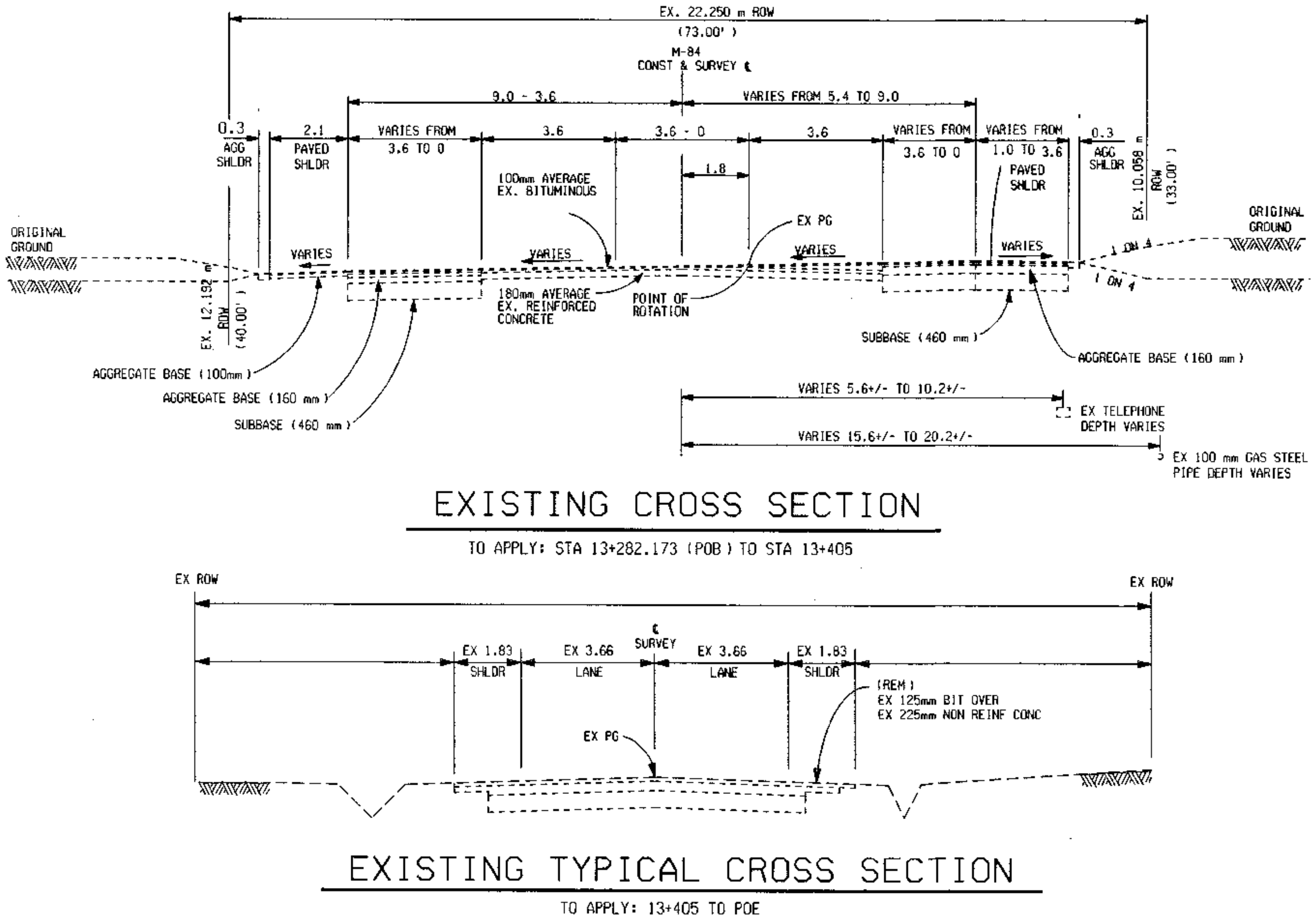


Figure 44. JN 31804A existing cross-sections for the M-84 project

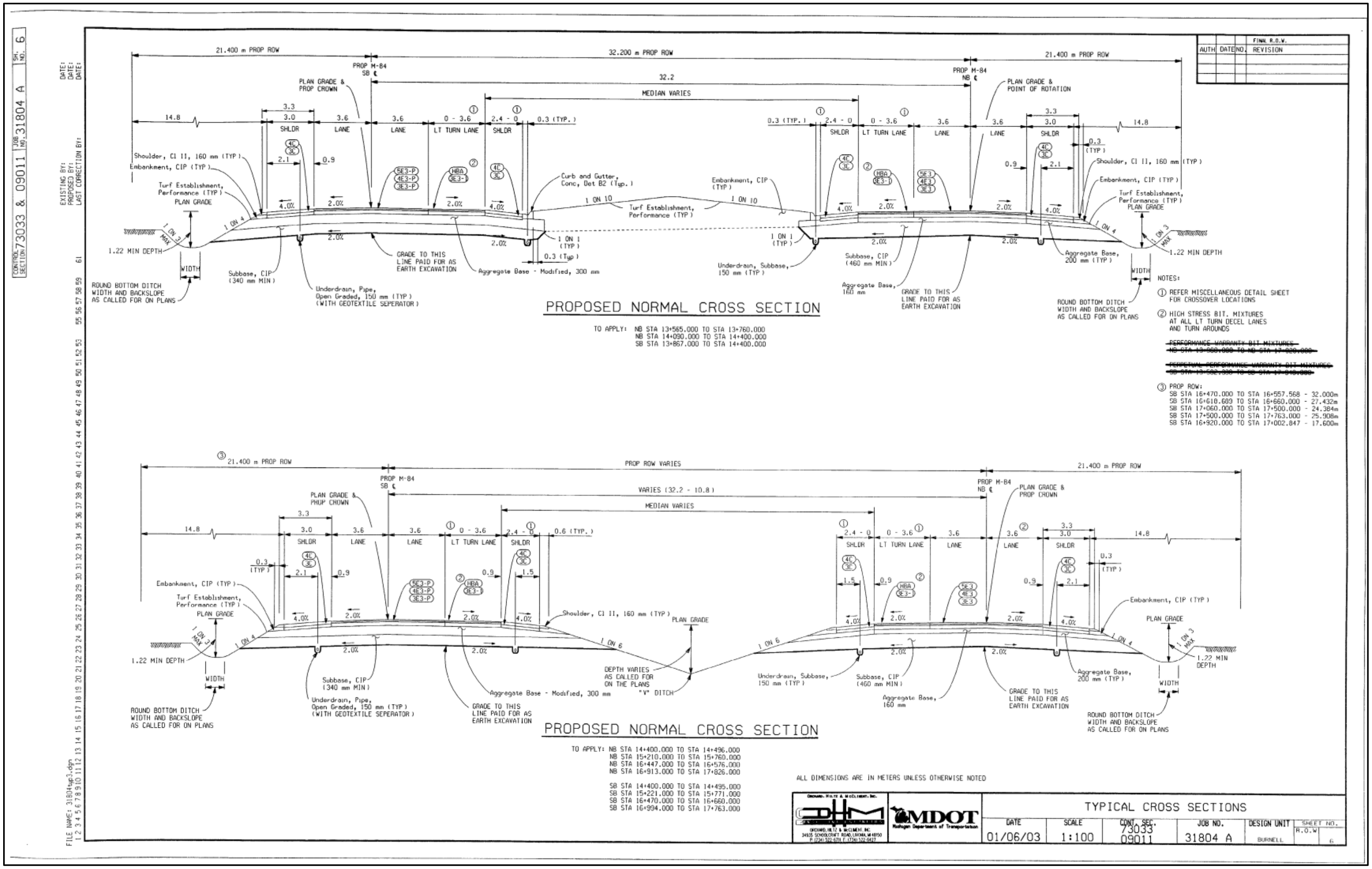
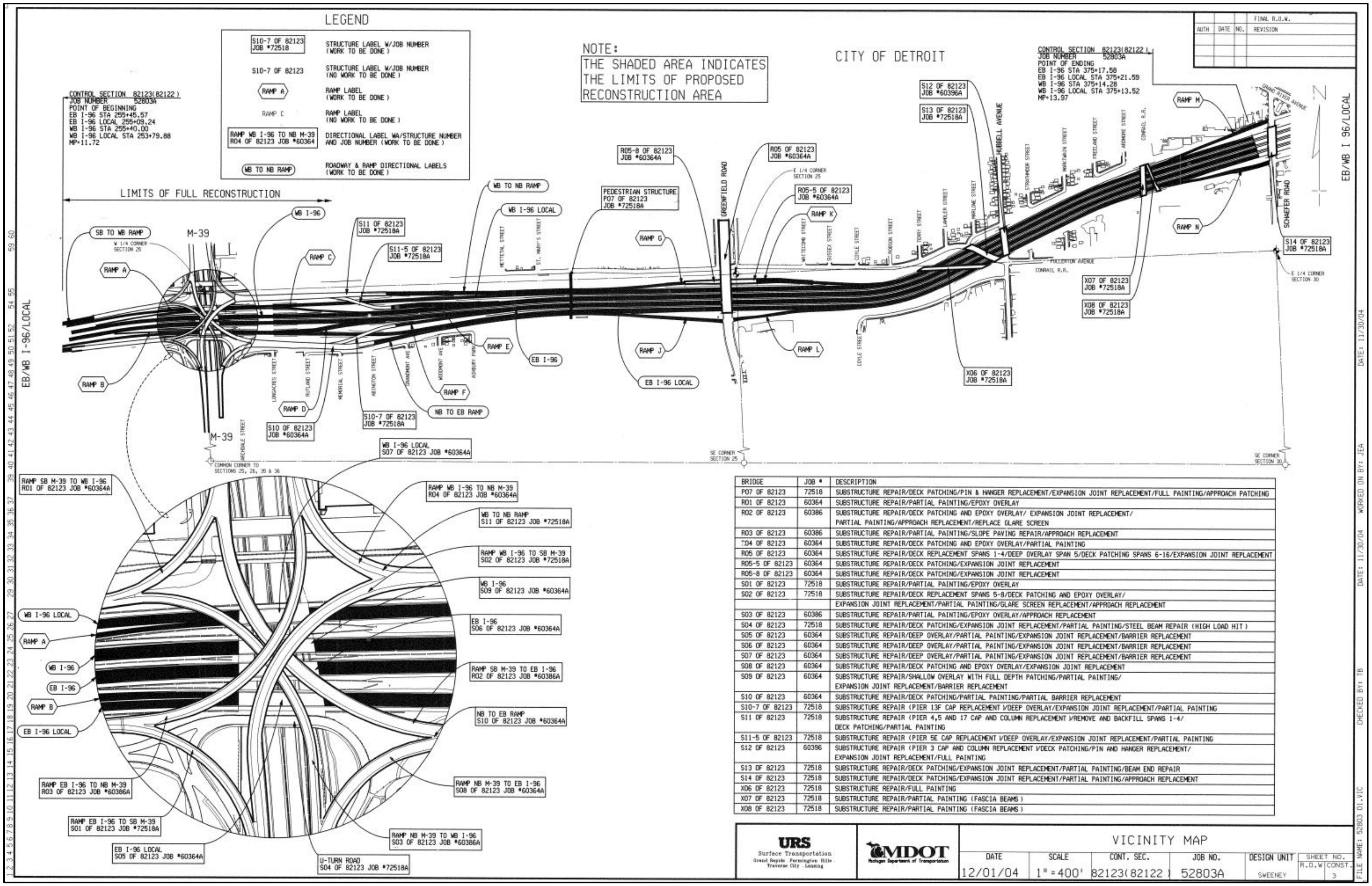


Figure 45. JN 31804 typical cross-section for the M-84 SB perpetual and NB standard pavement project



BRIDGE	JOB *	DESCRIPTION
P07 OF 82123	72518	SUBSTRUCTURE REPAIR/DECK PATCHING/PIN & HANGER REPLACEMENT/EXPANSION JOINT REPLACEMENT/FULL PAINTING/APPROACH PATCHING
R01 OF 82123	60364	SUBSTRUCTURE REPAIR/PARTIAL PAINTING/EPOXY OVERLAY
R02 OF 82123	60386	SUBSTRUCTURE REPAIR/DECK PATCHING AND EPOXY OVERLAY/ EXPANSION JOINT REPLACEMENT/ PARTIAL PAINTING/APPROACH REPLACEMENT/REPLACE GLARE SCREEN
R03 OF 82123	60386	SUBSTRUCTURE REPAIR/PARTIAL PAINTING/SLOPE PAVING REPAIR/APPROACH REPLACEMENT
R04 OF 82123	60364	SUBSTRUCTURE REPAIR/DECK PATCHING AND EPOXY OVERLAY/PARTIAL PAINTING
R05 OF 82123	60364	SUBSTRUCTURE REPAIR/DECK REPLACEMENT SPANS 1-4/DEEP OVERLAY SPAN 5/DECK PATCHING SPANS 6-16/EXPANSION JOINT REPLACEMENT
R05-5 OF 82123	60364	SUBSTRUCTURE REPAIR/DECK PATCHING/EXPANSION JOINT REPLACEMENT
R05-8 OF 82123	60364	SUBSTRUCTURE REPAIR/DECK PATCHING/EXPANSION JOINT REPLACEMENT
S01 OF 82123	72518	SUBSTRUCTURE REPAIR/PARTIAL PAINTING/EPOXY OVERLAY
S02 OF 82123	72518	SUBSTRUCTURE REPAIR/DECK REPLACEMENT SPANS 5-8/DECK PATCHING AND EPOXY OVERLAY/
		EXPANSION JOINT REPLACEMENT/PARTIAL PAINTING/GLARE SCREEN REPLACEMENT/APPROACH REPLACEMENT
S03 OF 82123	60386	SUBSTRUCTURE REPAIR/PARTIAL PAINTING/EPOXY OVERLAY/APPROACH REPLACEMENT
S04 OF 82123	72518	SUBSTRUCTURE REPAIR/DECK PATCHING/EXPANSION JOINT REPLACEMENT/PARTIAL PAINTING/STEEL BEAM REPAIR (HIGH LOAD HIT)
S05 OF 82123	60364	SUBSTRUCTURE REPAIR/DEEP OVERLAY/PARTIAL PAINTING/EXPANSION JOINT REPLACEMENT/BARRIER REPLACEMENT
S06 OF 82123	60364	SUBSTRUCTURE REPAIR/DEEP OVERLAY/PARTIAL PAINTING/EXPANSION JOINT REPLACEMENT/BARRIER REPLACEMENT
S07 OF 82123	60364	SUBSTRUCTURE REPAIR/DEEP OVERLAY/PARTIAL PAINTING/EXPANSION JOINT REPLACEMENT/BARRIER REPLACEMENT
S08 OF 82123	60364	SUBSTRUCTURE REPAIR/DECK PATCHING AND EPOXY OVERLAY/EXPANSION JOINT REPLACEMENT
S09 OF 82123	60364	SUBSTRUCTURE REPAIR/SHALLOW OVERLAY WITH FULL DEPTH PATCHING/PARTIAL PAINTING/ EXPANSION JOINT REPLACEMENT/BARRIER REPLACEMENT
S10 OF 82123	60364	SUBSTRUCTURE REPAIR/DECK PATCHING/PARTIAL PAINTING/PARTIAL BARRIER REPLACEMENT
S10-7 OF 82123	72518	SUBSTRUCTURE REPAIR (PIER 13F CAP REPLACEMENT)/DEEP OVERLAY/EXPANSION JOINT REPLACEMENT/PARTIAL PAINTING
S11 OF 82123	72518	SUBSTRUCTURE REPAIR (PIER 4,5 AND 17 CAP AND COLUMN REPLACEMENT)/REMOVE AND BACKFILL SPANS 1-4/ DECK PATCHING/PARTIAL PAINTING
S11-5 OF 82123	72518	SUBSTRUCTURE REPAIR (PIER 5E CAP REPLACEMENT)/DEEP OVERLAY/EXPANSION JOINT REPLACEMENT/PARTIAL PAINTING
S12 OF 82123	60396	SUBSTRUCTURE REPAIR (PIER 3 CAP AND COLUMN REPLACEMENT)/DECK PATCHING/PIN AND HANGER REPLACEMENT/ EXPANSION JOINT REPLACEMENT/FULL PAINTING
S13 OF 82123	72518	SUBSTRUCTURE REPAIR/DECK PATCHING/EXPANSION JOINT REPLACEMENT/PARTIAL PAINTING/BEAM END REPAIR
S14 OF 82123	72518	SUBSTRUCTURE REPAIR/DECK PATCHING/EXPANSION JOINT REPLACEMENT/PARTIAL PAINTING/APPROACH REPLACEMENT
X06 OF 82123	72518	SUBSTRUCTURE REPAIR/FULL PAINTING
X07 OF 82123	72518	SUBSTRUCTURE REPAIR/PARTIAL PAINTING (FASCIA BEAMS)
X08 OF 82123	72518	SUBSTRUCTURE REPAIR/PARTIAL PAINTING (FASCIA BEAMS)

Figure 46. JN 52803 project location for the I-96 perpetual pavement project

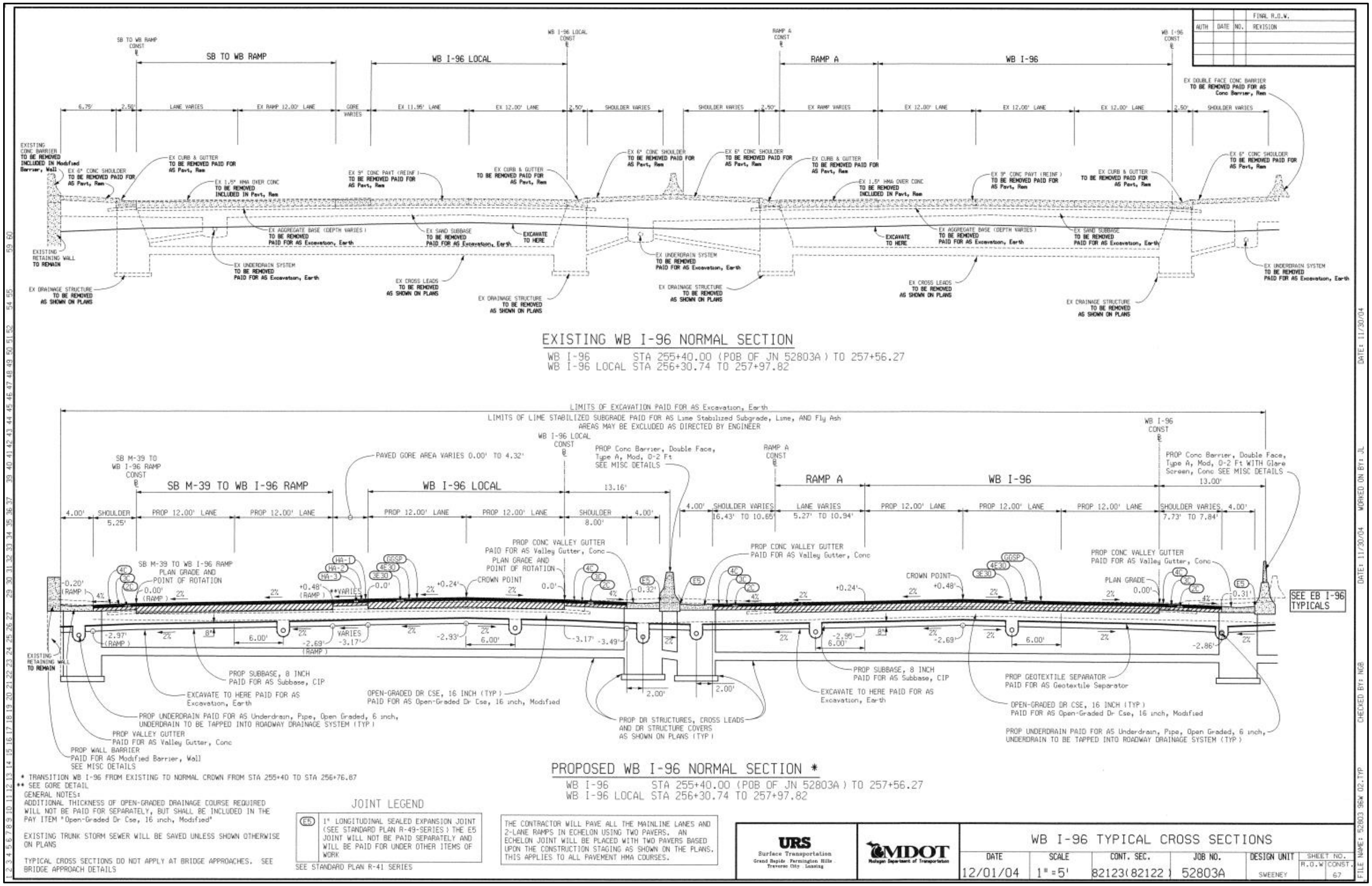
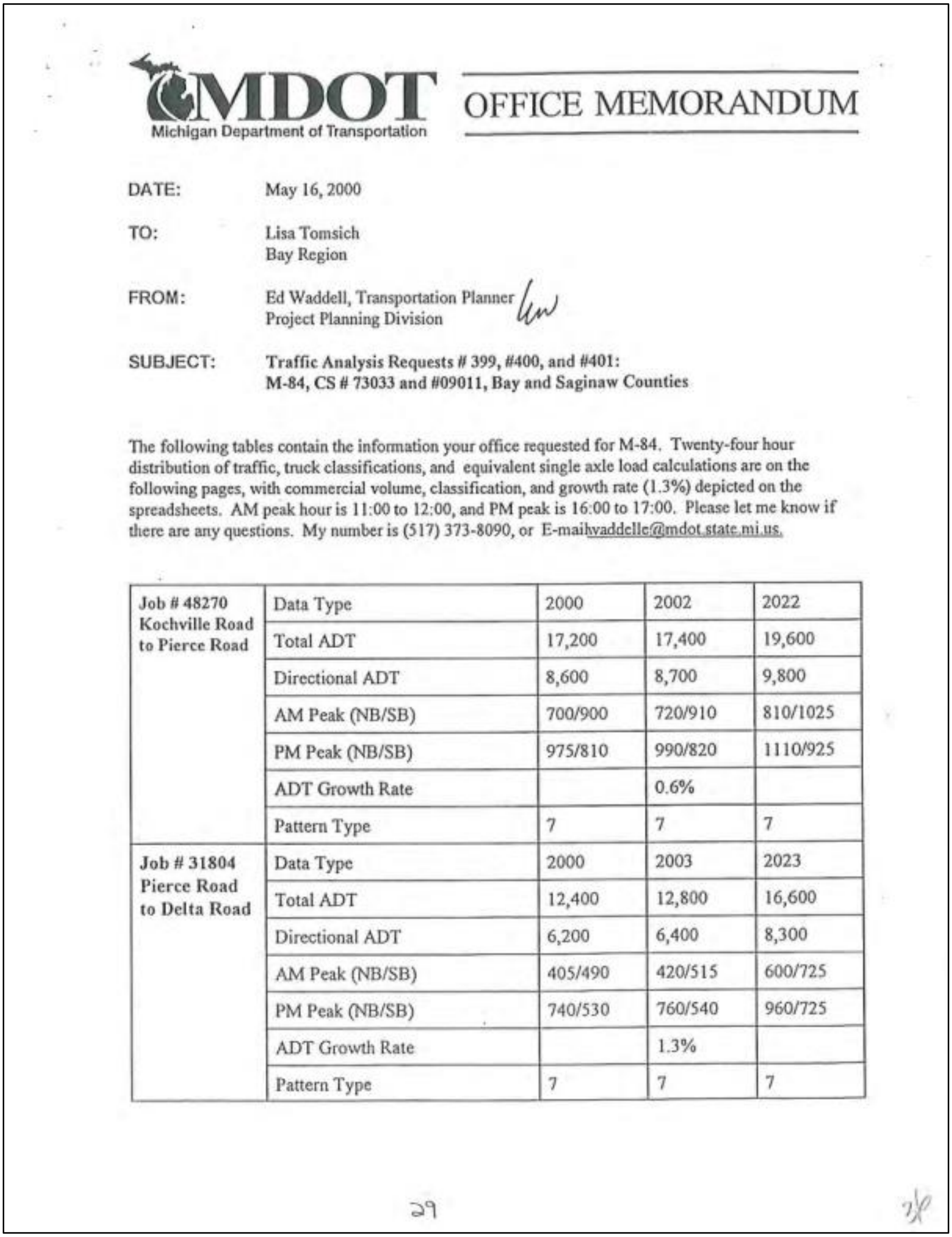


Figure 47. JN 52803 typical cross-section for the I-96 perpetual pavement project

Appendix B: Traffic Data



MDOT
Michigan Department of Transportation

OFFICE MEMORANDUM

DATE: May 16, 2000

TO: Lisa Tomsich
Bay Region

FROM: Ed Waddell, Transportation Planner
Project Planning Division

SUBJECT: **Traffic Analysis Requests # 399, #400, and #401:**
M-84, CS # 73033 and #09011, Bay and Saginaw Counties

The following tables contain the information your office requested for M-84. Twenty-four hour distribution of traffic, truck classifications, and equivalent single axle load calculations are on the following pages, with commercial volume, classification, and growth rate (1.3%) depicted on the spreadsheets. AM peak hour is 11:00 to 12:00, and PM peak is 16:00 to 17:00. Please let me know if there are any questions. My number is (517) 373-8090, or E-mailwaddelle@mdot.state.mi.us.

Job # 48270 Kochville Road to Pierce Road	Data Type	2000	2002	2022
	Total ADT	17,200	17,400	19,600
	Directional ADT	8,600	8,700	9,800
	AM Peak (NB/SB)	700/900	720/910	810/1025
	PM Peak (NB/SB)	975/810	990/820	1110/925
	ADT Growth Rate		0.6%	
	Pattern Type	7	7	7
Job # 31804 Pierce Road to Delta Road	Data Type	2000	2003	2023
	Total ADT	12,400	12,800	16,600
	Directional ADT	6,200	6,400	8,300
	AM Peak (NB/SB)	405/490	420/515	600/725
	PM Peak (NB/SB)	740/530	760/540	960/725
	ADT Growth Rate		1.3%	
	Pattern Type	7	7	7

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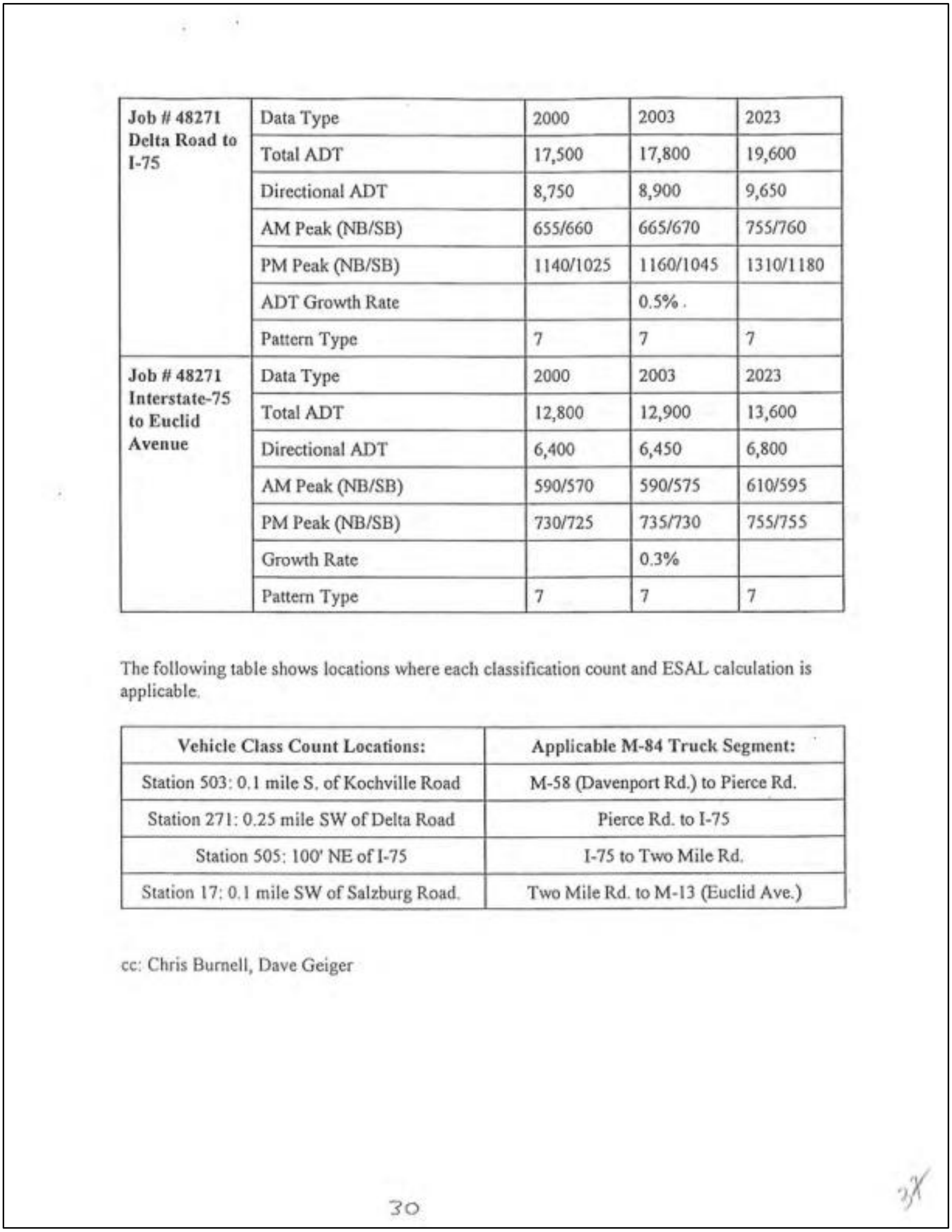
Figure 48. Office memorandum on M-84 traffic information, page 1



Job # 48271 Delta Road to I-75	Data Type	2000	2003	2023
	Total ADT	17,500	17,800	19,600
	Directional ADT	8,750	8,900	9,650
	AM Peak (NB/SB)	655/660	665/670	755/760
	PM Peak (NB/SB)	1140/1025	1160/1045	1310/1180
	ADT Growth Rate		0.5% .	
	Pattern Type	7	7	7
Job # 48271 Interstate-75 to Euclid Avenue	Data Type	2000	2003	2023
	Total ADT	12,800	12,900	13,600
	Directional ADT	6,400	6,450	6,800
	AM Peak (NB/SB)	590/570	590/575	610/595
	PM Peak (NB/SB)	730/725	735/730	755/755
	Growth Rate		0.3%	
	Pattern Type	7	7	7

The following table shows locations where each classification count and ESAL calculation is applicable.

Vehicle Class Count Locations:	Applicable M-84 Truck Segment:
Station 503: 0.1 mile S. of Kochville Road	M-58 (Davenport Rd.) to Pierce Rd.
Station 271: 0.25 mile SW of Delta Road	Pierce Rd. to I-75
Station 505: 100' NE of I-75	I-75 to Two Mile Rd.
Station 17: 0.1 mile SW of Salzburg Road.	Two Mile Rd. to M-13 (Euclid Ave.)

cc: Chris Burnell, Dave Geiger

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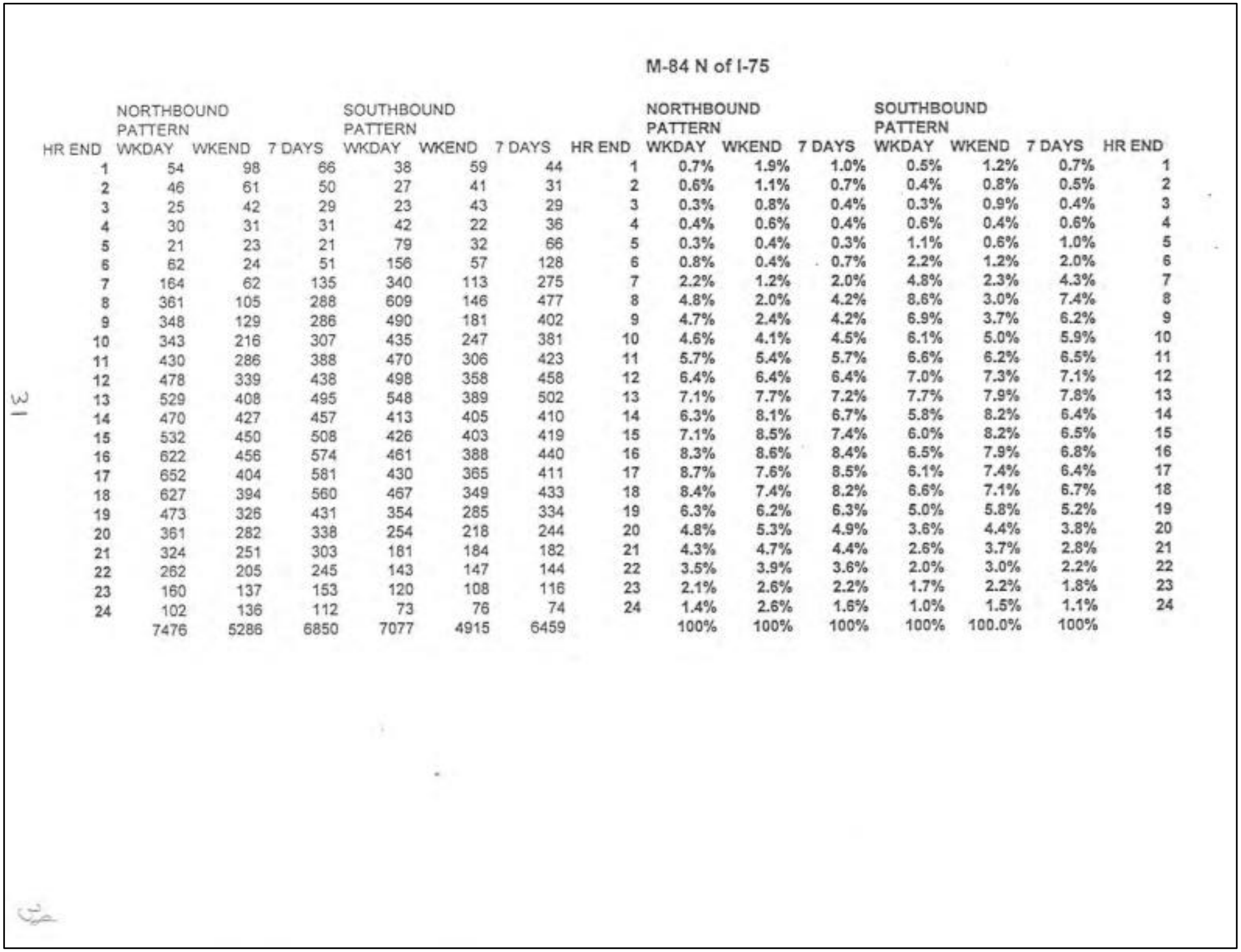
Figure 49. Office memorandum on M-84 traffic information, page 2



M-84 N of I-75

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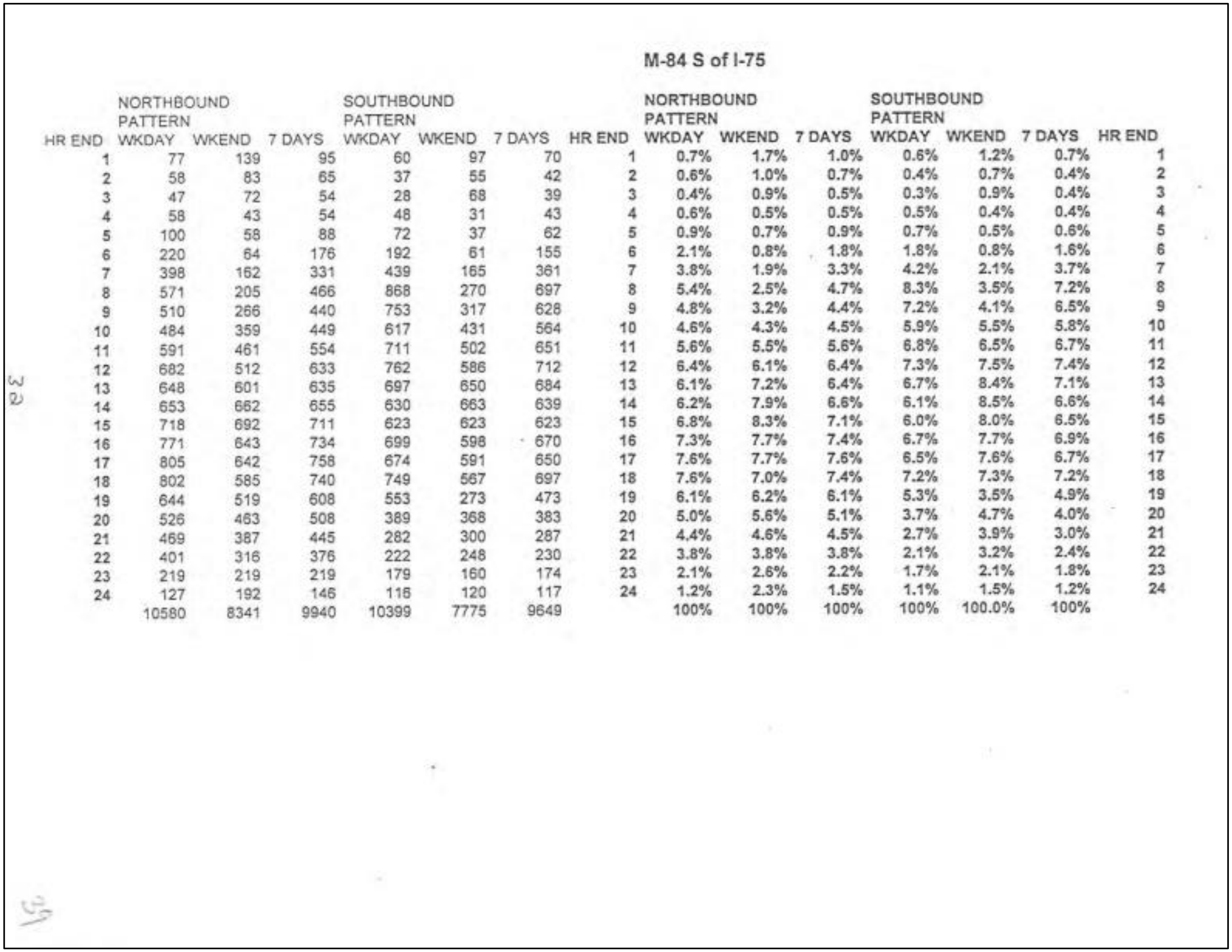
	NORTHBOUND PATTERN			SOUTHBOUND PATTERN				NORTHBOUND PATTERN			SOUTHBOUND PATTERN			
HR END	WKDAY	WKEND	7 DAYS	WKDAY	WKEND	7 DAYS	HR END	WKDAY	WKEND	7 DAYS	WKDAY	WKEND	7 DAYS	HR END
1	54	98	66	38	59	44	1	0.7%	1.9%	1.0%	0.5%	1.2%	0.7%	1
2	46	61	50	27	41	31	2	0.6%	1.1%	0.7%	0.4%	0.8%	0.5%	2
3	25	42	29	23	43	29	3	0.3%	0.8%	0.4%	0.3%	0.9%	0.4%	3
4	30	31	31	42	22	36	4	0.4%	0.6%	0.4%	0.6%	0.4%	0.6%	4
5	21	23	21	79	32	66	5	0.3%	0.4%	0.3%	1.1%	0.6%	1.0%	5
6	62	24	51	156	57	128	6	0.8%	0.4%	0.7%	2.2%	1.2%	2.0%	6
7	164	62	135	340	113	275	7	2.2%	1.2%	2.0%	4.8%	2.3%	4.3%	7
8	361	105	288	609	146	477	8	4.8%	2.0%	4.2%	8.6%	3.0%	7.4%	8
9	348	129	286	490	181	402	9	4.7%	2.4%	4.2%	6.9%	3.7%	6.2%	9
10	343	216	307	435	247	381	10	4.6%	4.1%	4.5%	6.1%	5.0%	5.9%	10
11	430	286	388	470	306	423	11	5.7%	5.4%	5.7%	6.6%	6.2%	6.5%	11
12	478	339	438	498	358	458	12	6.4%	6.4%	6.4%	7.0%	7.3%	7.1%	12
13	529	408	495	548	389	502	13	7.1%	7.7%	7.2%	7.7%	7.9%	7.8%	13
14	470	427	457	413	405	410	14	6.3%	8.1%	6.7%	5.8%	8.2%	6.4%	14
15	532	450	508	426	403	419	15	7.1%	8.5%	7.4%	6.0%	8.2%	6.5%	15
16	622	456	574	461	388	440	16	8.3%	8.6%	8.4%	6.5%	7.9%	6.8%	16
17	652	404	581	430	365	411	17	8.7%	7.6%	8.5%	6.1%	7.4%	6.4%	17
18	627	394	560	467	349	433	18	8.4%	7.4%	8.2%	6.6%	7.1%	6.7%	18
19	473	326	431	354	285	334	19	6.3%	6.2%	6.3%	5.0%	5.8%	5.2%	19
20	361	282	338	254	218	244	20	4.8%	5.3%	4.9%	3.6%	4.4%	3.8%	20
21	324	251	303	181	184	182	21	4.3%	4.7%	4.4%	2.6%	3.7%	2.8%	21
22	262	205	245	143	147	144	22	3.5%	3.9%	3.6%	2.0%	3.0%	2.2%	22
23	160	137	153	120	108	116	23	2.1%	2.6%	2.2%	1.7%	2.2%	1.8%	23
24	102	136	112	73	76	74	24	1.4%	2.6%	1.6%	1.0%	1.5%	1.1%	24
	7476	5286	6850	7077	4915	6459		100%	100%	100%	100%	100.0%	100%	

Figure 50. Office memorandum on M-84 traffic information, page 3

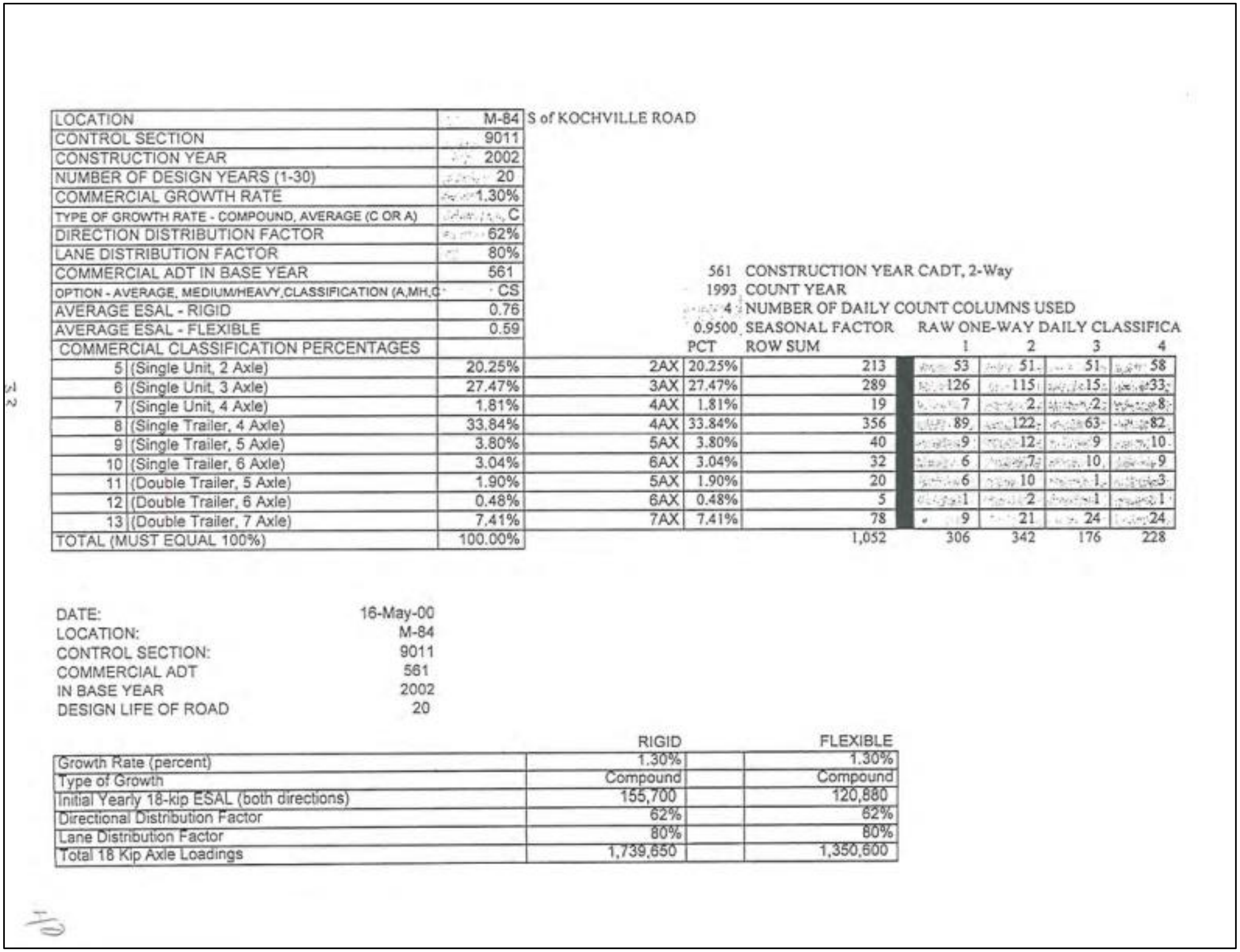


M-84 S of I-75

	NORTHBOUND PATTERN			SOUTHBOUND PATTERN			
HR END	WKDAY	WKEND	7 DAYS	WKDAY	WKEND	7 DAYS	HR END
1	77	139	95	60	97	70	1
2	58	83	65	37	55	42	2
3	47	72	54	28	68	39	3
4	58	43	54	48	31	43	4
5	100	58	88	72	37	62	5
6	220	64	176	192	61	155	6
7	398	162	331	439	165	361	7
8	571	205	466	868	270	697	8
9	510	266	440	753	317	628	9
10	484	359	449	617	431	564	10
11	591	461	554	711	502	651	11
12	682	512	633	762	586	712	12
13	648	601	635	697	650	684	13
14	653	662	655	630	663	639	14
15	718	692	711	623	623	623	15
16	771	643	734	699	598	670	16
17	805	642	758	674	591	650	17
18	802	585	740	749	567	697	18
19	644	519	608	553	273	473	19
20	526	463	508	389	368	383	20
21	469	387	445	282	300	287	21
22	401	316	376	222	248	230	22
23	219	219	219	179	160	174	23
24	127	192	146	116	120	117	24
	10580	8341	9940	10399	7775	9649	

NORTHBOUND PATTERN			SOUTHBOUND PATTERN			
WKDAY	WKEND	7 DAYS	WKDAY	WKEND	7 DAYS	HR END
0.7%	1.7%	1.0%	0.6%	1.2%	0.7%	1
0.6%	1.0%	0.7%	0.4%	0.7%	0.4%	2
0.4%	0.9%	0.5%	0.3%	0.9%	0.4%	3
0.6%	0.5%	0.5%	0.5%	0.4%	0.4%	4
0.9%	0.7%	0.9%	0.7%	0.5%	0.6%	5
2.1%	0.8%	1.8%	1.8%	0.8%	1.6%	6
3.8%	1.9%	3.3%	4.2%	2.1%	3.7%	7
5.4%	2.5%	4.7%	8.3%	3.5%	7.2%	8
4.8%	3.2%	4.4%	7.2%	4.1%	6.5%	9
4.6%	4.3%	4.5%	5.9%	5.5%	5.8%	10
5.6%	5.5%	5.6%	6.8%	6.5%	6.7%	11
6.4%	6.1%	6.4%	7.3%	7.5%	7.4%	12
6.1%	7.2%	6.4%	6.7%	8.4%	7.1%	13
6.2%	7.9%	6.6%	6.1%	8.5%	6.6%	14
6.8%	8.3%	7.1%	6.0%	8.0%	6.5%	15
7.3%	7.7%	7.4%	6.7%	7.7%	6.9%	16
7.6%	7.7%	7.6%	6.5%	7.6%	6.7%	17
7.6%	7.0%	7.4%	7.2%	7.3%	7.2%	18
6.1%	6.2%	6.1%	5.3%	3.5%	4.9%	19
5.0%	5.6%	5.1%	3.7%	4.7%	4.0%	20
4.4%	4.6%	4.5%	2.7%	3.9%	3.0%	21
3.8%	3.8%	3.8%	2.1%	3.2%	2.4%	22
2.1%	2.6%	2.2%	1.7%	2.1%	1.8%	23
1.2%	2.3%	1.5%	1.1%	1.5%	1.2%	24
100%	100%	100%	100%	100.0%	100%	

Figure 51. Office memorandum on M-84 traffic information, page 4



LOCATION	M-84	S of KOCHVILLE ROAD
CONTROL SECTION	9011	
CONSTRUCTION YEAR	2002	
NUMBER OF DESIGN YEARS (1-30)	20	
COMMERCIAL GROWTH RATE	1.30%	
TYPE OF GROWTH RATE - COMPOUND, AVERAGE (C OR A)	C	
DIRECTION DISTRIBUTION FACTOR	62%	
LANE DISTRIBUTION FACTOR	80%	
COMMERCIAL ADT IN BASE YEAR	561	
OPTION - AVERAGE, MEDIUM/HEAVY,CLASSIFICATION (A,MH,C	CS	
AVERAGE ESAL - RIGID	0.76	
AVERAGE ESAL - FLEXIBLE	0.59	

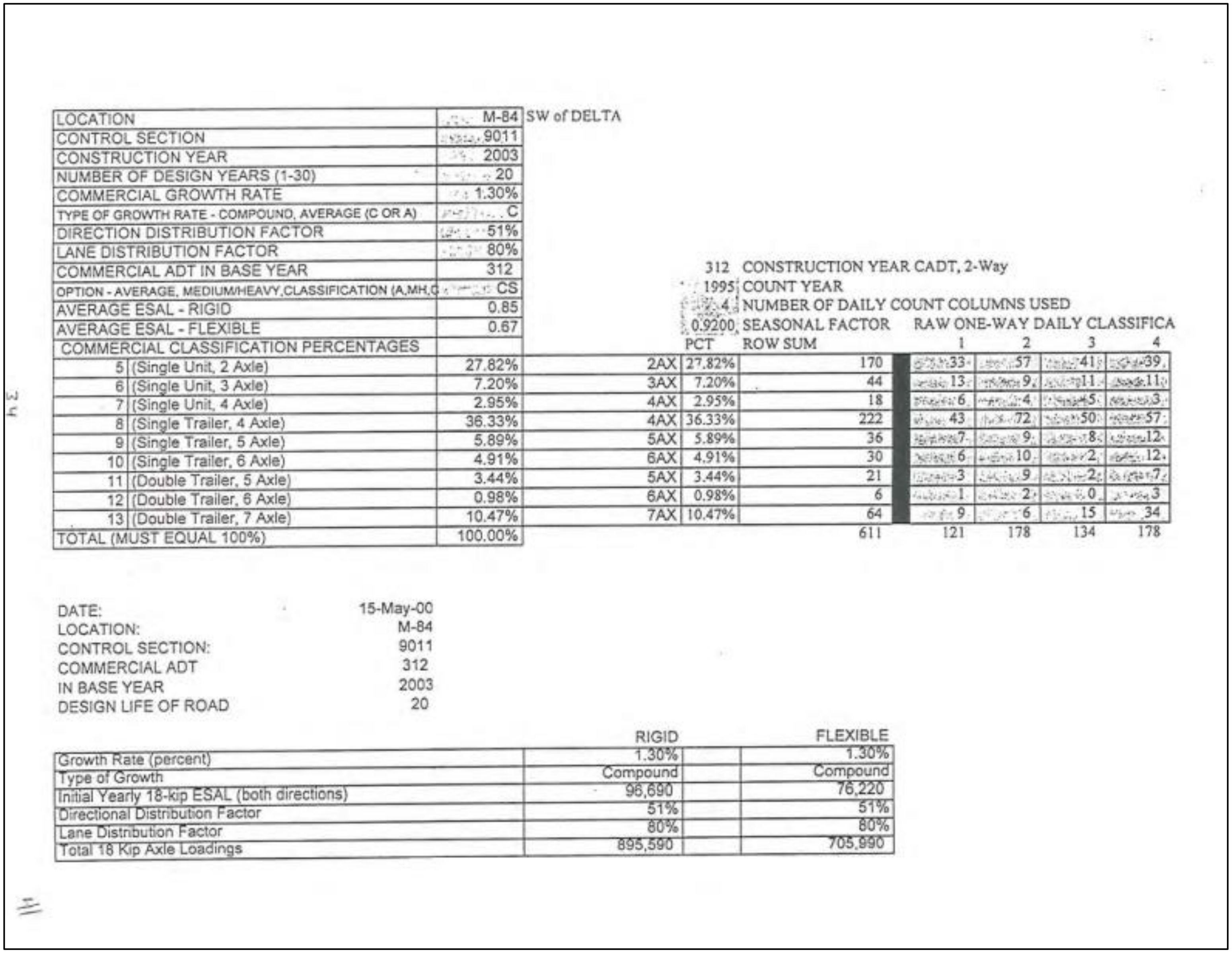
561 CONSTRUCTION YEAR CADT, 2-Way
1993 COUNT YEAR
4 NUMBER OF DAILY COUNT COLUMNS USED
0.9500 SEASONAL FACTOR RAW ONE-WAY DAILY CLASSIFICA

COMMERCIAL CLASSIFICATION PERCENTAGES				PCT	ROW SUM		1	2	3	4
5	(Single Unit, 2 Axle)	20.25%	2AX	20.25%	213		53	51	51	58
6	(Single Unit, 3 Axle)	27.47%	3AX	27.47%	289		126	115	15	33
7	(Single Unit, 4 Axle)	1.81%	4AX	1.81%	19		7	2	2	8
8	(Single Trailer, 4 Axle)	33.84%	4AX	33.84%	356		89	122	63	82
9	(Single Trailer, 5 Axle)	3.80%	5AX	3.80%	40		9	12	9	10
10	(Single Trailer, 6 Axle)	3.04%	6AX	3.04%	32		6	7	10	9
11	(Double Trailer, 5 Axle)	1.90%	5AX	1.90%	20		6	10	1	3
12	(Double Trailer, 6 Axle)	0.48%	6AX	0.48%	5		1	2	1	1
13	(Double Trailer, 7 Axle)	7.41%	7AX	7.41%	78		9	21	24	24
TOTAL (MUST EQUAL 100%)		100.00%			1,052		306	342	176	228

DATE:	16-May-00
LOCATION:	M-84
CONTROL SECTION:	9011
COMMERCIAL ADT	561
IN BASE YEAR	2002
DESIGN LIFE OF ROAD	20

	RIGID		FLEXIBLE
Growth Rate (percent)	1.30%		1.30%
Type of Growth	Compound		Compound
Initial Yearly 18-kip ESAL (both directions)	155,700		120,880
Directional Distribution Factor	62%		62%
Lane Distribution Factor	80%		80%
Total 18 Kip Axle Loadings	1,739,650		1,350,600

Figure 52. Office memorandum on M-84 traffic information, page 5



LOCATION	M-84	SW of DELTA
CONTROL SECTION	9011	
CONSTRUCTION YEAR	2003	
NUMBER OF DESIGN YEARS (1-30)	20	
COMMERCIAL GROWTH RATE	1.30%	
TYPE OF GROWTH RATE - COMPOUND, AVERAGE (C OR A)	C	
DIRECTION DISTRIBUTION FACTOR	51%	
LANE DISTRIBUTION FACTOR	80%	
COMMERCIAL ADT IN BASE YEAR	312	
OPTION - AVERAGE, MEDIUM/HEAVY,CLASSIFICATION (A,MH,C	CS	
AVERAGE ESAL - RIGID	0.85	
AVERAGE ESAL - FLEXIBLE	0.67	

312 CONSTRUCTION YEAR CADT, 2-Way

1995 COUNT YEAR

4 NUMBER OF DAILY COUNT COLUMNS USED

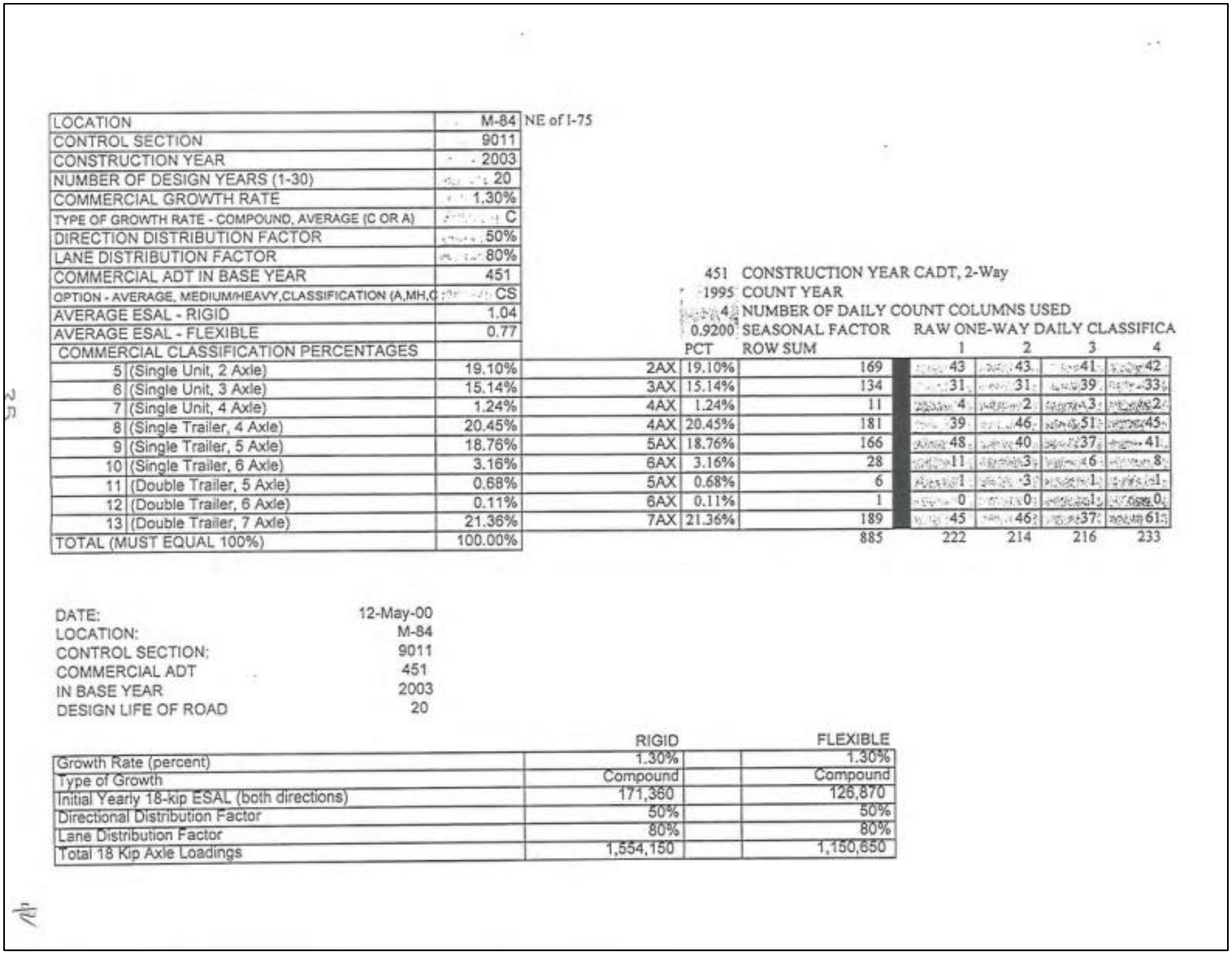
0.9200 SEASONAL FACTOR RAW ONE-WAY DAILY CLASSIFICA

COMMERCIAL CLASSIFICATION PERCENTAGES				PCT	ROW SUM	1	2	3	4
5	(Single Unit, 2 Axle)	27.82%	2AX	27.82%	170	33	57	41	39
6	(Single Unit, 3 Axle)	7.20%	3AX	7.20%	44	13	9	11	11
7	(Single Unit, 4 Axle)	2.95%	4AX	2.95%	18	6	4	5	3
8	(Single Trailer, 4 Axle)	36.33%	4AX	36.33%	222	43	72	50	57
9	(Single Trailer, 5 Axle)	5.89%	5AX	5.89%	36	7	9	8	12
10	(Single Trailer, 6 Axle)	4.91%	6AX	4.91%	30	6	10	2	12
11	(Double Trailer, 5 Axle)	3.44%	5AX	3.44%	21	3	9	2	7
12	(Double Trailer, 6 Axle)	0.98%	6AX	0.98%	6	1	2	0	3
13	(Double Trailer, 7 Axle)	10.47%	7AX	10.47%	64	9	6	15	34
TOTAL (MUST EQUAL 100%)		100.00%			611	121	178	134	178

DATE:	15-May-00
LOCATION:	M-84
CONTROL SECTION:	9011
COMMERCIAL ADT	312
IN BASE YEAR	2003
DESIGN LIFE OF ROAD	20

	RIGID		FLEXIBLE
Growth Rate (percent)	1.30%		1.30%
Type of Growth	Compound		Compound
Initial Yearly 18-kip ESAL (both directions)	96,690		76,220
Directional Distribution Factor	51%		51%
Lane Distribution Factor	80%		80%
Total 18 Kip Axle Loadings	895,590		705,990

Figure 53. Office memorandum on M-84 traffic information, page 6



LOCATION	M-84	NE of I-75
CONTROL SECTION	9011	
CONSTRUCTION YEAR	2003	
NUMBER OF DESIGN YEARS (1-30)	20	
COMMERCIAL GROWTH RATE	1.30%	
TYPE OF GROWTH RATE - COMPOUND, AVERAGE (C OR A)	C	
DIRECTION DISTRIBUTION FACTOR	50%	
LANE DISTRIBUTION FACTOR	80%	
COMMERCIAL ADT IN BASE YEAR	451	
OPTION - AVERAGE, MEDIUM/HEAVY,CLASSIFICATION (A,MH,C	CS	
AVERAGE ESAL - RIGID	1.04	
AVERAGE ESAL - FLEXIBLE	0.77	

451 CONSTRUCTION YEAR CADT, 2-Way

1995 COUNT YEAR

4 NUMBER OF DAILY COUNT COLUMNS USED

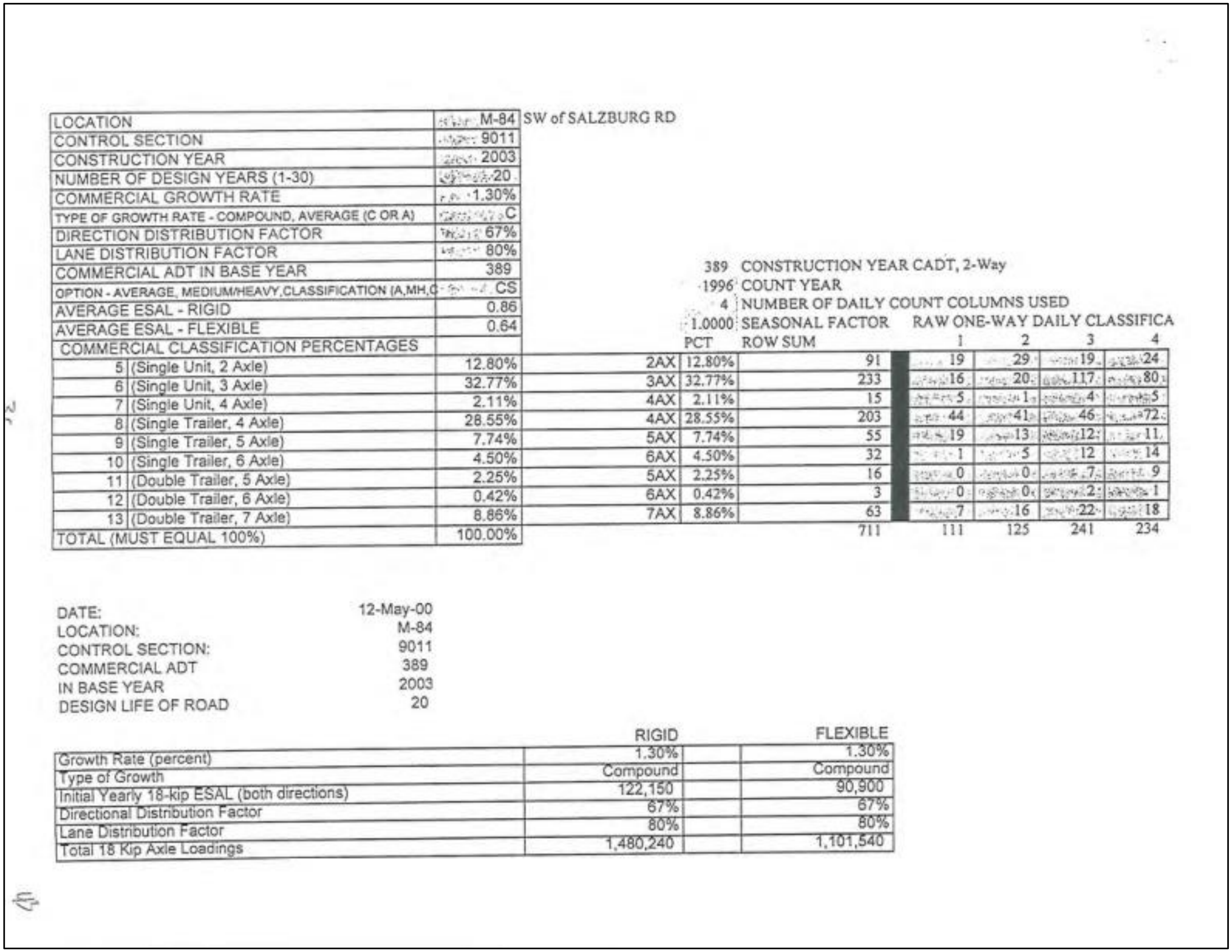
0.9200 SEASONAL FACTOR RAW ONE-WAY DAILY CLASSIFICA

COMMERCIAL CLASSIFICATION PERCENTAGES				PCT	ROW SUM	1	2	3	4
5	(Single Unit, 2 Axle)	19.10%	2AX	19.10%	169	43	43	41	42
6	(Single Unit, 3 Axle)	15.14%	3AX	15.14%	134	31	31	39	33
7	(Single Unit, 4 Axle)	1.24%	4AX	1.24%	11	4	2	3	2
8	(Single Trailer, 4 Axle)	20.45%	4AX	20.45%	181	39	46	51	45
9	(Single Trailer, 5 Axle)	18.76%	5AX	18.76%	166	48	40	37	41
10	(Single Trailer, 6 Axle)	3.16%	6AX	3.16%	28	11	3	6	8
11	(Double Trailer, 5 Axle)	0.68%	5AX	0.68%	6	1	3	1	1
12	(Double Trailer, 6 Axle)	0.11%	6AX	0.11%	1	0	0	1	0
13	(Double Trailer, 7 Axle)	21.36%	7AX	21.36%	189	45	46	37	61
TOTAL (MUST EQUAL 100%)		100.00%			885	222	214	216	233

DATE:	12-May-00
LOCATION:	M-84
CONTROL SECTION:	9011
COMMERCIAL ADT	451
IN BASE YEAR	2003
DESIGN LIFE OF ROAD	20

	RIGID		FLEXIBLE
Growth Rate (percent)	1.30%		1.30%
Type of Growth	Compound		Compound
Initial Yearly 18-kip ESAL (both directions)	171,360		126,870
Directional Distribution Factor	50%		50%
Lane Distribution Factor	80%		80%
Total 18 Kip Axle Loadings	1,554,150		1,150,650

Figure 54. Office memorandum on M-84 traffic information, Page 7



LOCATION	M-84 SW of SALZBURG RD
CONTROL SECTION	9011
CONSTRUCTION YEAR	2003
NUMBER OF DESIGN YEARS (1-30)	20
COMMERCIAL GROWTH RATE	1.30%
TYPE OF GROWTH RATE - COMPOUND, AVERAGE (C OR A)	C
DIRECTION DISTRIBUTION FACTOR	67%
LANE DISTRIBUTION FACTOR	80%
COMMERCIAL ADT IN BASE YEAR	389
OPTION - AVERAGE, MEDIUM/HEAVY,CLASSIFICATION (A,MH,C	CS
AVERAGE ESAL - RIGID	0.86
AVERAGE ESAL - FLEXIBLE	0.64

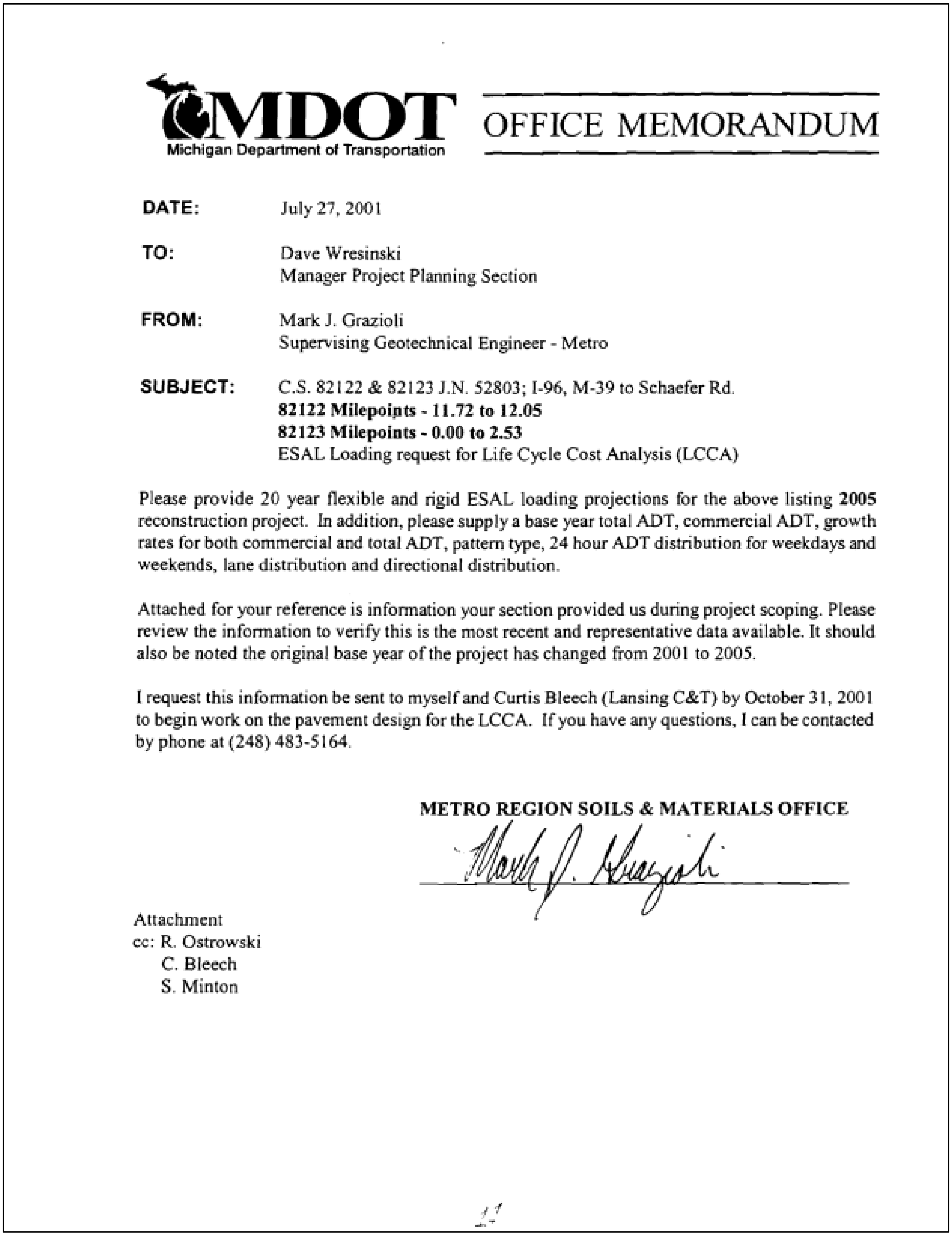
389 CONSTRUCTION YEAR CADT, 2-Way
1996 COUNT YEAR
4 NUMBER OF DAILY COUNT COLUMNS USED
1.0000 SEASONAL FACTOR RAW ONE-WAY DAILY CLASSIFICA

COMMERCIAL CLASSIFICATION PERCENTAGES				PCT	ROW SUM	1	2	3	4
5	(Single Unit, 2 Axle)	12.80%	2AX	12.80%	91	19	29	19	24
6	(Single Unit, 3 Axle)	32.77%	3AX	32.77%	233	16	20	117	80
7	(Single Unit, 4 Axle)	2.11%	4AX	2.11%	15	5	1	4	5
8	(Single Trailer, 4 Axle)	28.55%	4AX	28.55%	203	44	41	46	72
9	(Single Trailer, 5 Axle)	7.74%	5AX	7.74%	55	19	13	12	11
10	(Single Trailer, 6 Axle)	4.50%	6AX	4.50%	32	1	5	12	14
11	(Double Trailer, 5 Axle)	2.25%	5AX	2.25%	16	0	0	7	9
12	(Double Trailer, 6 Axle)	0.42%	6AX	0.42%	3	0	0	2	1
13	(Double Trailer, 7 Axle)	8.86%	7AX	8.86%	63	7	16	22	18
TOTAL (MUST EQUAL 100%)		100.00%			711	111	125	241	234

DATE:	12-May-00
LOCATION:	M-84
CONTROL SECTION:	9011
COMMERCIAL ADT	389
IN BASE YEAR	2003
DESIGN LIFE OF ROAD	20

	RIGID	FLEXIBLE
Growth Rate (percent)	1.30%	1.30%
Type of Growth	Compound	Compound
Initial Yearly 18-kip ESAL (both directions)	122,150	90,900
Directional Distribution Factor	67%	67%
Lane Distribution Factor	80%	80%
Total 18 Kip Axle Loadings	1,480,240	1,101,540

Figure 55. Office memorandum on M-84 traffic information, Page 8



MDOT OFFICE MEMORANDUM
Michigan Department of Transportation

DATE: July 27, 2001

TO: Dave Wresinski
Manager Project Planning Section

FROM: Mark J. Grazioli
Supervising Geotechnical Engineer - Metro

SUBJECT: C.S. 82122 & 82123 J.N. 52803; I-96, M-39 to Schaefer Rd.
82122 Milepoints - 11.72 to 12.05
82123 Milepoints - 0.00 to 2.53
ESAL Loading request for Life Cycle Cost Analysis (LCCA)

Please provide 20 year flexible and rigid ESAL loading projections for the above listing **2005** reconstruction project. In addition, please supply a base year total ADT, commercial ADT, growth rates for both commercial and total ADT, pattern type, 24 hour ADT distribution for weekdays and weekends, lane distribution and directional distribution.

Attached for your reference is information your section provided us during project scoping. Please review the information to verify this is the most recent and representative data available. It should also be noted the original base year of the project has changed from 2001 to 2005.

I request this information be sent to myself and Curtis Bleech (Lansing C&T) by October 31, 2001 to begin work on the pavement design for the LCCA. If you have any questions, I can be contacted by phone at (248) 483-5164.

METRO REGION SOILS & MATERIALS OFFICE

Mark J. Grazioli

Attachment
cc: R. Ostrowski
C. Bleech
S. Minton

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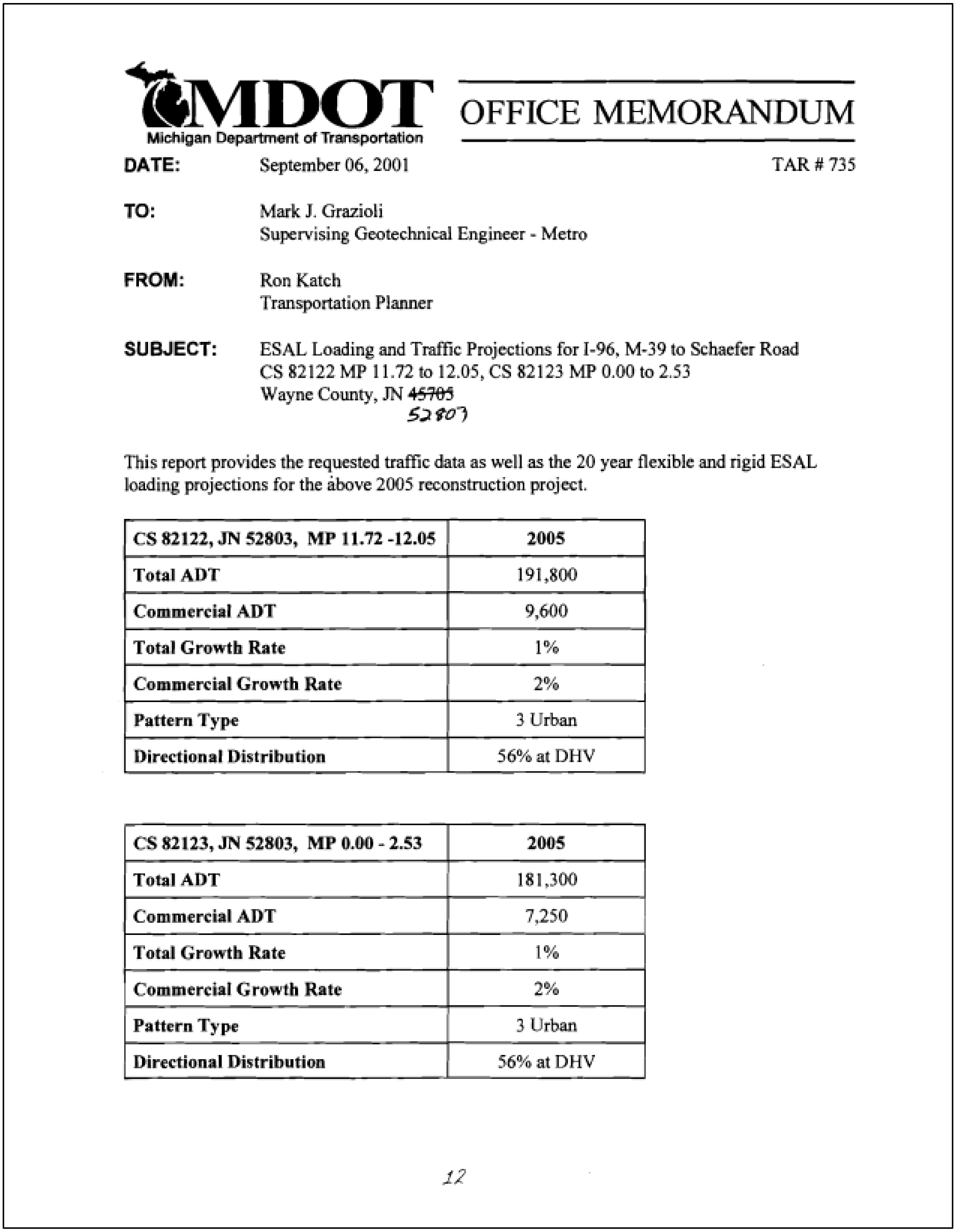
Figure 56. Office memorandum on I-96 traffic information, page 1



MDOT
Michigan Department of Transportation

OFFICE MEMORANDUM

DATE: September 06, 2001 TAR # 735

TO: Mark J. Grazioli
Supervising Geotechnical Engineer - Metro

FROM: Ron Katch
Transportation Planner

SUBJECT: ESAL Loading and Traffic Projections for I-96, M-39 to Schaefer Road
CS 82122 MP 11.72 to 12.05, CS 82123 MP 0.00 to 2.53
Wayne County, JN ~~45705~~
52803

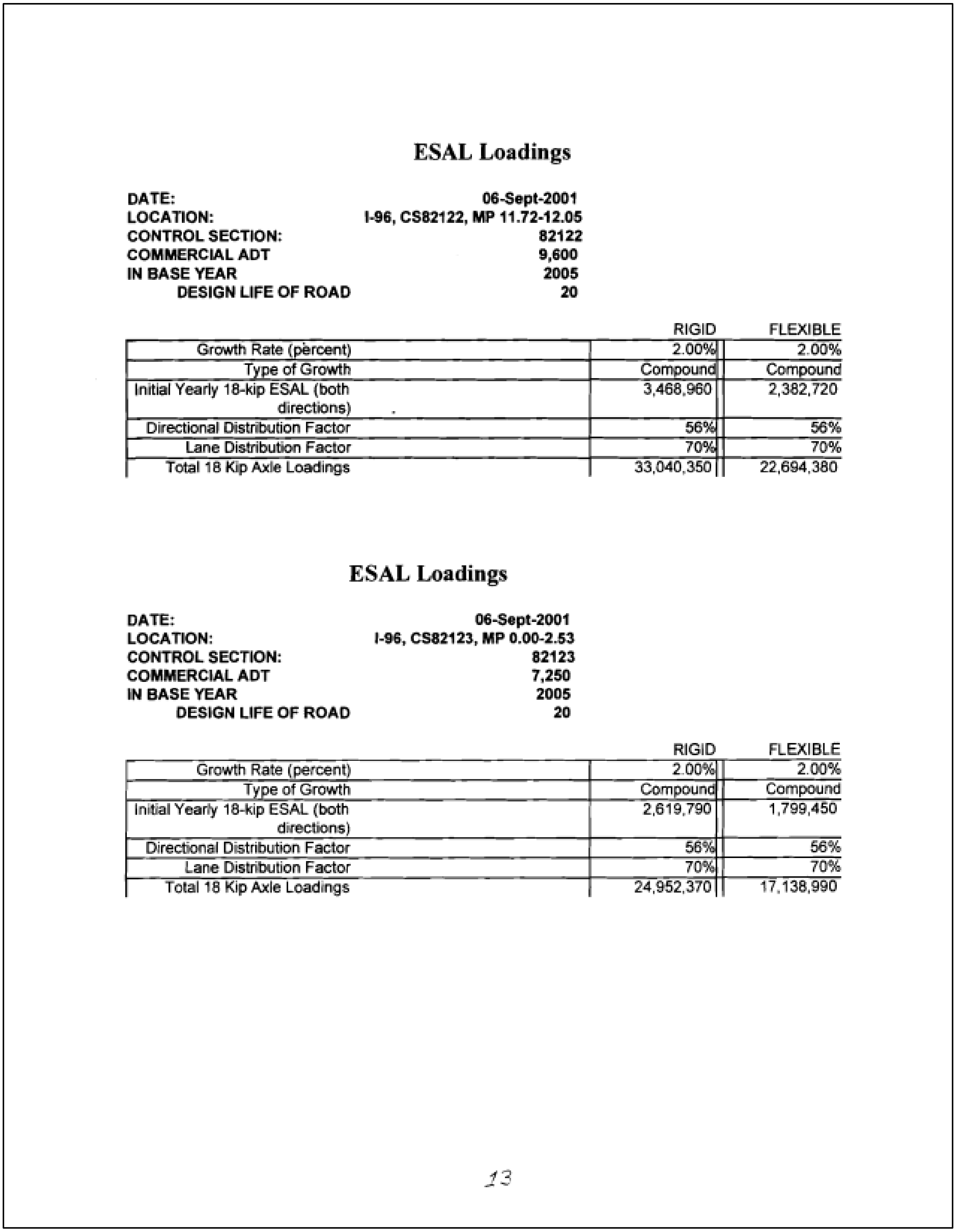
This report provides the requested traffic data as well as the 20 year flexible and rigid ESAL loading projections for the above 2005 reconstruction project.

CS 82122, JN 52803, MP 11.72 -12.05	2005
Total ADT	191,800
Commercial ADT	9,600
Total Growth Rate	1%
Commercial Growth Rate	2%
Pattern Type	3 Urban
Directional Distribution	56% at DHV

CS 82123, JN 52803, MP 0.00 - 2.53	2005
Total ADT	181,300
Commercial ADT	7,250
Total Growth Rate	1%
Commercial Growth Rate	2%
Pattern Type	3 Urban
Directional Distribution	56% at DHV

12

Figure 57. Office memorandum on I-96 traffic information, page 2



ESAL Loadings

DATE: 06-Sept-2001
LOCATION: I-96, CS82122, MP 11.72-12.05
CONTROL SECTION: 82122
COMMERCIAL ADT 9,600
IN BASE YEAR 2005
DESIGN LIFE OF ROAD 20

	RIGID	FLEXIBLE
Growth Rate (percent)	2.00%	2.00%
Type of Growth	Compound	Compound
Initial Yearly 18-kip ESAL (both directions)	3,468,960	2,382,720
Directional Distribution Factor	56%	56%
Lane Distribution Factor	70%	70%
Total 18 Kip Axle Loadings	33,040,350	22,694,380

ESAL Loadings

DATE: 06-Sept-2001
LOCATION: I-96, CS82123, MP 0.00-2.53
CONTROL SECTION: 82123
COMMERCIAL ADT 7,250
IN BASE YEAR 2005
DESIGN LIFE OF ROAD 20

	RIGID	FLEXIBLE
Growth Rate (percent)	2.00%	2.00%
Type of Growth	Compound	Compound
Initial Yearly 18-kip ESAL (both directions)	2,619,790	1,799,450
Directional Distribution Factor	56%	56%
Lane Distribution Factor	70%	70%
Total 18 Kip Axle Loadings	24,952,370	17,138,990

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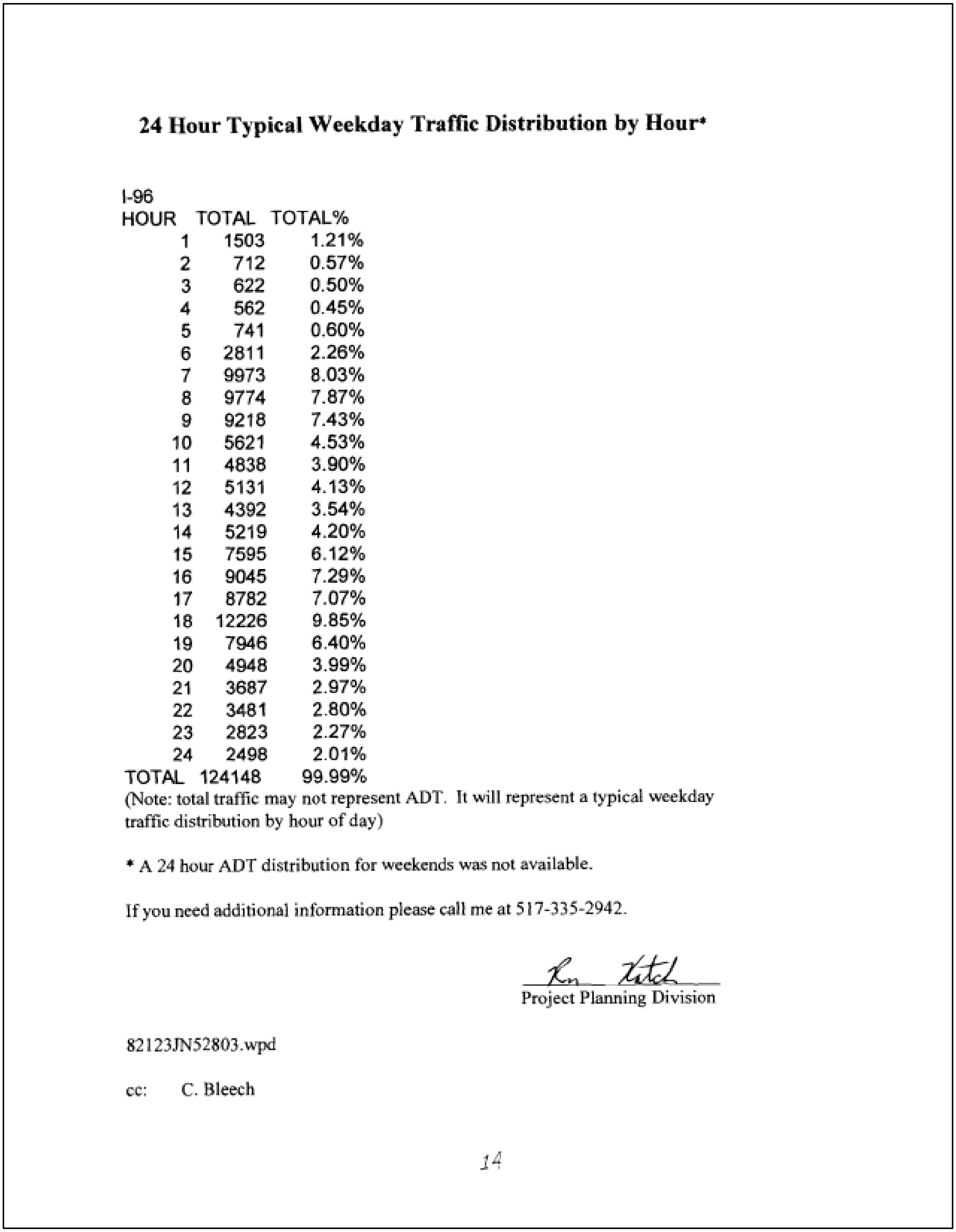
Figure 58. Office memorandum on I-96 traffic information, page 3



24 Hour Typical Weekday Traffic Distribution by Hour*

I-96

HOUR	TOTAL	TOTAL%
1	1503	1.21%
2	712	0.57%
3	622	0.50%
4	562	0.45%
5	741	0.60%
6	2811	2.26%
7	9973	8.03%
8	9774	7.87%
9	9218	7.43%
10	5621	4.53%
11	4838	3.90%
12	5131	4.13%
13	4392	3.54%
14	5219	4.20%
15	7595	6.12%
16	9045	7.29%
17	8782	7.07%
18	12226	9.85%
19	7946	6.40%
20	4948	3.99%
21	3687	2.97%
22	3481	2.80%
23	2823	2.27%
24	2498	2.01%
TOTAL	124148	99.99%

(Note: total traffic may not represent ADT. It will represent a typical weekday traffic distribution by hour of day)

* A 24 hour ADT distribution for weekends was not available.

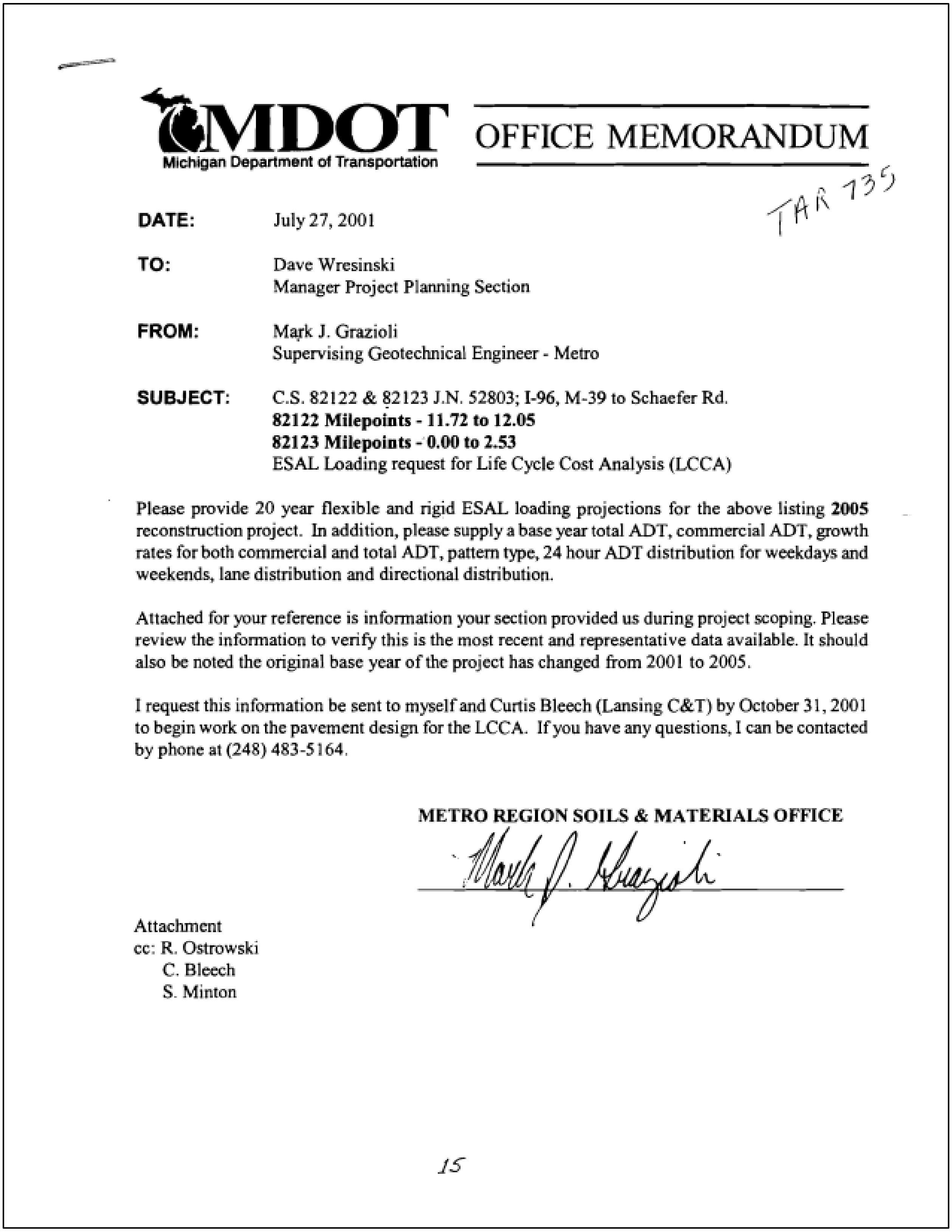
If you need additional information please call me at 517-335-2942.

Project Planning Division

82123JN52803.wpd

cc: C. Bleech

Figure 59. Office memorandum on I-96 traffic information, page 4



MDOT
Michigan Department of Transportation

OFFICE MEMORANDUM

TAR 735

DATE: July 27, 2001

TO: Dave Wresinski
Manager Project Planning Section

FROM: Mark J. Grazioli
Supervising Geotechnical Engineer - Metro

SUBJECT: C.S. 82122 & 82123 J.N. 52803; I-96, M-39 to Schaefer Rd.
82122 Milepoints - 11.72 to 12.05
82123 Milepoints - 0.00 to 2.53
ESAL Loading request for Life Cycle Cost Analysis (LCCA)

Please provide 20 year flexible and rigid ESAL loading projections for the above listing **2005** reconstruction project. In addition, please supply a base year total ADT, commercial ADT, growth rates for both commercial and total ADT, pattern type, 24 hour ADT distribution for weekdays and weekends, lane distribution and directional distribution.

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METRO REGION SOILS & MATERIALS OFFICE

Mark J. Grazioli

Attachment
cc: R. Ostrowski
C. Bleech
S. Minton

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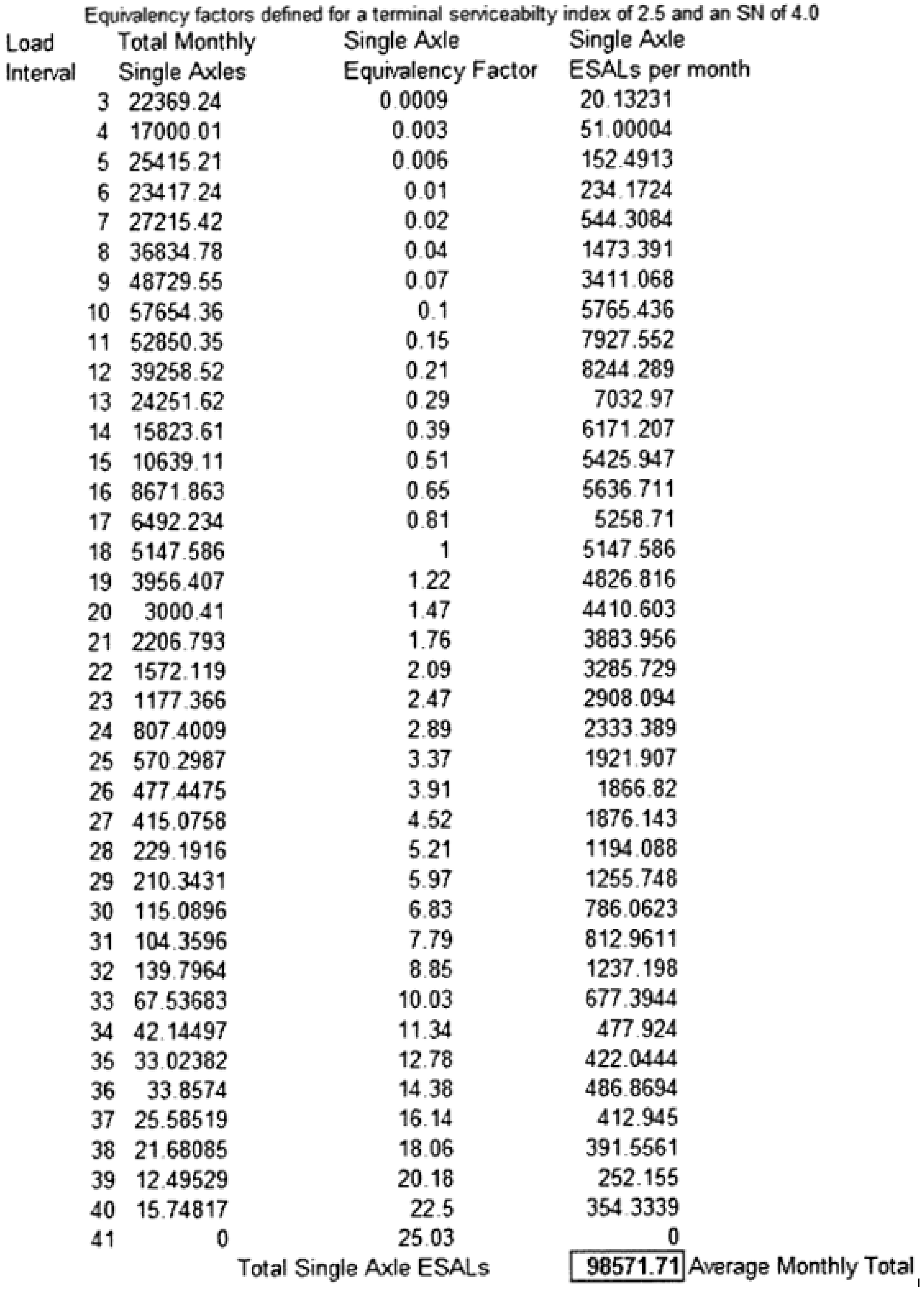
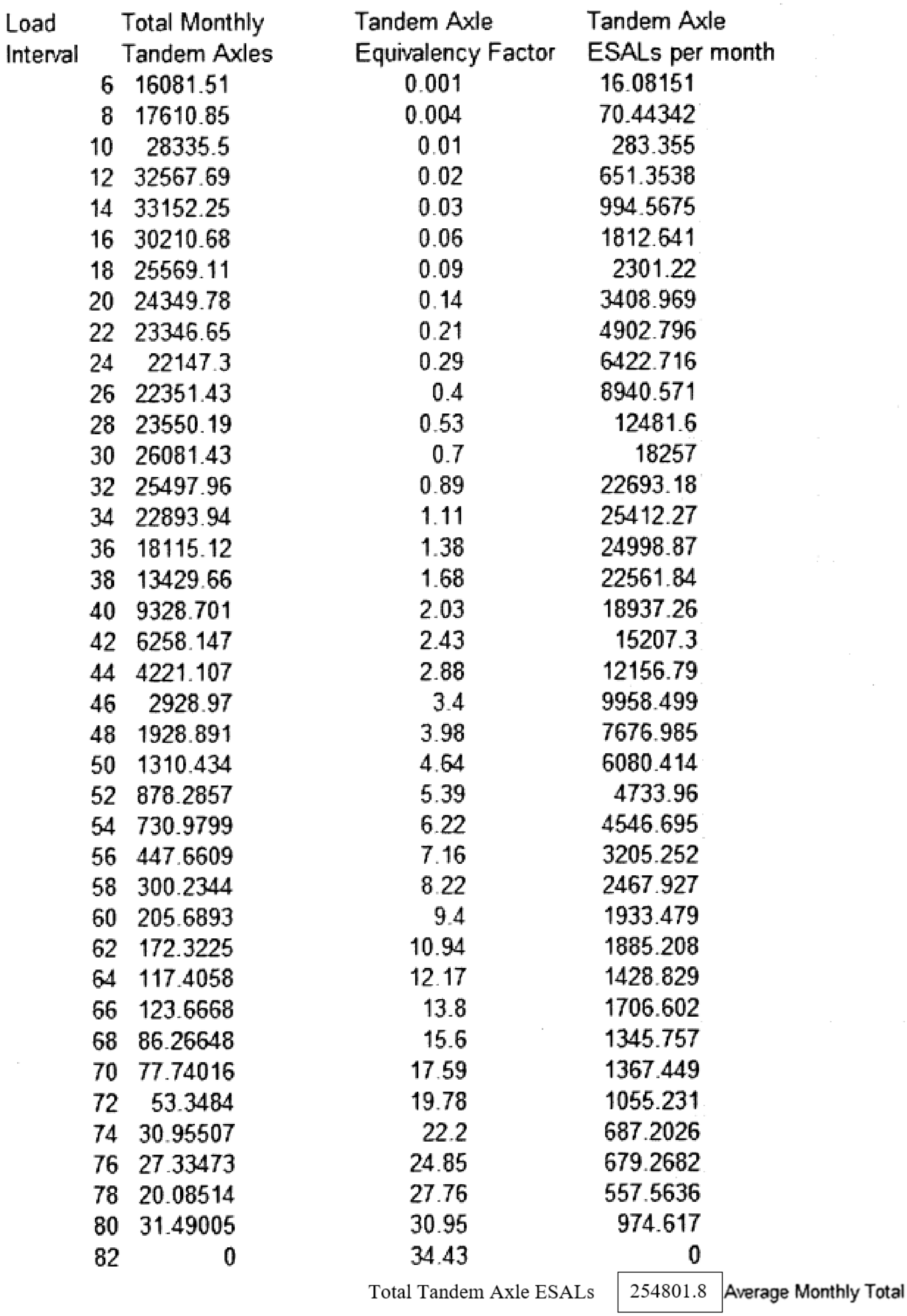
Figure 60. Office memorandum on I-96 traffic information, page 5



Equivalency factors defined for a terminal serviceabilty index of 2.5 and an SN of 4.0

Load Interval	Total Monthly Single Axles	Single Axle Equivalency Factor	Single Axle ESALs per month
3	22369.24	0.0009	20.13231
4	17000.01	0.003	51.00004
5	25415.21	0.006	152.4913
6	23417.24	0.01	234.1724
7	27215.42	0.02	544.3084
8	36834.78	0.04	1473.391
9	48729.55	0.07	3411.068
10	57654.36	0.1	5765.436
11	52850.35	0.15	7927.552
12	39258.52	0.21	8244.289
13	24251.62	0.29	7032.97
14	15823.61	0.39	6171.207
15	10639.11	0.51	5425.947
16	8671.863	0.65	5636.711
17	6492.234	0.81	5258.71
18	5147.586	1	5147.586
19	3956.407	1.22	4826.816
20	3000.41	1.47	4410.603
21	2206.793	1.76	3883.956
22	1572.119	2.09	3285.729
23	1177.366	2.47	2908.094
24	807.4009	2.89	2333.389
25	570.2987	3.37	1921.907
26	477.4475	3.91	1866.82
27	415.0758	4.52	1876.143
28	229.1916	5.21	1194.088
29	210.3431	5.97	1255.748
30	115.0896	6.83	786.0623
31	104.3596	7.79	812.9611
32	139.7964	8.85	1237.198
33	67.53683	10.03	677.3944
34	42.14497	11.34	477.924
35	33.02382	12.78	422.0444
36	33.8574	14.38	486.8694
37	25.58519	16.14	412.945
38	21.68085	18.06	391.5561
39	12.49529	20.18	252.155
40	15.74817	22.5	354.3339
41	0	25.03	0
		Total Single Axle ESALs	98571.71 Average Monthly Total

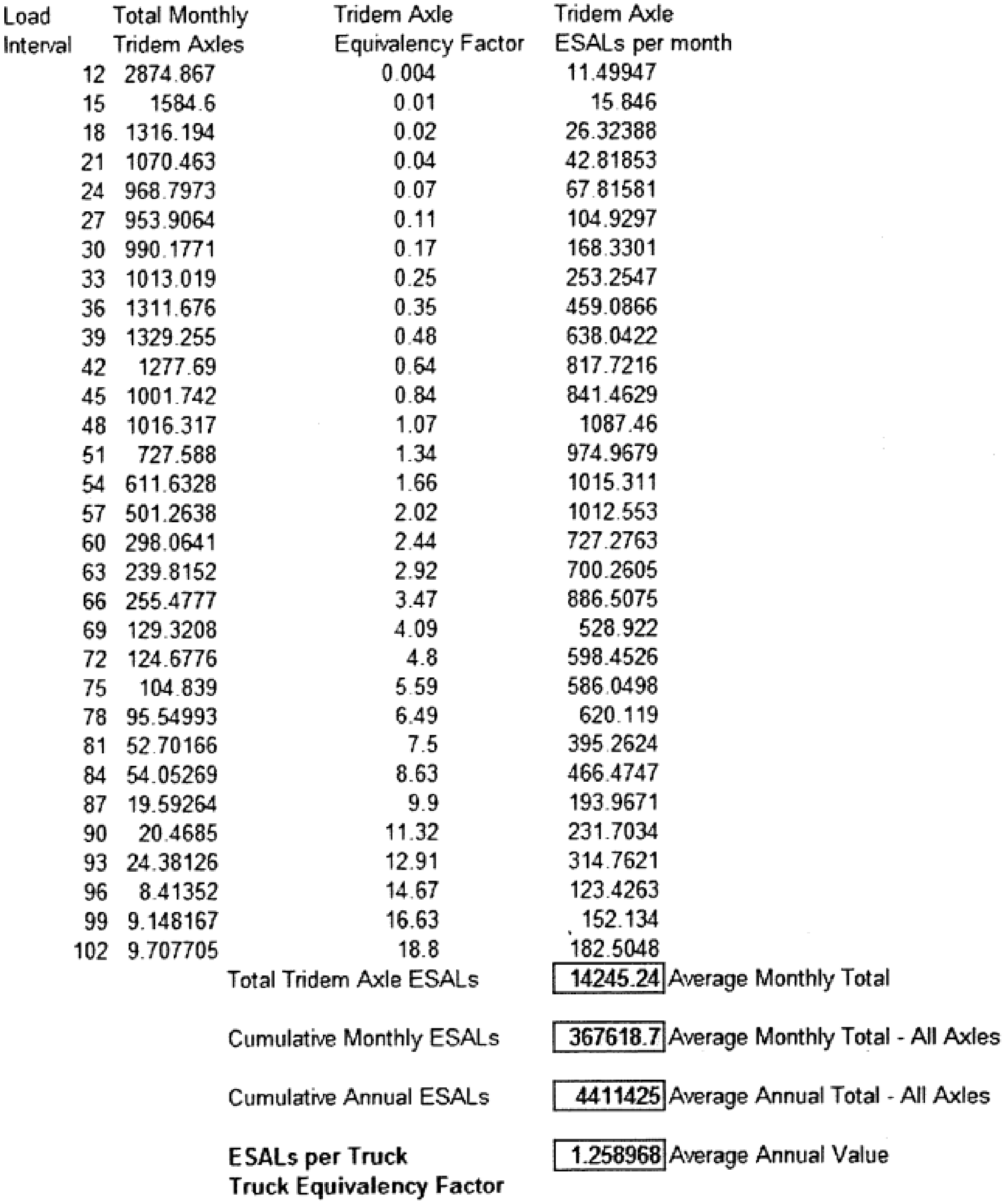
Figure 61. I-96 ESAL estimation using traffic and load distribution, page 1



Load Interval	Total Monthly Tandem Axles	Tandem Axle Equivalency Factor	Tandem Axle ESALs per month
6	16081.51	0.001	16.08151
8	17610.85	0.004	70.44342
10	28335.5	0.01	283.355
12	32567.69	0.02	651.3538
14	33152.25	0.03	994.5675
16	30210.68	0.06	1812.641
18	25569.11	0.09	2301.22
20	24349.78	0.14	3408.969
22	23346.65	0.21	4902.796
24	22147.3	0.29	6422.716
26	22351.43	0.4	8940.571
28	23550.19	0.53	12481.6
30	26081.43	0.7	18257
32	25497.96	0.89	22693.18
34	22893.94	1.11	25412.27
36	18115.12	1.38	24998.87
38	13429.66	1.68	22561.84
40	9328.701	2.03	18937.26
42	6258.147	2.43	15207.3
44	4221.107	2.88	12156.79
46	2928.97	3.4	9958.499
48	1928.891	3.98	7676.985
50	1310.434	4.64	6080.414
52	878.2857	5.39	4733.96
54	730.9799	6.22	4546.695
56	447.6609	7.16	3205.252
58	300.2344	8.22	2467.927
60	205.6893	9.4	1933.479
62	172.3225	10.94	1885.208
64	117.4058	12.17	1428.829
66	123.6668	13.8	1706.602
68	86.26648	15.6	1345.757
70	77.74016	17.59	1367.449
72	53.3484	19.78	1055.231
74	30.95507	22.2	687.2026
76	27.33473	24.85	679.2682
78	20.08514	27.76	557.5636
80	31.49005	30.95	974.617
82	0	34.43	0

Total Tandem Axle ESALs 254801.8 Average Monthly Total

Figure 62. I-96 ESAL estimation using traffic and load distribution, page 2



Load Interval	Total Monthly Tridem Axles	Tridem Axle Equivalency Factor	Tridem Axle ESALs per month
12	2874.867	0.004	11.49947
15	1584.6	0.01	15.846
18	1316.194	0.02	26.32388
21	1070.463	0.04	42.81853
24	968.7973	0.07	67.81581
27	953.9064	0.11	104.9297
30	990.1771	0.17	168.3301
33	1013.019	0.25	253.2547
36	1311.676	0.35	459.0866
39	1329.255	0.48	638.0422
42	1277.69	0.64	817.7216
45	1001.742	0.84	841.4629
48	1016.317	1.07	1087.46
51	727.588	1.34	974.9679
54	611.6328	1.66	1015.311
57	501.2638	2.02	1012.553
60	298.0641	2.44	727.2763
63	239.8152	2.92	700.2605
66	255.4777	3.47	886.5075
69	129.3208	4.09	528.922
72	124.6776	4.8	598.4526
75	104.839	5.59	586.0498
78	95.54993	6.49	620.119
81	52.70166	7.5	395.2624
84	54.05269	8.63	466.4747
87	19.59264	9.9	193.9671
90	20.4685	11.32	231.7034
93	24.38126	12.91	314.7621
96	8.41352	14.67	123.4263
99	9.148167	16.63	152.134
102	9.707705	18.8	182.5048

Total Tridem Axle ESALs $\boxed{14245.24}$ Average Monthly Total

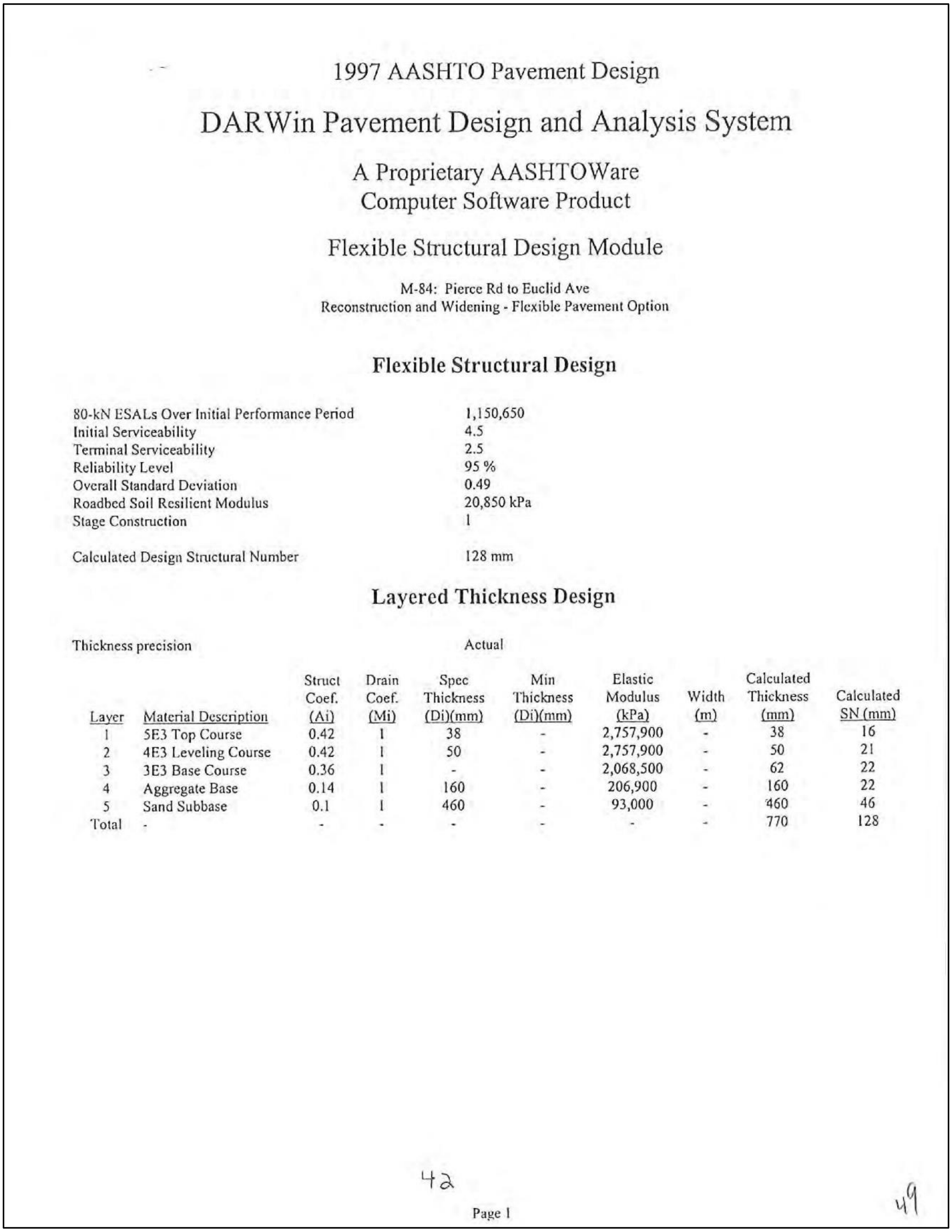
Cumulative Monthly ESALs $\boxed{367618.7}$ Average Monthly Total - All Axles

Cumulative Annual ESALs $\boxed{4411425}$ Average Annual Total - All Axles

ESALs per Truck
Truck Equivalency Factor $\boxed{1.258968}$ Average Annual Value

Figure 63. I-96 ESAL estimation using traffic and load distribution, page 3

Appendix C: Pavement Design Data



1997 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product

Flexible Structural Design Module

M-84: Pierce Rd to Euclid Ave
Reconstruction and Widening - Flexible Pavement Option

Flexible Structural Design

80-kN ESALs Over Initial Performance Period	1,150,650
Initial Serviceability	4.5
Terminal Serviceability	2.5
Reliability Level	95 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	20,850 kPa
Stage Construction	1
Calculated Design Structural Number	128 mm

Layered Thickness Design

Thickness precision Actual

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Spec Thickness (Di)(mm)	Min Thickness (Di)(mm)	Elastic Modulus (kPa)	Width (m)	Calculated Thickness (mm)	Calculated SN (mm)
1	5E3 Top Course	0.42	1	38	-	2,757,900	-	38	16
2	4E3 Leveling Course	0.42	1	50	-	2,757,900	-	50	21
3	3E3 Base Course	0.36	1	-	-	2,068,500	-	62	22
4	Aggregate Base	0.14	1	160	-	206,900	-	160	22
5	Sand Subbase	0.1	1	460	-	93,000	-	460	46
Total	-	-	-	-	-	-	-	770	128

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Page 1

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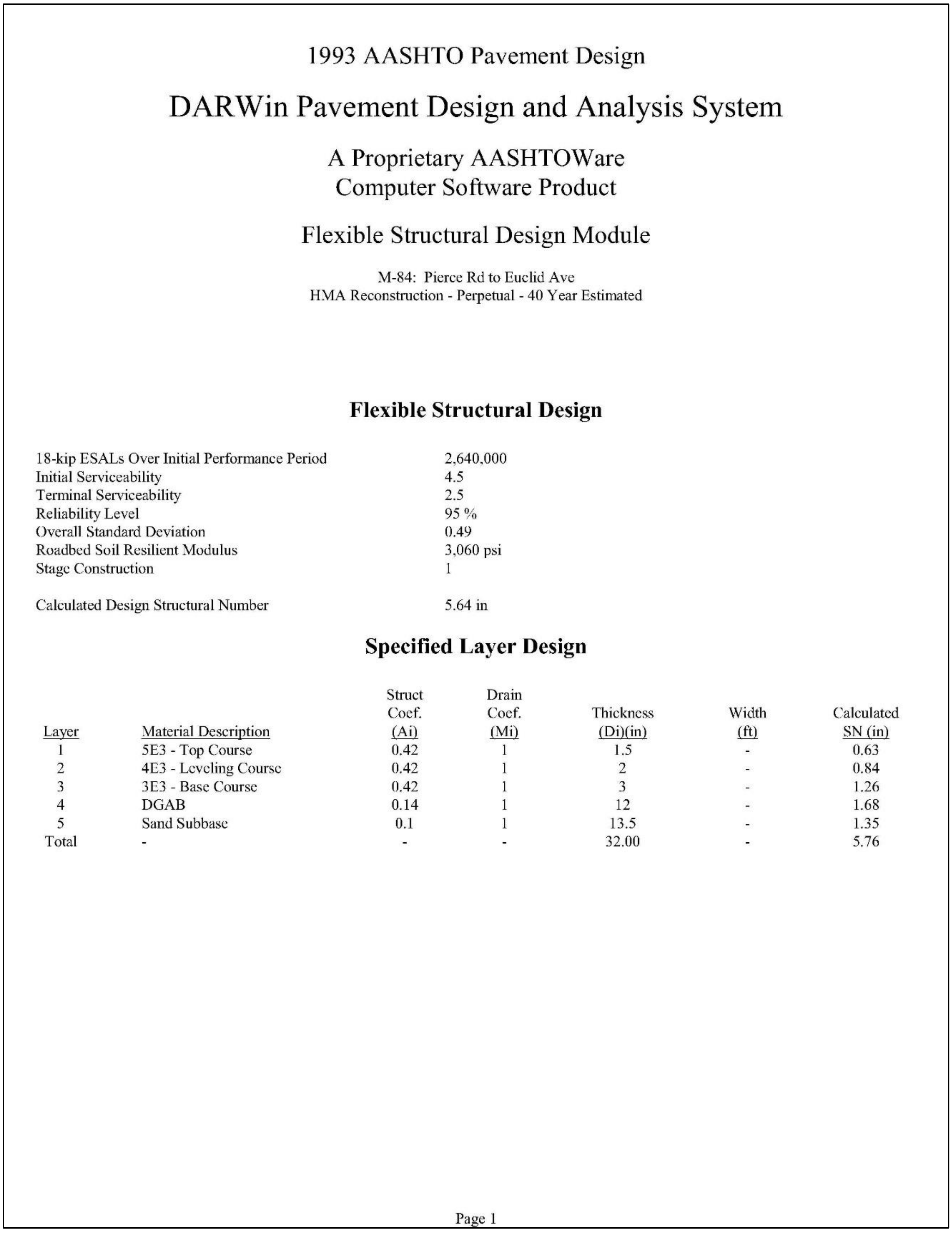
Figure 64. M-84 Original AASHTO 1993 pavement design, 20 years



1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product

Flexible Structural Design Module

M-84: Pierce Rd to Euclid Ave
HMA Reconstruction - Perpetual - 40 Year Estimated

Flexible Structural Design

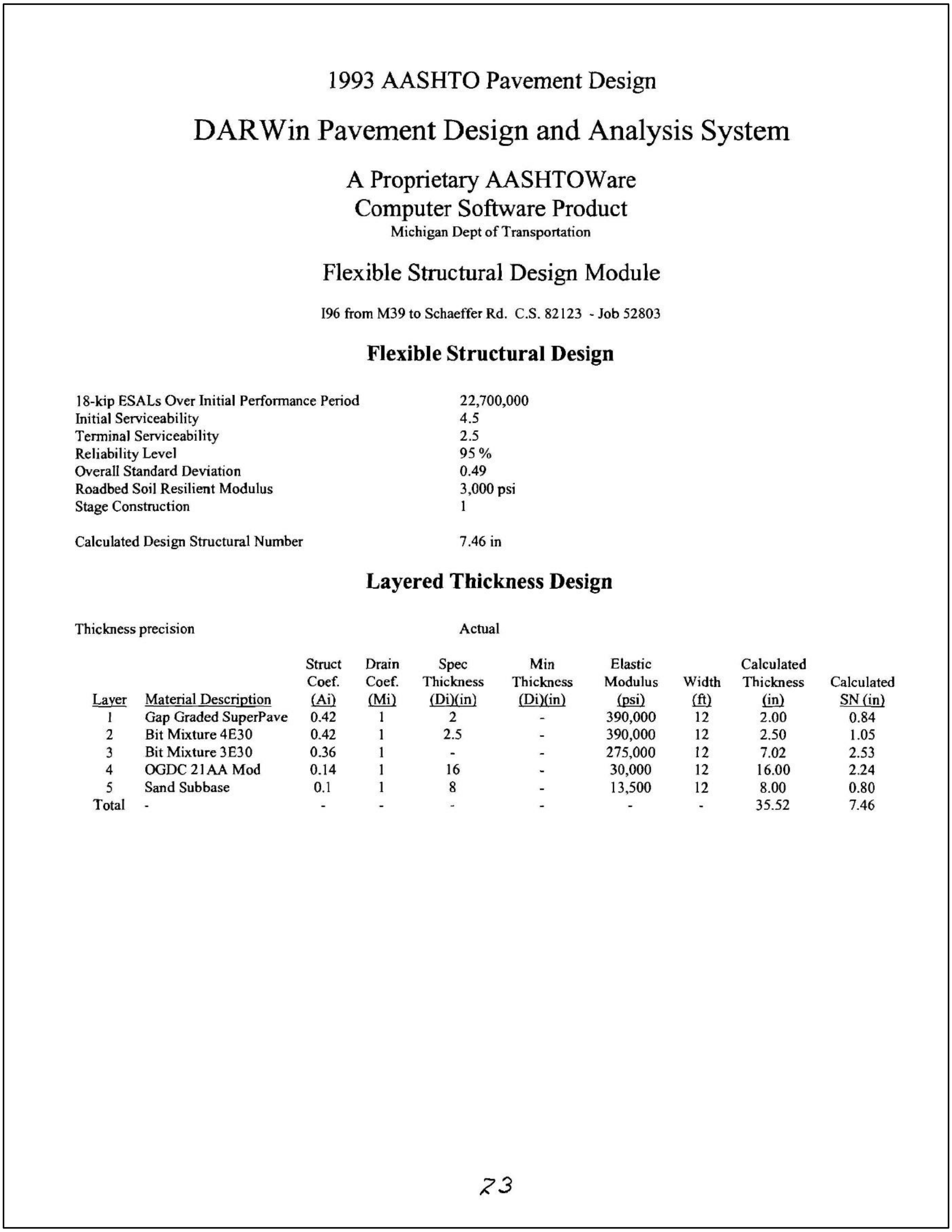
18-kip ESALs Over Initial Performance Period	2,640,000
Initial Serviceability	4.5
Terminal Serviceability	2.5
Reliability Level	95 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	3,060 psi
Stage Construction	1
Calculated Design Structural Number	5.64 in

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
1	5E3 - Top Course	0.42	1	1.5	-	0.63
2	4E3 - Leveling Course	0.42	1	2	-	0.84
3	3E3 - Base Course	0.42	1	3	-	1.26
4	DGAB	0.14	1	12	-	1.68
5	Sand Subbase	0.1	1	13.5	-	1.35
Total	-	-	-	32.00	-	5.76

Page 1

Figure 65. M-84 Estimated AASHTO 1993 pavement design, 40 years



1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product
Michigan Dept of Transportation

Flexible Structural Design Module

I96 from M39 to Schaeffer Rd. C.S. 82123 - Job 52803

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	22,700,000
Initial Serviceability	4.5
Terminal Serviceability	2.5
Reliability Level	95 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	3,000 psi
Stage Construction	1
Calculated Design Structural Number	7.46 in

Layered Thickness Design

Thickness precision Actual

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Spec Thickness (Di)(in)	Min Thickness (Di)(in)	Elastic Modulus (psi)	Width (ft)	Calculated Thickness (in)	Calculated SN (in)
1	Gap Graded SuperPave	0.42	1	2	-	390,000	12	2.00	0.84
2	Bit Mixture 4E30	0.42	1	2.5	-	390,000	12	2.50	1.05
3	Bit Mixture 3E30	0.36	1	-	-	275,000	12	7.02	2.53
4	OGDC 21AA Mod	0.14	1	16	-	30,000	12	16.00	2.24
5	Sand Subbase	0.1	1	8	-	13,500	12	8.00	0.80
Total	-	-	-	-	-	-	-	35.52	7.46

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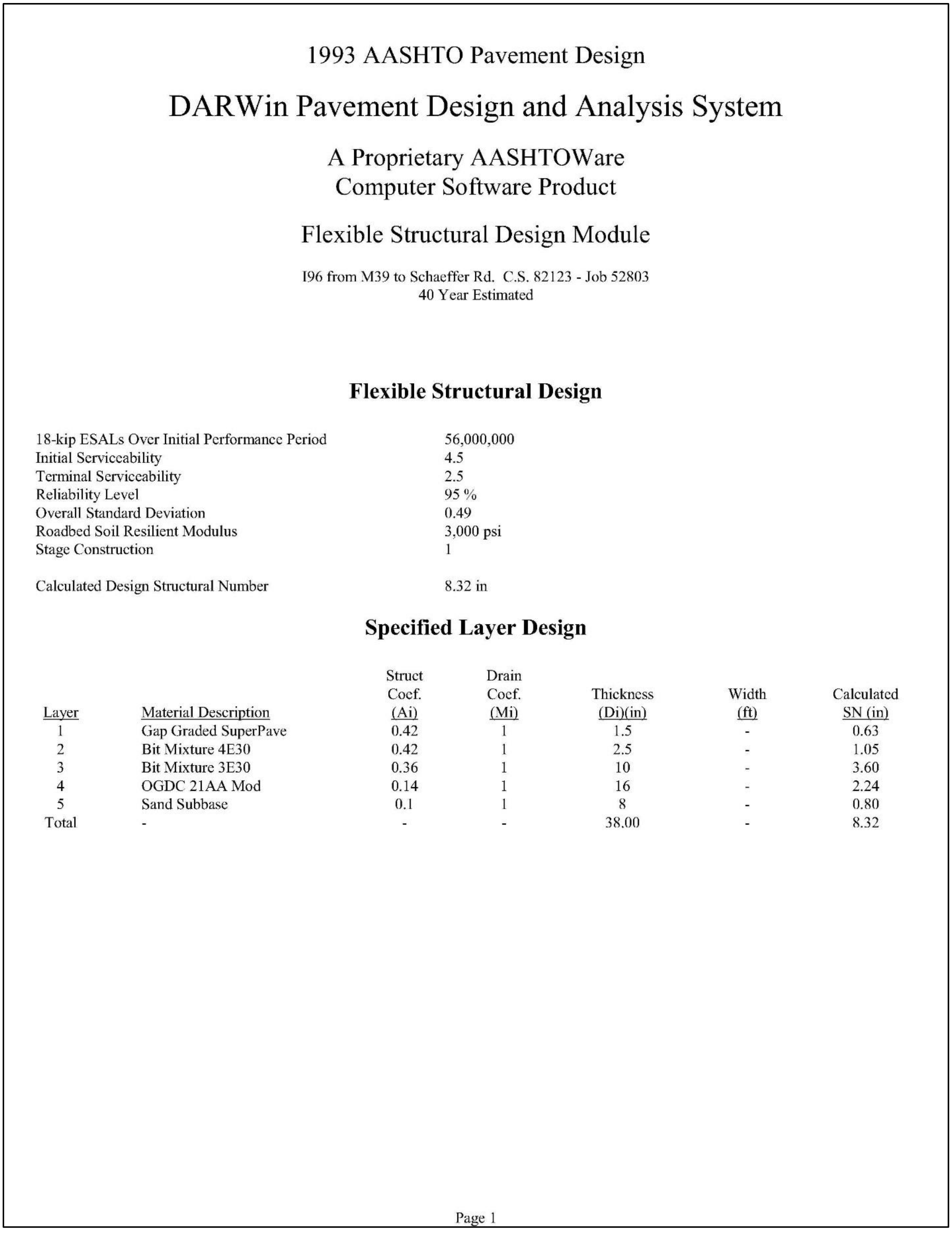
Figure 66. I-96 Original AASHTO 1993 pavement design, 20 years



1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product

Flexible Structural Design Module

I96 from M39 to Schaeffer Rd. C.S. 82123 - Job 52803
40 Year Estimated

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	56,000,000
Initial Serviceability	4.5
Terminal Serviceability	2.5
Reliability Level	95 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	3,000 psi
Stage Construction	1
Calculated Design Structural Number	8.32 in

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
1	Gap Graded SuperPave	0.42	1	1.5	-	0.63
2	Bit Mixture 4E30	0.42	1	2.5	-	1.05
3	Bit Mixture 3E30	0.36	1	10	-	3.60
4	OGDC 21AA Mod	0.14	1	16	-	2.24
5	Sand Subbase	0.1	1	8	-	0.80
Total	-	-	-	38.00	-	8.32

Page 1

Figure 67. I-96 Estimated AASHTO 1993 pavement design, 40 years

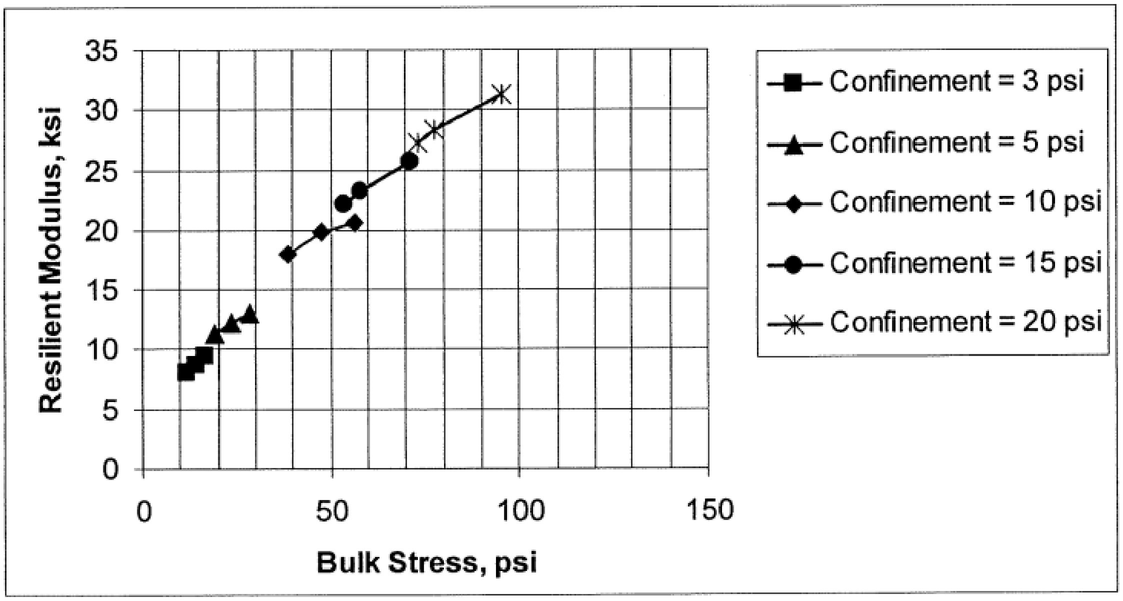


Figure 68. Sand subbase average repeated load resilient modulus test results extracted from LTPP database for I-96 ME-based designs

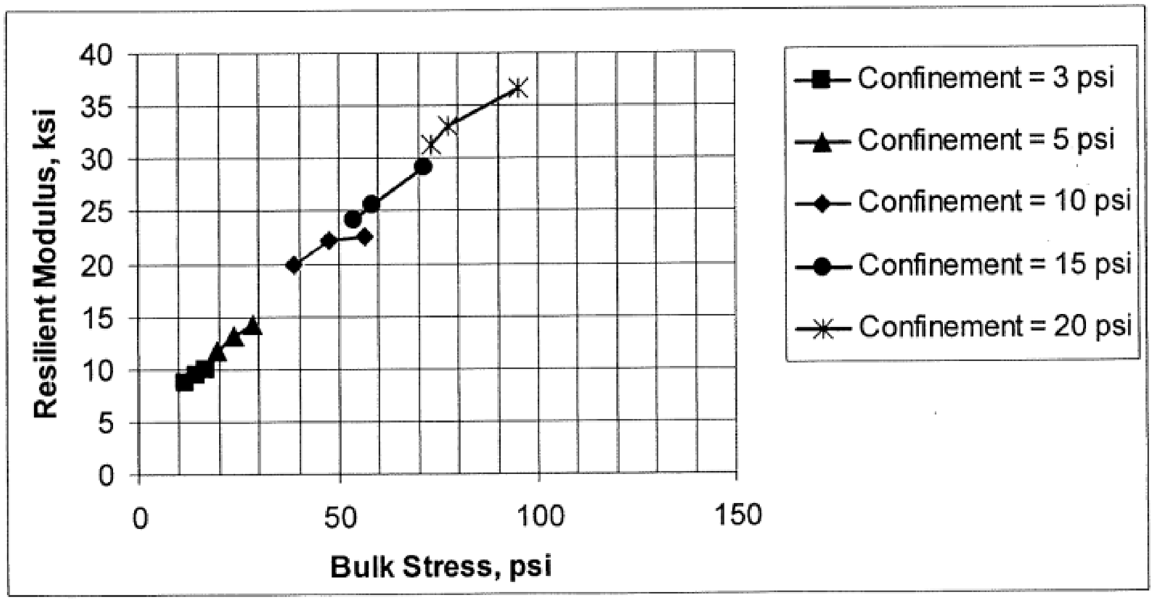
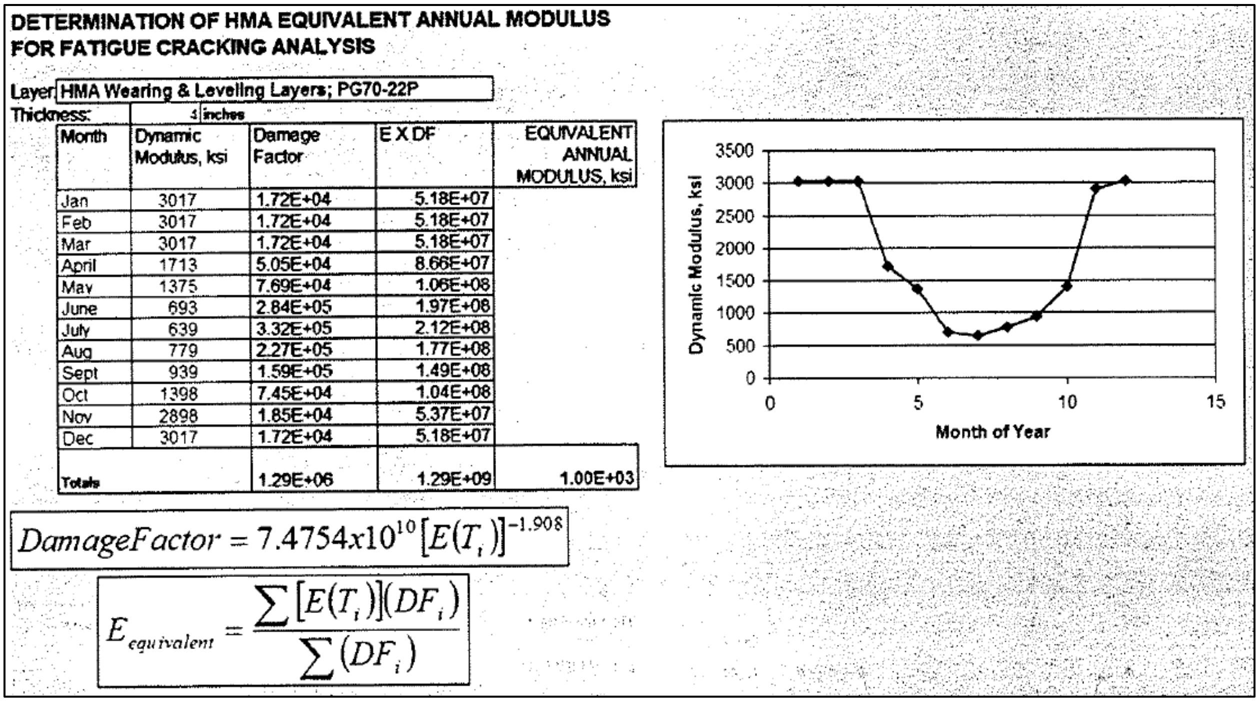


Figure 69. Aggregate base (21AA) average repeated load resilient modulus test results extracted from LTPP database for I-96 ME-based designs



DETERMINATION OF HMA EQUIVALENT ANNUAL MODULUS FOR FATIGUE CRACKING ANALYSIS

Layer: HMA Wearing & Leveling Layers; PG70-22P

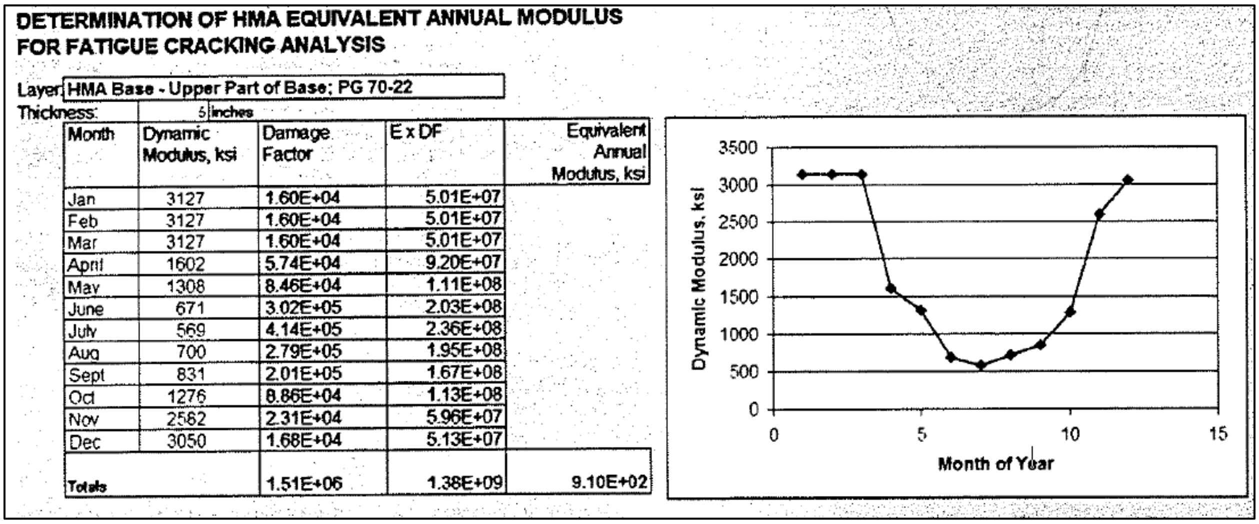
Thickness: 4 inches

Month	Dynamic Modulus, ksi	Damage Factor	E X DF	EQUIVALENT ANNUAL MODULUS, ksi
Jan	3017	1.72E+04	5.18E+07	
Feb	3017	1.72E+04	5.18E+07	
Mar	3017	1.72E+04	5.18E+07	
April	1713	5.05E+04	8.66E+07	
May	1375	7.69E+04	1.06E+08	
June	693	2.84E+05	1.97E+08	
July	639	3.32E+05	2.12E+08	
Aug	779	2.27E+05	1.77E+08	
Sept	939	1.59E+05	1.49E+08	
Oct	1398	7.45E+04	1.04E+08	
Nov	2898	1.85E+04	5.37E+07	
Dec	3017	1.72E+04	5.18E+07	
Totals		1.29E+06	1.29E+09	1.00E+03

$$DamageFactor = 7.4754x10^{10}\left[E(T_i)\right]^{-1.908}$$

$$E_{equivalent} = \frac{\sum\left[E(T_i)\right](DF_i)}{\sum(DF_i)}$$

Figure 70. HMA surface and leveling course layers monthly average dynamic modulus values per Witczak dynamic modulus regression equation for ME-based designs



DETERMINATION OF HMA EQUIVALENT ANNUAL MODULUS FOR FATIGUE CRACKING ANALYSIS

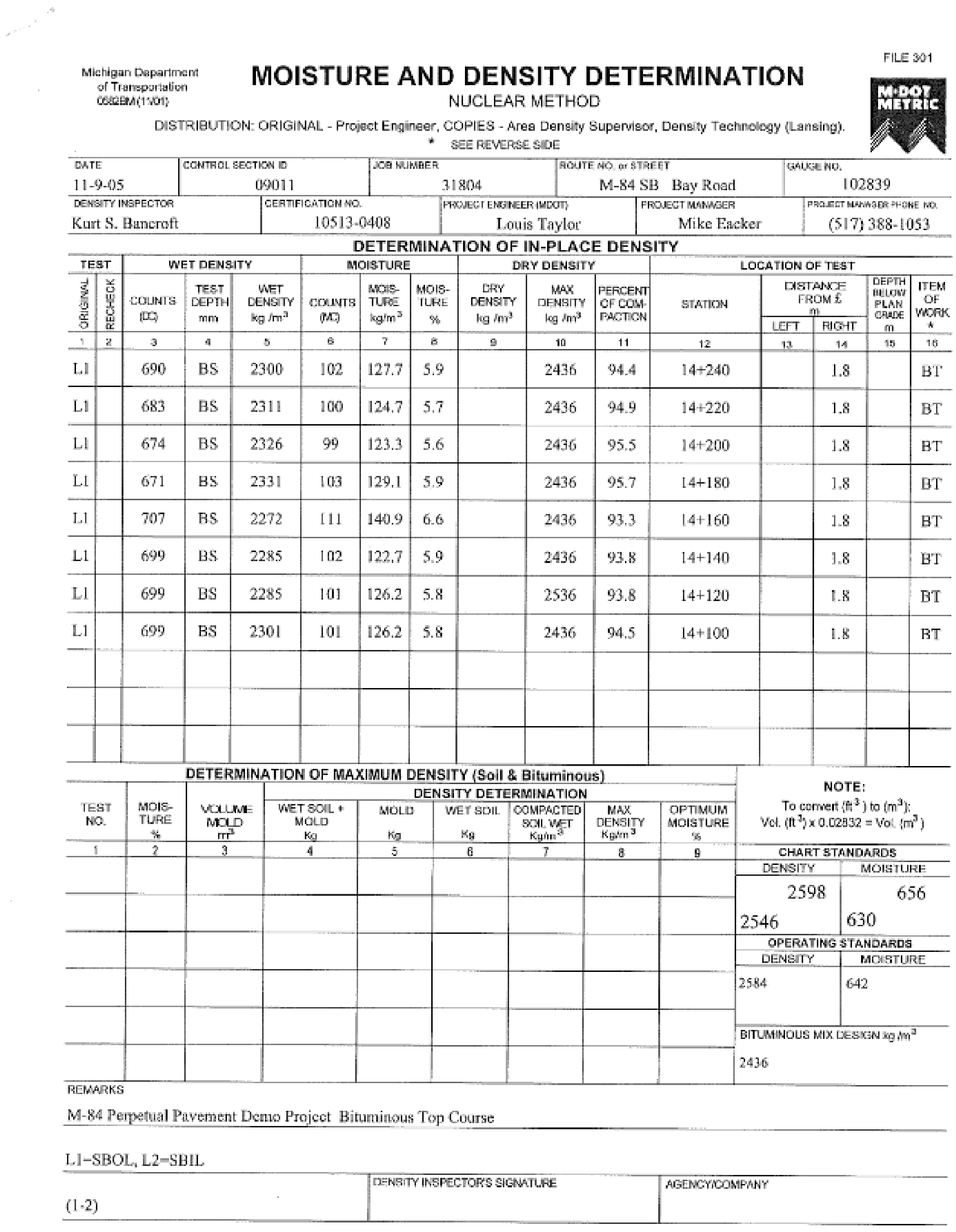
Layer: HMA Base - Upper Part of Base; PG 70-22

Thickness: 5 inches

Month	Dynamic Modulus, ksi	Damage Factor	E x DF	Equivalent Annual Modulus, ksi
Jan	3127	1.60E+04	5.01E+07	
Feb	3127	1.60E+04	5.01E+07	
Mar	3127	1.60E+04	5.01E+07	
April	1602	5.74E+04	9.20E+07	
May	1308	8.46E+04	1.11E+08	
June	671	3.02E+05	2.03E+08	
July	569	4.14E+05	2.36E+08	
Aug	700	2.79E+05	1.95E+08	
Sept	831	2.01E+05	1.67E+08	
Oct	1276	8.86E+04	1.13E+08	
Nov	2562	2.31E+04	5.96E+07	
Dec	3050	1.68E+04	5.13E+07	
Totals		1.51E+06	1.38E+09	9.10E+02

Figure 71. HMA base course layer (upper portion) monthly average dynamic modulus values per Witczak dynamic modulus regression equation for ME-based designs

Appendix D: Pre- and Post-Construction Related Records



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0582BM(11/01)

MOISTURE AND DENSITY DETERMINATION

NUCLEAR METHOD

FILE 301

M-DOT METRIC

DISTRIBUTION: ORIGINAL - Project Engineer, COPIES - Area Density Supervisor, Density Technology (Lansing).

* SEE REVERSE SIDE

DATE	CONTROL SECTION ID	JOB NUMBER	ROUTE NO. or STREET	GAUGE NO.
11-9-05	09011	31804	M-84 SB Bay Road	102839

DENSITY INSPECTOR	CERTIFICATION NO.	PROJECT ENGINEER (MDOT)	PROJECT MANAGER	PROJECT MANAGER PHONE NO.
Kurt S. Bancroft	10513-0408	Louis Taylor	Mike Eacker	(517) 388-1053

DETERMINATION OF IN-PLACE DENSITY

TEST		WET DENSITY			MOISTURE			DRY DENSITY			LOCATION OF TEST				
ORIGINAL	RECHECK	COUNTS (DC)	TEST DEPTH mm	WET DENSITY kg /m^3	COUNTS (MC)	MOIS-TURE kg/m^3	MOIS-TURE %	DRY DENSITY kg /m^3	MAX DENSITY kg /m^3	PERCENT OF COM-PACTION	STATION	DISTANCE FROM ℄ m		DEPTH BELOW PLAN GRADE m	ITEM OF WORK *
												LEFT	RIGHT		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
L1		690	BS	2300	102	127.7	5.9		2436	94.4	14+240		1.8		BT
L1		683	BS	2311	100	124.7	5.7		2436	94.9	14+220		1.8		BT
L1		674	BS	2326	99	123.3	5.6		2436	95.5	14+200		1.8		BT
L1		671	BS	2331	103	129.1	5.9		2436	95.7	14+180		1.8		BT
L1		707	BS	2272	111	140.9	6.6		2436	93.3	14+160		1.8		BT
L1		699	BS	2285	102	122.7	5.9		2436	93.8	14+140		1.8		BT
L1		699	BS	2285	101	126.2	5.8		2536	93.8	14+120		1.8		BT
L1		699	BS	2301	101	126.2	5.8		2436	94.5	14+100		1.8		BT

DETERMINATION OF MAXIMUM DENSITY (Soil & Bituminous)

TEST NO.	MOIS-TURE %	VOLUME MOLD m^3	DENSITY DETERMINATION					
			WET SOIL + MOLD Kg	MOLD Kg	WET SOIL Kg	COMPACTED SOIL WET Kg/m^3	MAX DENSITY Kg/m^3	OPTIMUM MOISTURE %
1	2	3	4	5	6	7	8	9

NOTE:
To convert (ft^3) to (m^3):
Vol. (ft^3) x 0.02832 = Vol. (m^3)

CHART STANDARDS

DENSITY	MOISTURE
2598 2546	656 630

OPERATING STANDARDS

DENSITY	MOISTURE
2584	642

BITUMINOUS MIX DESIGN kg /m^3
2436

REMARKS
M-84 Perpetual Pavement Demo Project Bituminous Top Course

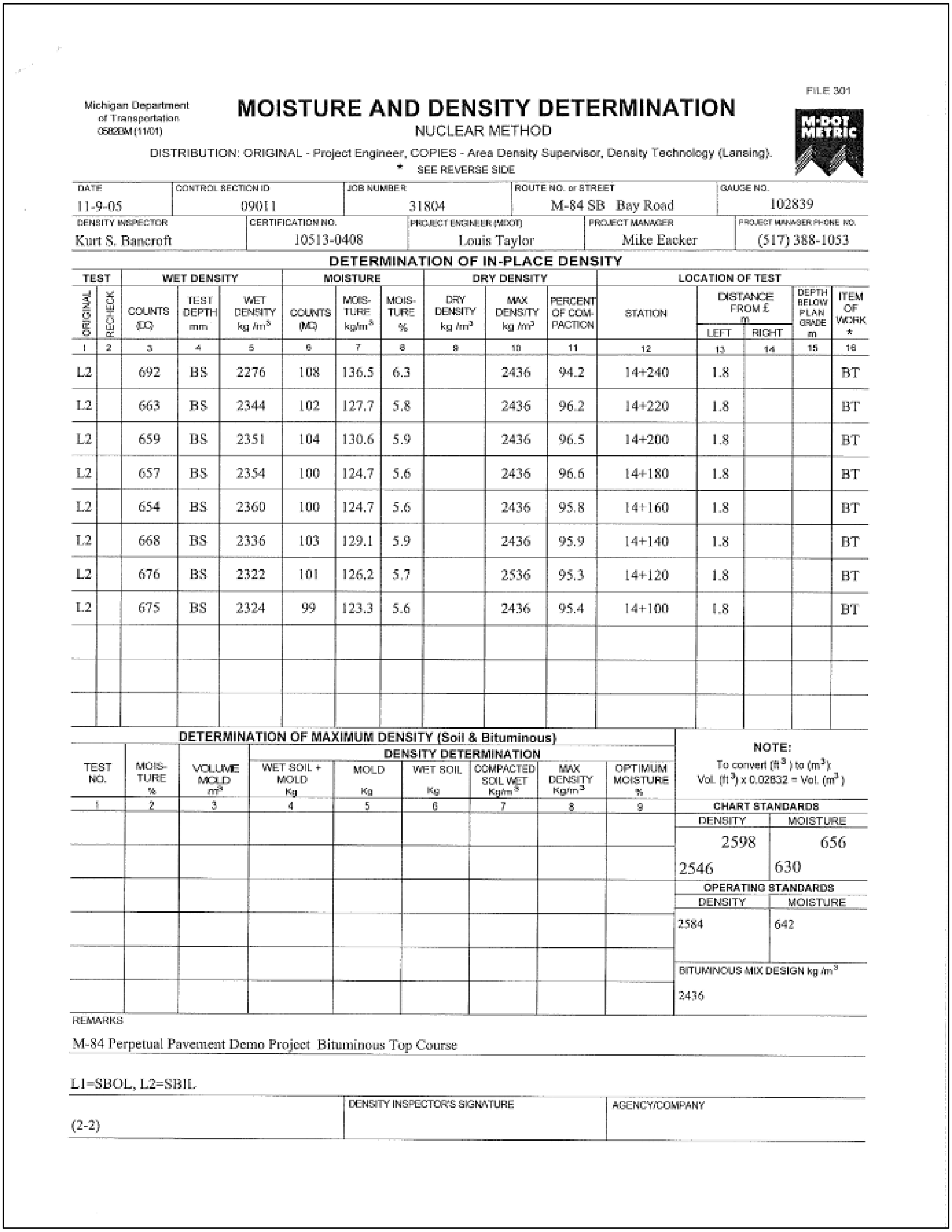
L1=SBOL, L2=SBIL

(1-2)

DENSITY INSPECTOR'S SIGNATURE

AGENCY/COMPANY

Figure 72. Moisture and density determination on M-84 SB HMA-top layer, page 1



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MOISTURE AND DENSITY DETERMINATION

NUCLEAR METHOD

DISTRIBUTION: ORIGINAL - Project Engineer, COPIES - Area Density Supervisor, Density Technology (Lansing).

* SEE REVERSE SIDE

DATE	CONTROL SECTION ID	JOB NUMBER	ROUTE NO. or STREET	GAUGE NO.
11-9-05	09011	31804	M-84 SB Bay Road	102839

DENSITY INSPECTOR	CERTIFICATION NO.	PROJECT ENGINEER (MDOT)	PROJECT MANAGER	PROJECT MANAGER PHONE NO.
Kurt S. Bancroft	10513-0408	Louis Taylor	Mike Eacker	(517) 388-1053

DETERMINATION OF IN-PLACE DENSITY

TEST		WET DENSITY			MOISTURE			DRY DENSITY			LOCATION OF TEST				
ORIGINAL	RECHECK	COUNTS (DC)	TEST DEPTH mm	WET DENSITY kg /m³	COUNTS (MC)	MOISTURE kg/m³	MOISTURE %	DRY DENSITY kg /m³	MAX DENSITY kg /m³	PERCENT OF COMPACTION	STATION	DISTANCE FROM ℄ m LEFT	DISTANCE FROM ℄ m RIGHT	DEPTH BELOW PLAN GRADE m	ITEM OF WORK *
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
L2		692	BS	2276	108	136.5	6.3		2436	94.2	14+240	1.8			BT
L2		663	BS	2344	102	127.7	5.8		2436	96.2	14+220	1.8			BT
L2		659	BS	2351	104	130.6	5.9		2436	96.5	14+200	1.8			BT
L2		657	BS	2354	100	124.7	5.6		2436	96.6	14+180	1.8			BT
L2		654	BS	2360	100	124.7	5.6		2436	95.8	14+160	1.8			BT
L2		668	BS	2336	103	129.1	5.9		2436	95.9	14+140	1.8			BT
L2		676	BS	2322	101	126.2	5.7		2536	95.3	14+120	1.8			BT
L2		675	BS	2324	99	123.3	5.6		2436	95.4	14+100	1.8			BT

DETERMINATION OF MAXIMUM DENSITY (Soil & Bituminous)

TEST NO.	MOISTURE %	VOLUME MOLD m³	DENSITY DETERMINATION WET SOIL + MOLD Kg	MOLD Kg	WET SOIL Kg	COMPACTED SOIL WET Kg/m³	MAX DENSITY Kg/m³	OPTIMUM MOISTURE %
1	2	3	4	5	6	7	8	9

NOTE:
To convert (ft³) to (m³):
Vol. (ft³) x 0.02832 = Vol. (m³)

CHART STANDARDS

DENSITY	MOISTURE
2598	656
2546	630

OPERATING STANDARDS

DENSITY	MOISTURE
2584	642

BITUMINOUS MIX DESIGN kg /m³
2436

REMARKS
M-84 Perpetual Pavement Demo Project Bituminous Top Course

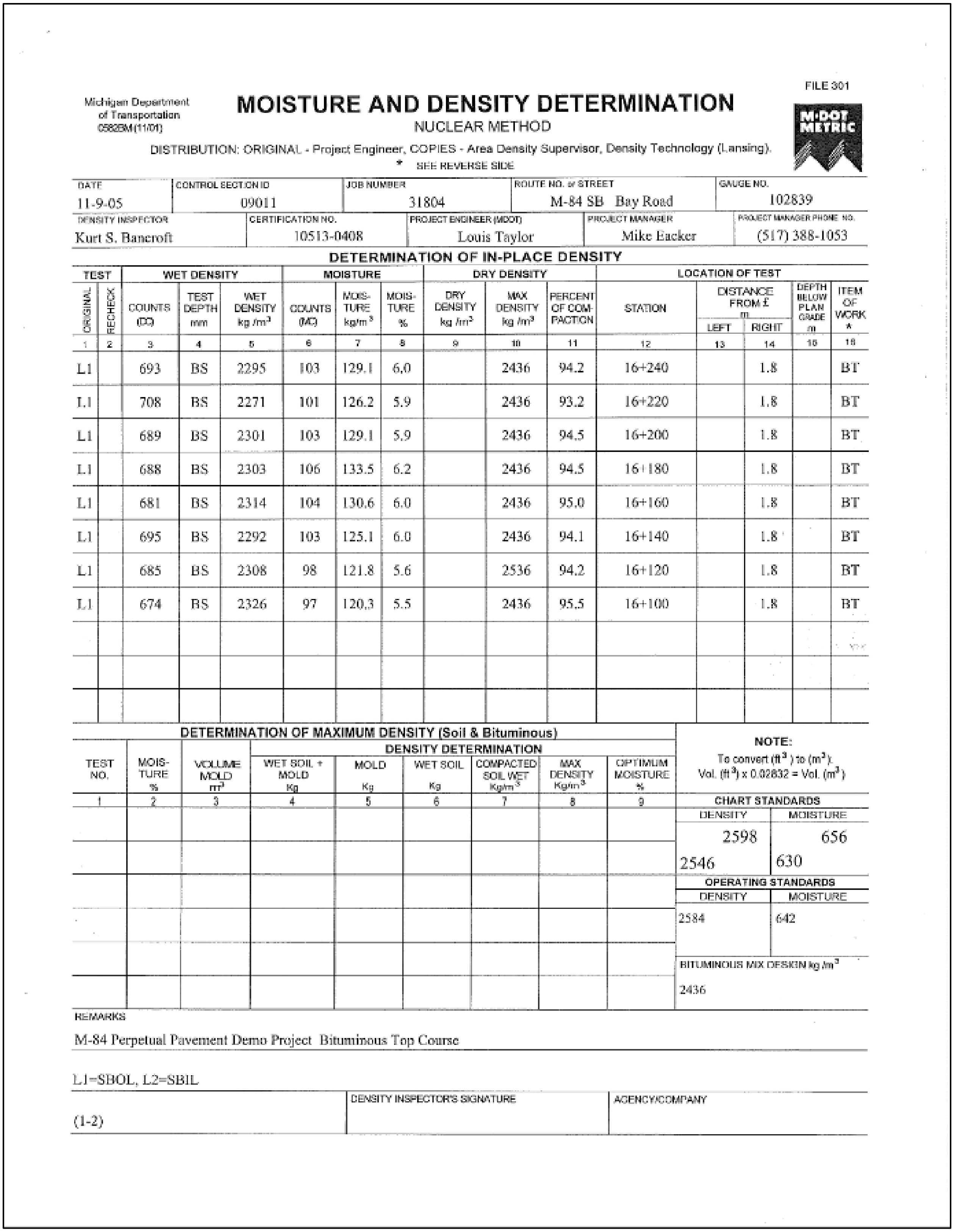
L1=SBOL, L2=SBIL

(2-2)

DENSITY INSPECTOR'S SIGNATURE

AGENCY/COMPANY

Figure 73. Moisture and density determination on M-84 SB HMA-top layer, page 2



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MOISTURE AND DENSITY DETERMINATION

NUCLEAR METHOD

M-DOT METRIC

DISTRIBUTION: ORIGINAL - Project Engineer, COPIES - Area Density Supervisor, Density Technology (Lansing).

* SEE REVERSE SIDE

DATE	CONTROL SECTION ID	JOB NUMBER	ROUTE NO. or STREET	GAUGE NO.
11-9-05	09011	31804	M-84 SB Bay Road	102839

DENSITY INSPECTOR	CERTIFICATION NO.	PROJECT ENGINEER (MDOT)	PROJECT MANAGER	PROJECT MANAGER PHONE NO.
Kurt S. Bancroft	10513-0408	Louis Taylor	Mike Eacker	(517) 388-1053

DETERMINATION OF IN-PLACE DENSITY

TEST		WET DENSITY			MOISTURE			DRY DENSITY			LOCATION OF TEST				
ORIGINAL	RECHECK	COUNTS (DC)	TEST DEPTH mm	WET DENSITY kg /m³	COUNTS (MC)	MOIS-TURE kg/m³	MOIS-TURE %	DRY DENSITY kg /m³	MAX DENSITY kg /m³	PERCENT OF COM-PACTION	STATION	DISTANCE FROM ℄ m LEFT	DISTANCE FROM ℄ m RIGHT	DEPTH BELOW PLAN GRADE m	ITEM OF WORK *
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
L1		693	BS	2295	103	129.1	6.0		2436	94.2	16+240		1.8		BT
L1		708	BS	2271	101	126.2	5.9		2436	93.2	16+220		1.8		BT
L1		689	BS	2301	103	129.1	5.9		2436	94.5	16+200		1.8		BT
L1		688	BS	2303	106	133.5	6.2		2436	94.5	16+180		1.8		BT
L1		681	BS	2314	104	130.6	6.0		2436	95.0	16+160		1.8		BT
L1		695	BS	2292	103	125.1	6.0		2436	94.1	16+140		1.8		BT
L1		685	BS	2308	98	121.8	5.6		2536	94.2	16+120		1.8		BT
L1		674	BS	2326	97	120.3	5.5		2436	95.5	16+100		1.8		BT

DETERMINATION OF MAXIMUM DENSITY (Soil & Bituminous)

TEST NO.	MOIS-TURE %	VOLUME MOLD m³	DENSITY DETERMINATION WET SOIL + MOLD Kg	MOLD Kg	WET SOIL Kg	COMPACTED SOIL WET Kg/m³	MAX DENSITY Kg/m³	OPTIMUM MOISTURE %
1	2	3	4	5	6	7	8	9

NOTE:

To convert (ft³) to (m³):
Vol. (ft³) x 0.02832 = Vol. (m³)

CHART STANDARDS

DENSITY	MOISTURE
2598	656
2546	630

OPERATING STANDARDS

DENSITY	MOISTURE
2584	642

BITUMINOUS MIX DESIGN kg /m³

2436

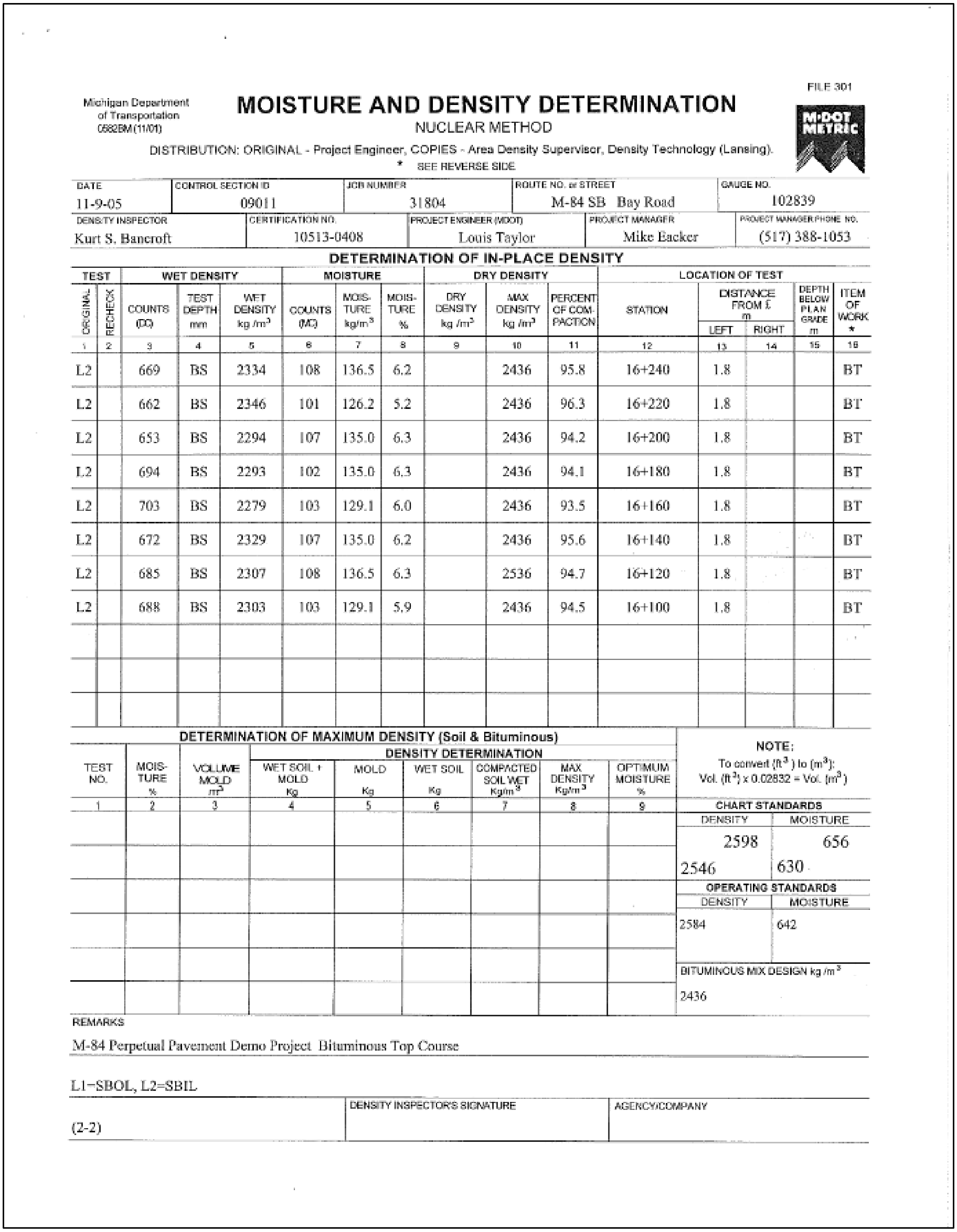
REMARKS

M-84 Perpetual Pavement Demo Project Bituminous Top Course

L1=SBOL, L2=SBIL

	DENSITY INSPECTOR'S SIGNATURE	AGENCY/COMPANY
(1-2)		

Figure 74. Moisture and density determination on M-84 SB HMA-top layer, page 3



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MOISTURE AND DENSITY DETERMINATION

NUCLEAR METHOD

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DATE	CONTROL SECTION ID	JOB NUMBER	ROUTE NO. or STREET	GAUGE NO.
11-9-05	09011	31804	M-84 SB Bay Road	102839

DENSITY INSPECTOR	CERTIFICATION NO.	PROJECT ENGINEER (MDOT)	PROJECT MANAGER	PROJECT MANAGER PHONE NO.
Kurt S. Bancroft	10513-0408	Louis Taylor	Mike Eacker	(517) 388-1053

DETERMINATION OF IN-PLACE DENSITY

TEST		WET DENSITY			MOISTURE			DRY DENSITY			LOCATION OF TEST				
ORIGINAL	RECHECK	COUNTS (DC)	TEST DEPTH mm	WET DENSITY kg /m³	COUNTS (MC)	MOIS-TURE kg/m³	MOIS-TURE %	DRY DENSITY kg /m³	MAX DENSITY kg /m³	PERCENT OF COM-PACTION	STATION	DISTANCE FROM ℄ m LEFT	DISTANCE FROM ℄ m RIGHT	DEPTH BELOW PLAN GRADE m	ITEM OF WORK *
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
L2		669	BS	2334	108	136.5	6.2		2436	95.8	16+240	1.8			BT
L2		662	BS	2346	101	126.2	5.2		2436	96.3	16+220	1.8			BT
L2		653	BS	2294	107	135.0	6.3		2436	94.2	16+200	1.8			BT
L2		694	BS	2293	102	135.0	6.3		2436	94.1	16+180	1.8			BT
L2		703	BS	2279	103	129.1	6.0		2436	93.5	16+160	1.8			BT
L2		672	BS	2329	107	135.0	6.2		2436	95.6	16+140	1.8			BT
L2		685	BS	2307	108	136.5	6.3		2536	94.7	16+120	1.8			BT
L2		688	BS	2303	103	129.1	5.9		2436	94.5	16+100	1.8			BT

DETERMINATION OF MAXIMUM DENSITY (Soil & Bituminous)

TEST NO.	MOIS-TURE %	VOLUME MOLD m³	DENSITY DETERMINATION					
			WET SOIL + MOLD Kg	MOLD Kg	WET SOIL Kg	COMPACTED SOIL WET Kg/m³	MAX DENSITY Kg/m³	OPTIMUM MOISTURE %
1	2	3	4	5	6	7	8	9

NOTE:
To convert (ft³) to (m³):
Vol. (ft³) x 0.02832 = Vol. (m³)

CHART STANDARDS	
DENSITY	MOISTURE
2598	656
2546	630

OPERATING STANDARDS	
DENSITY	MOISTURE
2584	642

BITUMINOUS MIX DESIGN kg /m³
2436

REMARKS
M-84 Perpetual Pavement Demo Project Bituminous Top Course

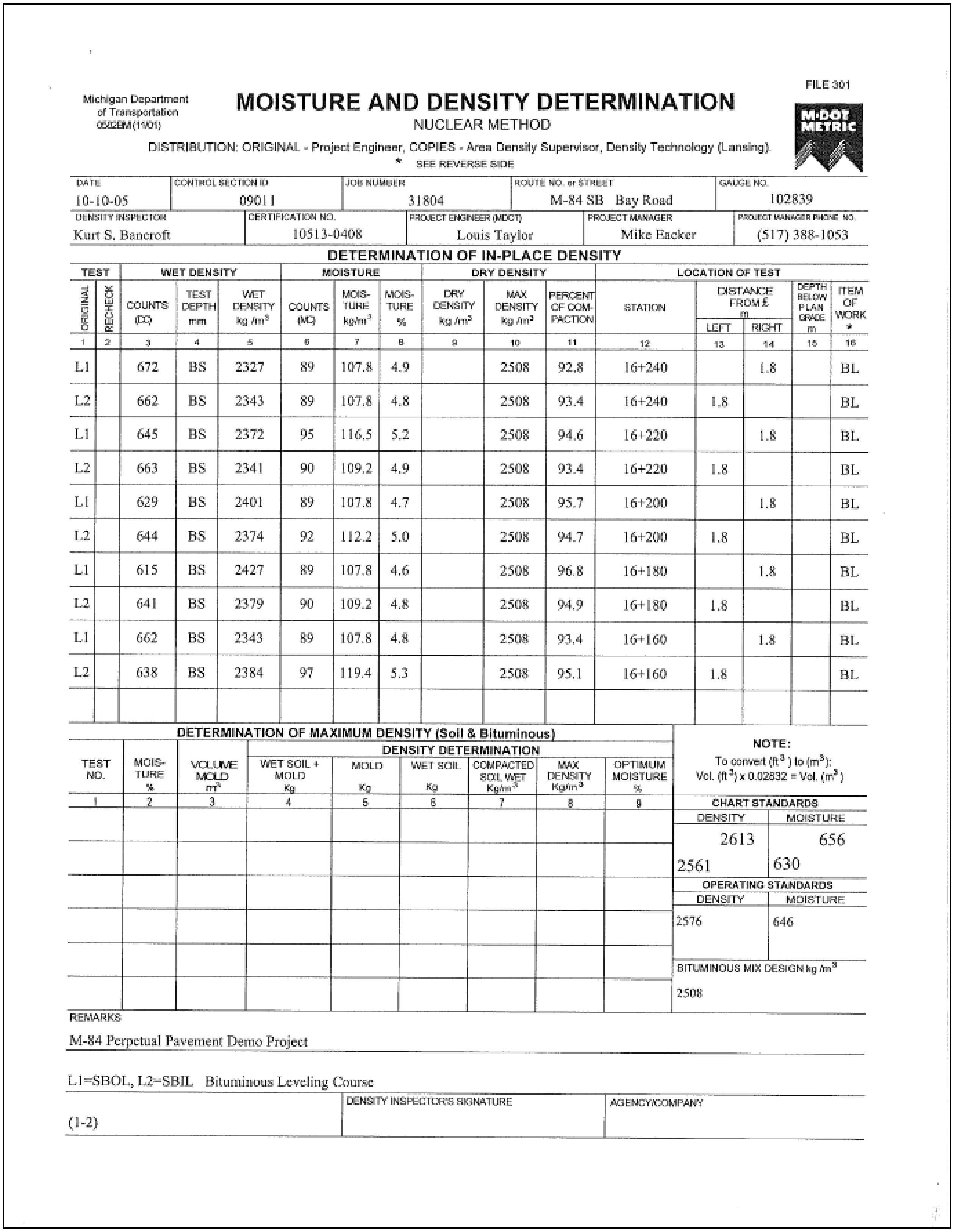
L1=SBOL, L2=SBIL

(2-2)

DENSITY INSPECTOR'S SIGNATURE

AGENCY/COMPANY

Figure 75. Moisture and density determination on M-84 SB HMA-top layer, page 4



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MOISTURE AND DENSITY DETERMINATION

NUCLEAR METHOD

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M·DOT METRIC

DATE: 10-10-05
CONTROL SECTION ID: 09011
JOB NUMBER: 31804
ROUTE NO. or STREET: M-84 SB Bay Road
GAUGE NO.: 102839
DENSITY INSPECTOR: Kurt S. Bancroft
CERTIFICATION NO.: 10513-0408
PROJECT ENGINEER (MDOT): Louis Taylor
PROJECT MANAGER: Mike Eacker
PROJECT MANAGER PHONE NO.: (517) 388-1053

DETERMINATION OF IN-PLACE DENSITY

TEST		WET DENSITY			MOISTURE			DRY DENSITY			LOCATION OF TEST				
ORIGINAL	RECHECK	COUNTS (DC)	TEST DEPTH mm	WET DENSITY kg /m³	COUNTS (MC)	MOIS-TURE kg/m³	MOIS-TURE %	DRY DENSITY kg /m³	MAX DENSITY kg /m³	PERCENT OF COM-PACTION	STATION	DISTANCE FROM ℄ m LEFT	DISTANCE FROM ℄ m RIGHT	DEPTH BELOW PLAN GRADE m	ITEM OF WORK *
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
L1		672	BS	2327	89	107.8	4.9		2508	92.8	16+240		1.8		BL
L2		662	BS	2343	89	107.8	4.8		2508	93.4	16+240	1.8			BL
L1		645	BS	2372	95	116.5	5.2		2508	94.6	16+220		1.8		BL
L2		663	BS	2341	90	109.2	4.9		2508	93.4	16+220	1.8			BL
L1		629	BS	2401	89	107.8	4.7		2508	95.7	16+200		1.8		BL
L2		644	BS	2374	92	112.2	5.0		2508	94.7	16+200	1.8			BL
L1		615	BS	2427	89	107.8	4.6		2508	96.8	16+180		1.8		BL
L2		641	BS	2379	90	109.2	4.8		2508	94.9	16+180	1.8			BL
L1		662	BS	2343	89	107.8	4.8		2508	93.4	16+160		1.8		BL
L2		638	BS	2384	97	119.4	5.3		2508	95.1	16+160	1.8			BL

DETERMINATION OF MAXIMUM DENSITY (Soil & Bituminous)

			DENSITY DETERMINATION					
TEST NO.	MOIS-TURE %	VOLUME MOLD m³	WET SOIL + MOLD Kg	MOLD Kg	WET SOIL Kg	COMPACTED SOIL WET Kg/m³	MAX DENSITY Kg/m³	OPTIMUM MOISTURE %
1	2	3	4	5	6	7	8	9

NOTE:
To convert (ft³) to (m³):
Vol. (ft³) x 0.02832 = Vol. (m³)

CHART STANDARDS	
DENSITY	MOISTURE
2613	656
2561	630

OPERATING STANDARDS	
DENSITY	MOISTURE
2576	646

BITUMINOUS MIX DESIGN kg /m³: 2508

REMARKS
M-84 Perpetual Pavement Demo Project

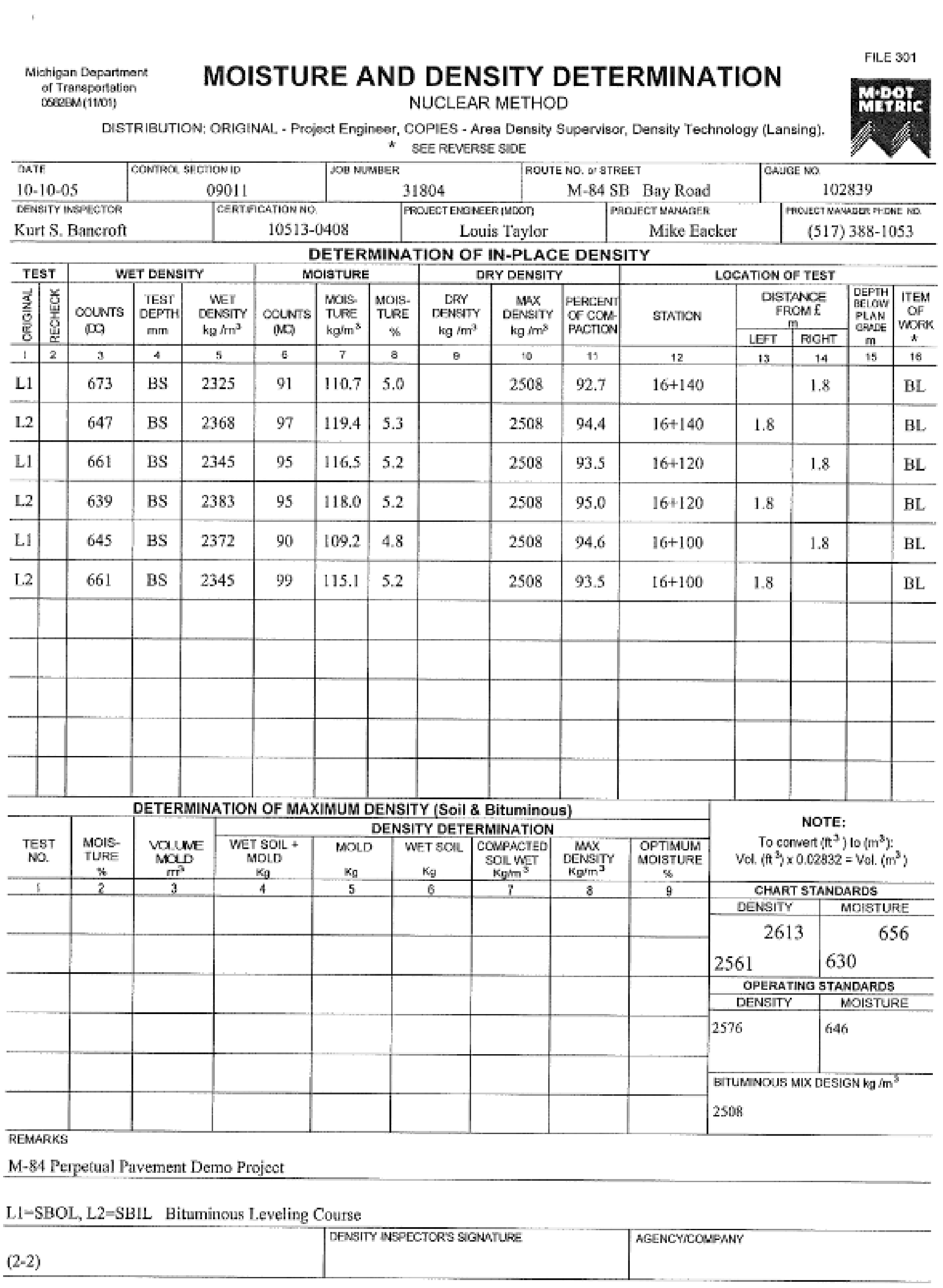
L1=SBOL, L2=SBIL Bituminous Leveling Course

(1-2)

DENSITY INSPECTOR'S SIGNATURE

AGENCY/COMPANY

Figure 76. Moisture and density determination on M-84 SB HMA-leveling layer, page 1



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MOISTURE AND DENSITY DETERMINATION

NUCLEAR METHOD

DISTRIBUTION: ORIGINAL - Project Engineer, COPIES - Area Density Supervisor, Density Technology (Lansing).

* SEE REVERSE SIDE

M-DOT METRIC

DATE	CONTROL SECTION ID	JOB NUMBER	ROUTE NO. or STREET	GAUGE NO.
10-10-05	09011	31804	M-84 SB Bay Road	102839

DENSITY INSPECTOR	CERTIFICATION NO.	PROJECT ENGINEER (MDOT)	PROJECT MANAGER	PROJECT MANAGER PHONE NO.
Kurt S. Bancroft	10513-0408	Louis Taylor	Mike Eacker	(517) 388-1053

DETERMINATION OF IN-PLACE DENSITY

TEST		WET DENSITY			MOISTURE			DRY DENSITY			LOCATION OF TEST				
ORIGINAL	RECHECK	COUNTS (DC)	TEST DEPTH mm	WET DENSITY kg /m³	COUNTS (MC)	MOIS-TURE kg/m³	MOIS-TURE %	DRY DENSITY kg /m³	MAX DENSITY kg /m³	PERCENT OF COM-PACTION	STATION	DISTANCE FROM ℄ m LEFT	DISTANCE FROM ℄ m RIGHT	DEPTH BELOW PLAN GRADE m	ITEM OF WORK *
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
L1		673	BS	2325	91	110.7	5.0		2508	92.7	16+140		1.8		BL
L2		647	BS	2368	97	119.4	5.3		2508	94.4	16+140	1.8			BL
L1		661	BS	2345	95	116.5	5.2		2508	93.5	16+120		1.8		BL
L2		639	BS	2383	95	118.0	5.2		2508	95.0	16+120	1.8			BL
L1		645	BS	2372	90	109.2	4.8		2508	94.6	16+100		1.8		BL
L2		661	BS	2345	99	115.1	5.2		2508	93.5	16+100	1.8			BL

DETERMINATION OF MAXIMUM DENSITY (Soil & Bituminous)

TEST NO.	MOIS-TURE %	VOLUME MOLD m³	DENSITY DETERMINATION WET SOIL + MOLD Kg	MOLD Kg	WET SOIL Kg	COMPACTED SOIL WET Kg/m³	MAX DENSITY Kg/m³	OPTIMUM MOISTURE %
1	2	3	4	5	6	7	8	9

NOTE:
To convert (ft³) to (m³):
Vol. (ft³) x 0.02832 = Vol. (m³)

CHART STANDARDS	
DENSITY	MOISTURE
2613 2561	656 630

OPERATING STANDARDS	
DENSITY	MOISTURE
2576	646

BITUMINOUS MIX DESIGN kg /m³
2508

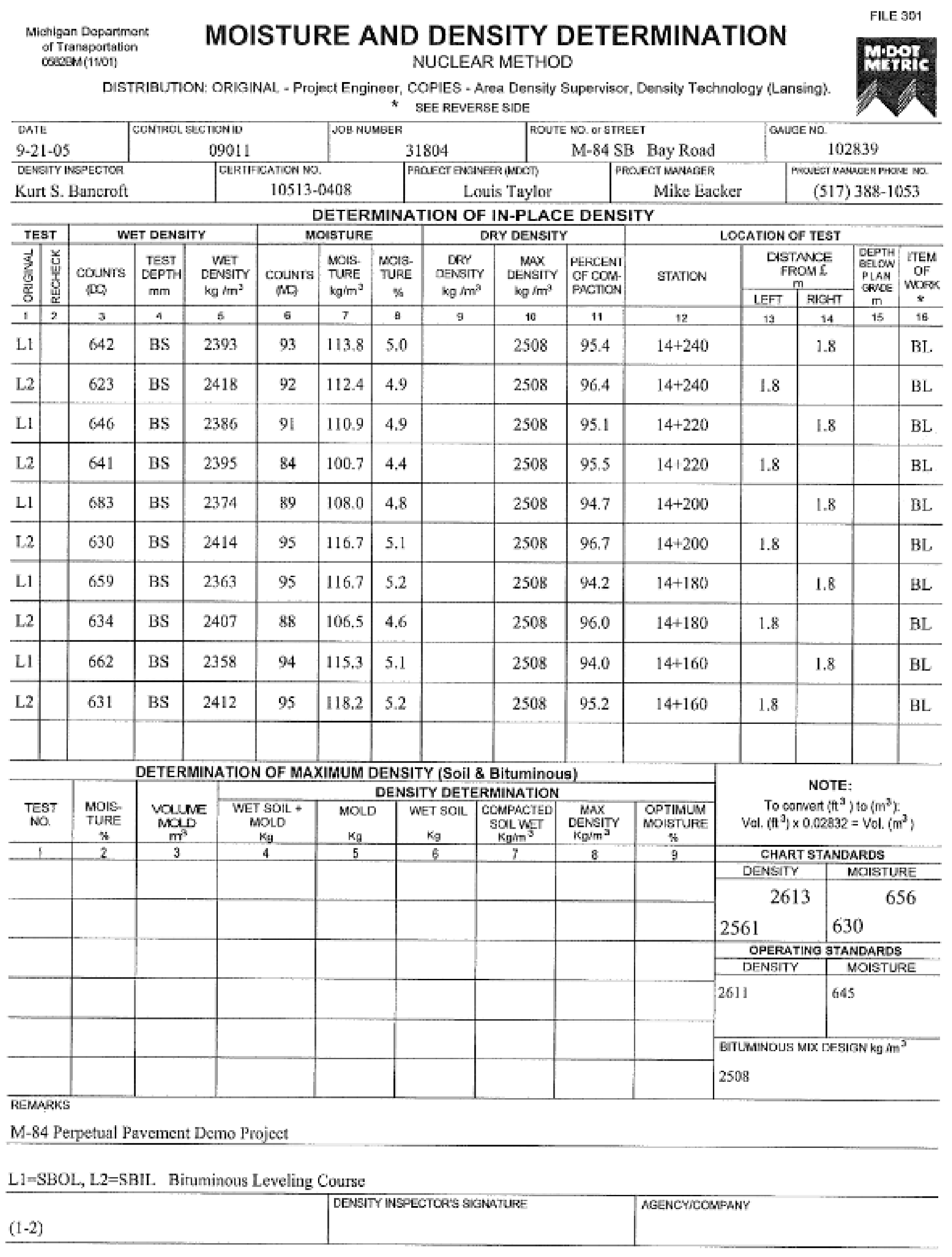
REMARKS

M-84 Perpetual Pavement Demo Project

L1=SBOL, L2=SBIL Bituminous Leveling Course

(2-2)	DENSITY INSPECTOR'S SIGNATURE	AGENCY/COMPANY

Figure 77. Moisture and density determination on M-84 SB HMA-leveling layer, page 2



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M·DOT METRIC

MOISTURE AND DENSITY DETERMINATION

NUCLEAR METHOD

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DATE	CONTROL SECTION ID	JOB NUMBER	ROUTE NO. or STREET	GAUGE NO.
9-21-05	09011	31804	M-84 SB Bay Road	102839

DENSITY INSPECTOR	CERTIFICATION NO.	PROJECT ENGINEER (MDOT)	PROJECT MANAGER	PROJECT MANAGER PHONE NO.
Kurt S. Bancroft	10513-0408	Louis Taylor	Mike Backer	(517) 388-1053

DETERMINATION OF IN-PLACE DENSITY

TEST		WET DENSITY			MOISTURE			DRY DENSITY			LOCATION OF TEST				
ORIGINAL	RECHECK	COUNTS (DC)	TEST DEPTH mm	WET DENSITY kg /m³	COUNTS (MC)	MOIS-TURE kg/m³	MOIS-TURE %	DRY DENSITY kg /m³	MAX DENSITY kg /m³	PERCENT OF COM-PACTION	STATION	DISTANCE FROM ℄ m LEFT	DISTANCE FROM ℄ m RIGHT	DEPTH BELOW PLAN GRADE m	ITEM OF WORK *
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
L1		642	BS	2393	93	113.8	5.0		2508	95.4	14+240		1.8		BL
L2		623	BS	2418	92	112.4	4.9		2508	96.4	14+240	1.8			BL
L1		646	BS	2386	91	110.9	4.9		2508	95.1	14+220		1.8		BL
L2		641	BS	2395	84	100.7	4.4		2508	95.5	14+220	1.8			BL
L1		683	BS	2374	89	108.0	4.8		2508	94.7	14+200		1.8		BL
L2		630	BS	2414	95	116.7	5.1		2508	96.7	14+200	1.8			BL
L1		659	BS	2363	95	116.7	5.2		2508	94.2	14+180		1.8		BL
L2		634	BS	2407	88	106.5	4.6		2508	96.0	14+180	1.8			BL
L1		662	BS	2358	94	115.3	5.1		2508	94.0	14+160		1.8		BL
L2		631	BS	2412	95	118.2	5.2		2508	95.2	14+160	1.8			BL

DETERMINATION OF MAXIMUM DENSITY (Soil & Bituminous)

			DENSITY DETERMINATION					
TEST NO.	MOIS-TURE %	VOLUME MOLD m³	WET SOIL + MOLD Kg	MOLD Kg	WET SOIL Kg	COMPACTED SOIL WET Kg/m³	MAX DENSITY Kg/m³	OPTIMUM MOISTURE %
1	2	3	4	5	6	7	8	9

NOTE:
To convert (ft³) to (m³):
Vol. (ft³) x 0.02832 = Vol. (m³)

CHART STANDARDS	
DENSITY	MOISTURE
2613 2561	656 630

OPERATING STANDARDS	
DENSITY	MOISTURE
2611	645

BITUMINOUS MIX DESIGN kg /m³
2508

REMARKS
M-84 Perpetual Pavement Demo Project

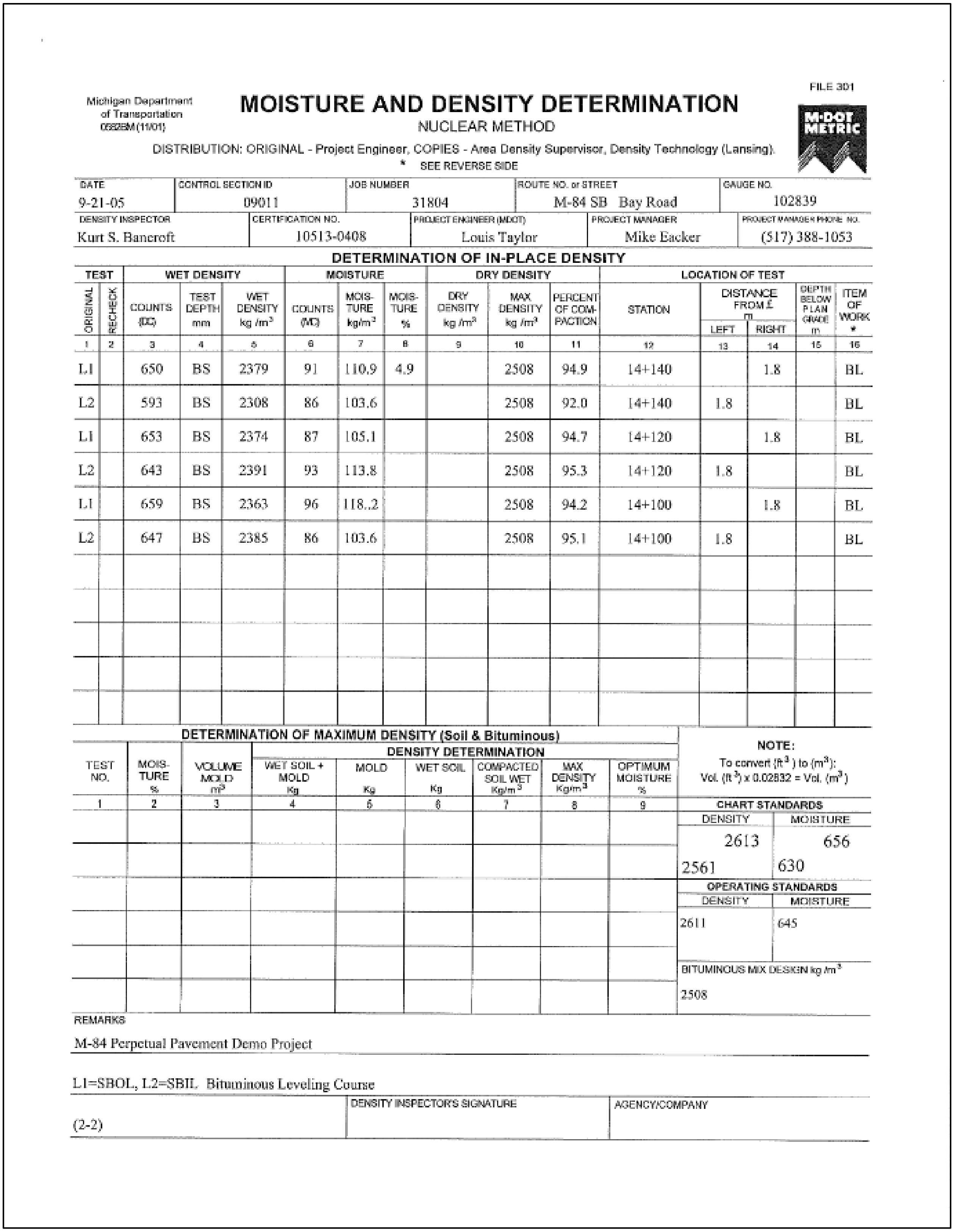
L1=SBOL, L2=SBIL. Bituminous Leveling Course

(1-2)

DENSITY INSPECTOR'S SIGNATURE

AGENCY/COMPANY

Figure 78. Moisture and density determination on M-84 SB HMA-leveling layer, page 3



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FILE 301

MOISTURE AND DENSITY DETERMINATION

NUCLEAR METHOD

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* SEE REVERSE SIDE

M-DOT METRIC

DATE	CONTROL SECTION ID	JOB NUMBER	ROUTE NO. or STREET	GAUGE NO.
9-21-05	09011	31804	M-84 SB Bay Road	102839

DENSITY INSPECTOR	CERTIFICATION NO.	PROJECT ENGINEER (MDOT)	PROJECT MANAGER	PROJECT MANAGER PHONE NO.
Kurt S. Bancroft	10513-0408	Louis Taylor	Mike Eacker	(517) 388-1053

DETERMINATION OF IN-PLACE DENSITY

TEST		WET DENSITY			MOISTURE			DRY DENSITY			LOCATION OF TEST				
ORIGINAL	RECHECK	COUNTS (DC)	TEST DEPTH mm	WET DENSITY kg /m^3	COUNTS (MC)	MOISTURE kg/m^2	MOISTURE %	DRY DENSITY kg /m^3	MAX DENSITY kg /m^3	PERCENT OF COMPACTION	STATION	DISTANCE FROM ℄ m LEFT	DISTANCE FROM ℄ m RIGHT	DEPTH BELOW PLAN GRADE m	ITEM OF WORK *
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
L1		650	BS	2379	91	110.9	4.9		2508	94.9	14+140		1.8		BL
L2		593	BS	2308	86	103.6			2508	92.0	14+140	1.8			BL
L1		653	BS	2374	87	105.1			2508	94.7	14+120		1.8		BL
L2		643	BS	2391	93	113.8			2508	95.3	14+120	1.8			BL
L1		659	BS	2363	96	118..2			2508	94.2	14+100		1.8		BL
L2		647	BS	2385	86	103.6			2508	95.1	14+100	1.8			BL

DETERMINATION OF MAXIMUM DENSITY (Soil & Bituminous)

TEST NO.	MOISTURE %	VOLUME MOLD m^3	DENSITY DETERMINATION WET SOIL + MOLD Kg	MOLD Kg	WET SOIL Kg	COMPACTED SOIL WET Kg/m^3	MAX DENSITY Kg/m^3	OPTIMUM MOISTURE %
1	2	3	4	5	6	7	8	9

NOTE:
To convert (ft^3) to (m^3):
Vol. (ft^3) x 0.02832 = Vol. (m^3)

CHART STANDARDS	
DENSITY	MOISTURE
2613 2561	656 630

OPERATING STANDARDS	
DENSITY	MOISTURE
2611	645

BITUMINOUS MIX DESIGN kg /m^3
2508

REMARKS
M-84 Perpetual Pavement Demo Project

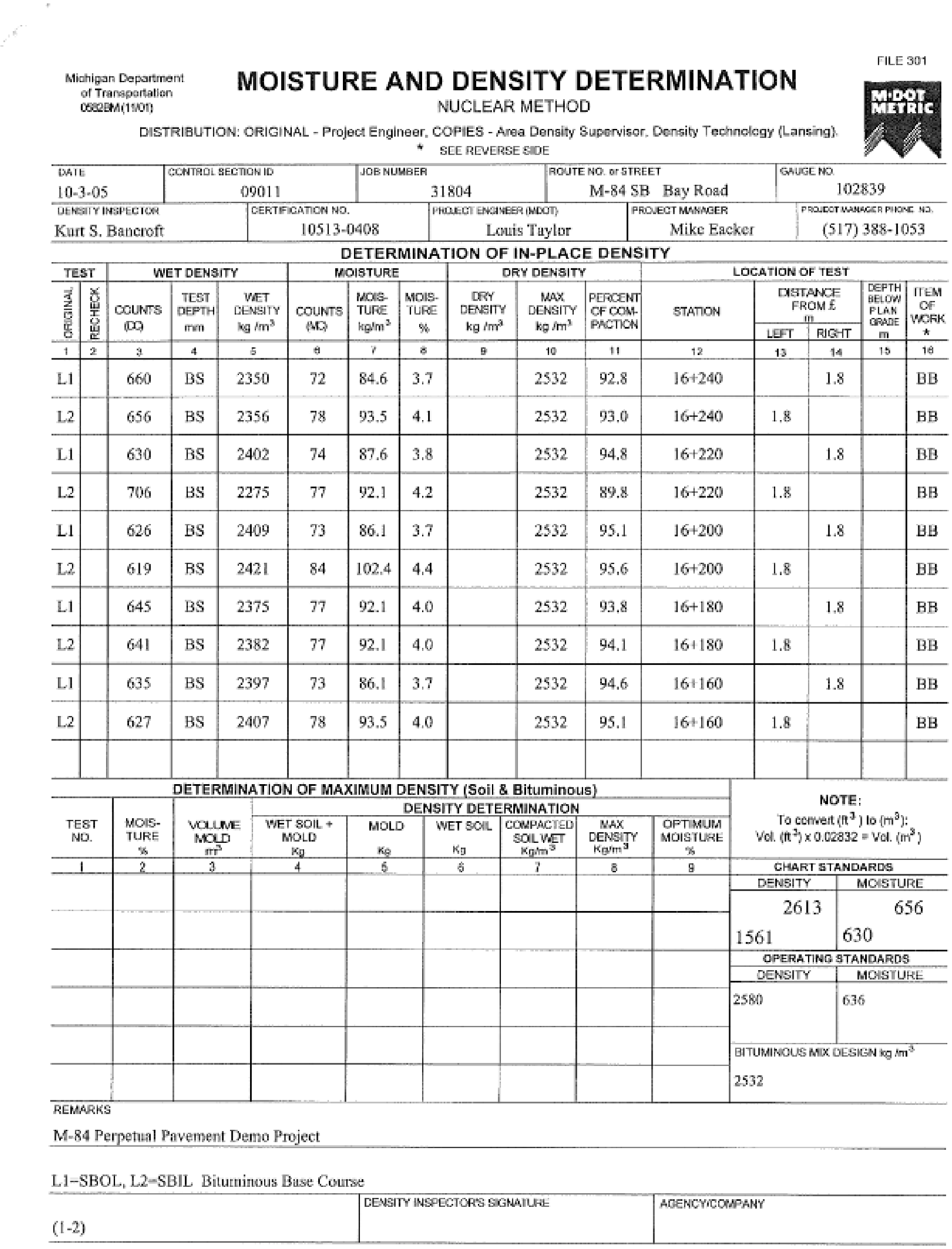
L1=SBOL, L2=SBIL Bituminous Leveling Course

(2-2)

DENSITY INSPECTOR'S SIGNATURE

AGENCY/COMPANY

Figure 79. Moisture and density determination on M-84 SB HMA-leveling layer, page 4



FILE 301

Michigan Department
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0582BM(11/01)

MOISTURE AND DENSITY DETERMINATION

NUCLEAR METHOD

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* SEE REVERSE SIDE

DATE	CONTROL SECTION ID	JOB NUMBER	ROUTE NO. or STREET	GAUGE NO.
10-3-05	09011	31804	M-84 SB Bay Road	102839

DENSITY INSPECTOR	CERTIFICATION NO.	PROJECT ENGINEER (MDOT)	PROJECT MANAGER	PROJECT MANAGER PHONE NO.
Kurt S. Bancroft	10513-0408	Louis Taylor	Mike Eacker	(517) 388-1053

DETERMINATION OF IN-PLACE DENSITY

TEST		WET DENSITY			MOISTURE			DRY DENSITY			LOCATION OF TEST				
ORIGINAL	RECHECK	COUNTS (DC)	TEST DEPTH mm	WET DENSITY kg /m³	COUNTS (MC)	MOIS-TURE kg/m³	MOIS-TURE %	DRY DENSITY kg /m³	MAX DENSITY kg /m³	PERCENT OF COM-PACTION	STATION	DISTANCE FROM ℄ m LEFT	DISTANCE FROM ℄ m RIGHT	DEPTH BELOW PLAN GRADE m	ITEM OF WORK *
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
L1		660	BS	2350	72	84.6	3.7		2532	92.8	16+240		1.8		BB
L2		656	BS	2356	78	93.5	4.1		2532	93.0	16+240	1.8			BB
L1		630	BS	2402	74	87.6	3.8		2532	94.8	16+220		1.8		BB
L2		706	BS	2275	77	92.1	4.2		2532	89.8	16+220	1.8			BB
L1		626	BS	2409	73	86.1	3.7		2532	95.1	16+200		1.8		BB
L2		619	BS	2421	84	102.4	4.4		2532	95.6	16+200	1.8			BB
L1		645	BS	2375	77	92.1	4.0		2532	93.8	16+180		1.8		BB
L2		641	BS	2382	77	92.1	4.0		2532	94.1	16+180	1.8			BB
L1		635	BS	2397	73	86.1	3.7		2532	94.6	16+160		1.8		BB
L2		627	BS	2407	78	93.5	4.0		2532	95.1	16+160	1.8			BB

DETERMINATION OF MAXIMUM DENSITY (Soil & Bituminous)

			DENSITY DETERMINATION					
TEST NO.	MOIS-TURE %	VOLUME MOLD m³	WET SOIL + MOLD Kg	MOLD Kg	WET SOIL Kg	COMPACTED SOIL WET Kg/m³	MAX DENSITY Kg/m³	OPTIMUM MOISTURE %
1	2	3	4	5	6	7	8	9

NOTE:
To convert (ft³) to (m³):
Vol. (ft³) x 0.02832 = Vol. (m³)

CHART STANDARDS	
DENSITY	MOISTURE
2613 1561	656 630

OPERATING STANDARDS	
DENSITY	MOISTURE
2580	636

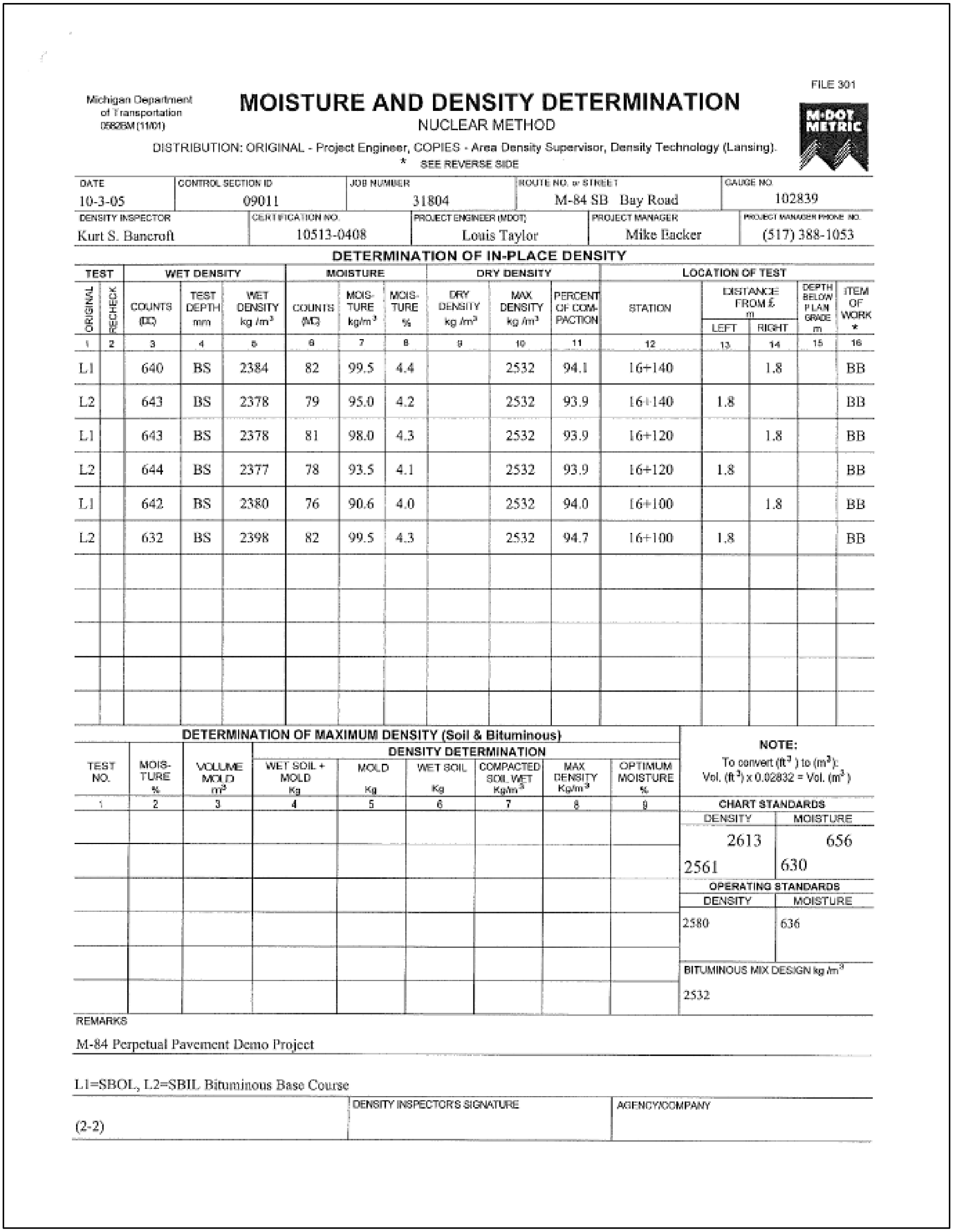
BITUMINOUS MIX DESIGN kg /m³
2532

REMARKS
M-84 Perpetual Pavement Demo Project

L1=SBOL, L2=SBIL Bituminous Base Course

	DENSITY INSPECTOR'S SIGNATURE	AGENCY/COMPANY
(1-2)		

Figure 80. Moisture and density determination on M-84 SB HMA-base layer, page 1



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FILE 301

M-DOT METRIC

MOISTURE AND DENSITY DETERMINATION

NUCLEAR METHOD

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* SEE REVERSE SIDE

DATE: 10-3-05
CONTROL SECTION ID: 09011
JOB NUMBER: 31804
ROUTE NO. or STREET: M-84 SB Bay Road
GAUGE NO.: 102839
DENSITY INSPECTOR: Kurt S. Bancroft
CERTIFICATION NO.: 10513-0408
PROJECT ENGINEER (MDOT): Louis Taylor
PROJECT MANAGER: Mike Backer
PROJECT MANAGER PHONE NO.: (517) 388-1053

DETERMINATION OF IN-PLACE DENSITY

TEST		WET DENSITY			MOISTURE			DRY DENSITY			LOCATION OF TEST				
ORIGINAL	RECHECK	COUNTS (DC)	TEST DEPTH mm	WET DENSITY kg /m³	COUNTS (MC)	MOISTURE kg/m³	MOISTURE %	DRY DENSITY kg /m³	MAX DENSITY kg /m³	PERCENT OF COMPACTION	STATION	DISTANCE FROM ℄ m LEFT	DISTANCE FROM ℄ m RIGHT	DEPTH BELOW PLAN GRADE m	ITEM OF WORK *
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
L1		640	BS	2384	82	99.5	4.4		2532	94.1	16+140		1.8		BB
L2		643	BS	2378	79	95.0	4.2		2532	93.9	16+140	1.8			BB
L1		643	BS	2378	81	98.0	4.3		2532	93.9	16+120		1.8		BB
L2		644	BS	2377	78	93.5	4.1		2532	93.9	16+120	1.8			BB
L1		642	BS	2380	76	90.6	4.0		2532	94.0	16+100		1.8		BB
L2		632	BS	2398	82	99.5	4.3		2532	94.7	16+100	1.8			BB

DETERMINATION OF MAXIMUM DENSITY (Soil & Bituminous)

TEST NO.	MOISTURE %	VOLUME MOLD m³	DENSITY DETERMINATION					
			WET SOIL + MOLD Kg	MOLD Kg	WET SOIL Kg	COMPACTED SOIL WET Kg/m³	MAX DENSITY Kg/m³	OPTIMUM MOISTURE %
1	2	3	4	5	6	7	8	9

NOTE:
To convert (ft³) to (m³):
Vol. (ft³) x 0.02832 = Vol. (m³)

CHART STANDARDS

DENSITY	MOISTURE
2613 2561	656 630

OPERATING STANDARDS

DENSITY	MOISTURE
2580	636

BITUMINOUS MIX DESIGN kg /m³: 2532

REMARKS
M-84 Perpetual Pavement Demo Project

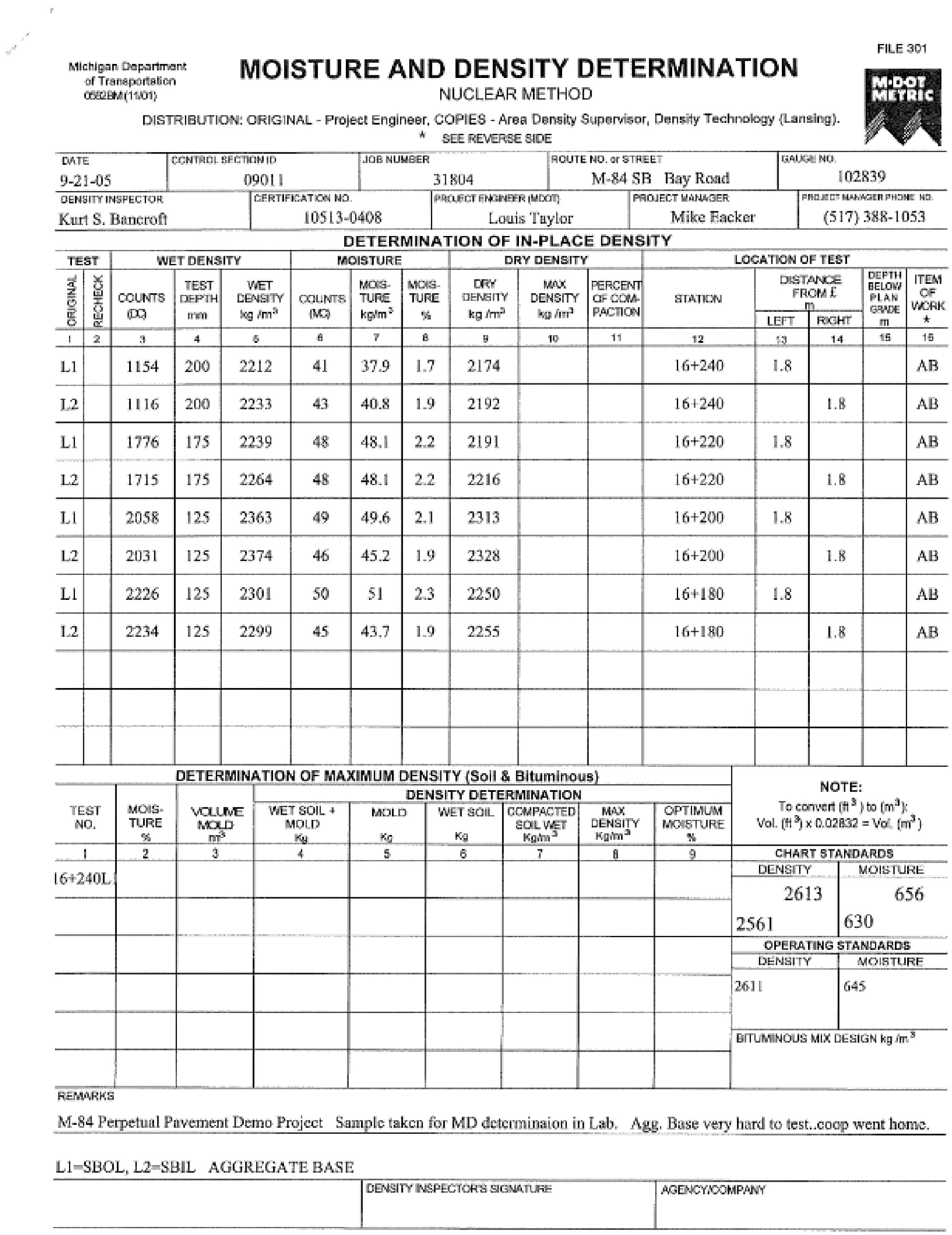
L1=SBOL, L2=SBIL Bituminous Base Course

(2-2)

DENSITY INSPECTOR'S SIGNATURE

AGENCY/COMPANY

Figure 81. Moisture and density determination on M-84 SB HMA-base layer, page 2



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FILE 301

MOISTURE AND DENSITY DETERMINATION

NUCLEAR METHOD

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DATE	CONTROL SECTION ID	JOB NUMBER	ROUTE NO. or STREET	GAUGE NO.
9-21-05	09011	31804	M-84 SB Bay Road	102839

DENSITY INSPECTOR	CERTIFICATION NO.	PROJECT ENGINEER (MDOT)	PROJECT MANAGER	PROJECT MANAGER PHONE NO.
Kurt S. Bancroft	10513-0408	Louis Taylor	Mike Eacker	(517) 388-1053

DETERMINATION OF IN-PLACE DENSITY

TEST		WET DENSITY			MOISTURE			DRY DENSITY			LOCATION OF TEST				
ORIGINAL	RECHECK	COUNTS (DC)	TEST DEPTH mm	WET DENSITY kg /m³	COUNTS (MC)	MOIS-TURE kg/m³	MOIS-TURE %	DRY DENSITY kg /m³	MAX DENSITY kg /m³	PERCENT OF COM-PACTION	STATION	DISTANCE FROM ℄ m LEFT	DISTANCE FROM ℄ m RIGHT	DEPTH BELOW PLAN GRADE m	ITEM OF WORK *
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
L1		1154	200	2212	41	37.9	1.7	2174			16+240	1.8			AB
L2		1116	200	2233	43	40.8	1.9	2192			16+240		1.8		AB
L1		1776	175	2239	48	48.1	2.2	2191			16+220	1.8			AB
L2		1715	175	2264	48	48.1	2.2	2216			16+220		1.8		AB
L1		2058	125	2363	49	49.6	2.1	2313			16+200	1.8			AB
L2		2031	125	2374	46	45.2	1.9	2328			16+200		1.8		AB
L1		2226	125	2301	50	51	2.3	2250			16+180	1.8			AB
L2		2234	125	2299	45	43.7	1.9	2255			16+180		1.8		AB

DETERMINATION OF MAXIMUM DENSITY (Soil & Bituminous)

TEST NO.	MOIS-TURE %	VOLUME MOLD m³	DENSITY DETERMINATION WET SOIL + MOLD Kg	MOLD Kg	WET SOIL Kg	COMPACTED SOIL WET Kg/m³	MAX DENSITY Kg/m³	OPTIMUM MOISTURE %
1	2	3	4	5	6	7	8	9
16+240L								

NOTE:
To convert (ft³) to (m³):
Vol. (ft³) x 0.02832 = Vol. (m³)

CHART STANDARDS

DENSITY	MOISTURE
2613 2561	656 630

OPERATING STANDARDS

DENSITY	MOISTURE
2611	645

BITUMINOUS MIX DESIGN kg /m³

REMARKS

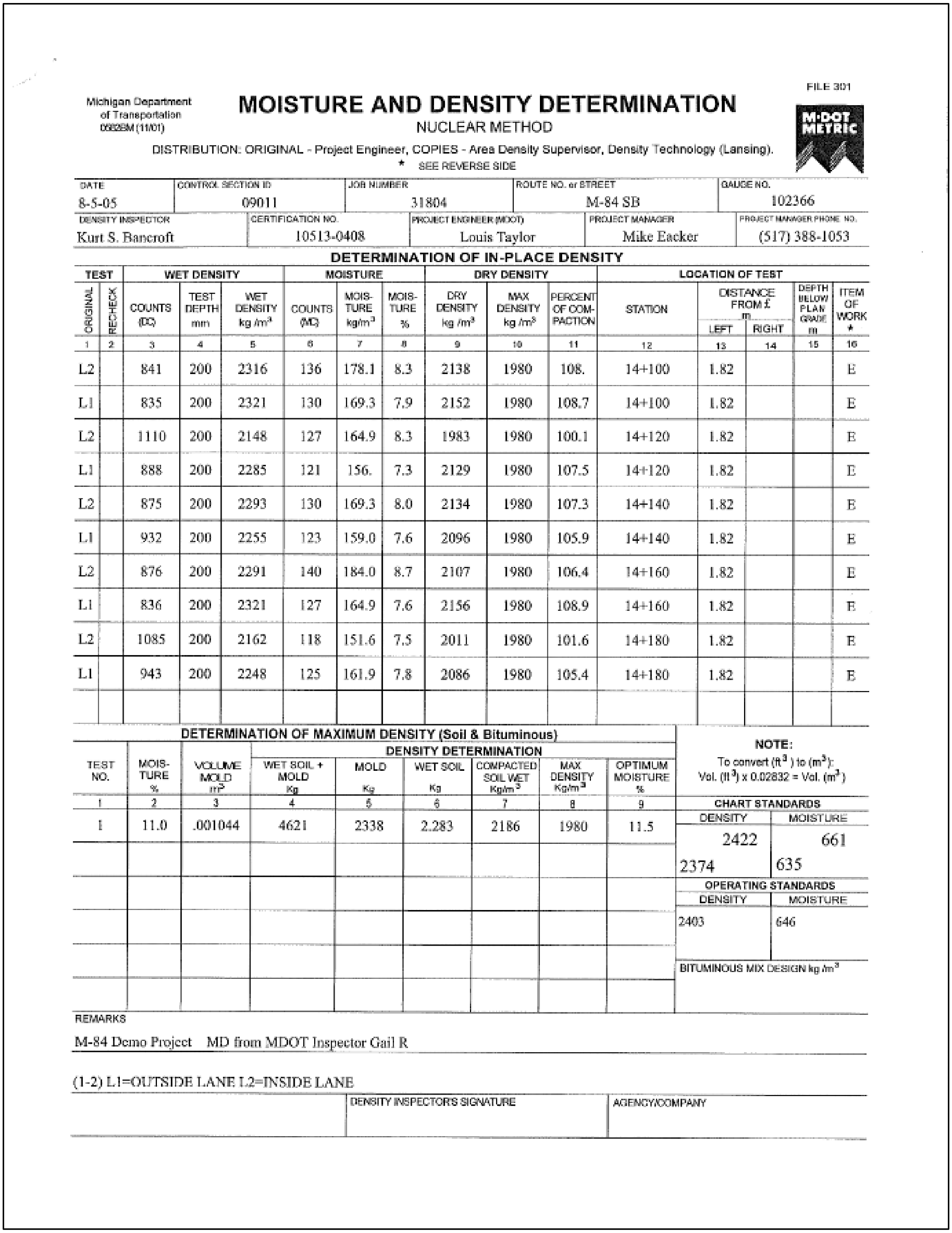
M-84 Perpetual Pavement Demo Project   Sample taken for MD determinaion in Lab.   Agg. Base very hard to test..coop went home.

L1=SBOL, L2=SBIL   AGGREGATE BASE

DENSITY INSPECTOR'S SIGNATURE

AGENCY/COMPANY

Figure 82. Moisture and density determination on M-84 SB aggregate base layer



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MOISTURE AND DENSITY DETERMINATION

NUCLEAR METHOD

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M·DOT METRIC

DATE	CONTROL SECTION ID	JOB NUMBER	ROUTE NO. or STREET	GAUGE NO.
8-5-05	09011	31804	M-84 SB	102366

DENSITY INSPECTOR	CERTIFICATION NO.	PROJECT ENGINEER (MDOT)	PROJECT MANAGER	PROJECT MANAGER PHONE NO.
Kurt S. Bancroft	10513-0408	Louis Taylor	Mike Eacker	(517) 388-1053

DETERMINATION OF IN-PLACE DENSITY

TEST		WET DENSITY			MOISTURE			DRY DENSITY			LOCATION OF TEST				
ORIGINAL	RECHECK	COUNTS (DC)	TEST DEPTH mm	WET DENSITY kg /m³	COUNTS (MC)	MOIS-TURE kg/m³	MOIS-TURE %	DRY DENSITY kg /m³	MAX DENSITY kg /m³	PERCENT OF COM-PACTION	STATION	DISTANCE FROM ℄ m LEFT	DISTANCE FROM ℄ m RIGHT	DEPTH BELOW PLAN GRADE m	ITEM OF WORK *
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
L2		841	200	2316	136	178.1	8.3	2138	1980	108.	14+100	1.82			E
L1		835	200	2321	130	169.3	7.9	2152	1980	108.7	14+100	1.82			E
L2		1110	200	2148	127	164.9	8.3	1983	1980	100.1	14+120	1.82			E
L1		888	200	2285	121	156.	7.3	2129	1980	107.5	14+120	1.82			E
L2		875	200	2293	130	169.3	8.0	2134	1980	107.3	14+140	1.82			E
L1		932	200	2255	123	159.0	7.6	2096	1980	105.9	14+140	1.82			E
L2		876	200	2291	140	184.0	8.7	2107	1980	106.4	14+160	1.82			E
L1		836	200	2321	127	164.9	7.6	2156	1980	108.9	14+160	1.82			E
L2		1085	200	2162	118	151.6	7.5	2011	1980	101.6	14+180	1.82			E
L1		943	200	2248	125	161.9	7.8	2086	1980	105.4	14+180	1.82			E

DETERMINATION OF MAXIMUM DENSITY (Soil & Bituminous)

TEST NO.	MOIS-TURE %	VOLUME MOLD m³	DENSITY DETERMINATION					
			WET SOIL + MOLD Kg	MOLD Kg	WET SOIL Kg	COMPACTED SOIL WET Kg/m³	MAX DENSITY Kg/m³	OPTIMUM MOISTURE %
1	2	3	4	5	6	7	8	9
1	11.0	.001044	4621	2338	2.283	2186	1980	11.5

NOTE:
To convert (ft^3) to (m^3):
Vol. $(ft^3) \times 0.02832 =$ Vol. (m^3)

CHART STANDARDS

DENSITY	MOISTURE
2422	661
2374	635

OPERATING STANDARDS

DENSITY	MOISTURE
2403	646

BITUMINOUS MIX DESIGN kg /m³

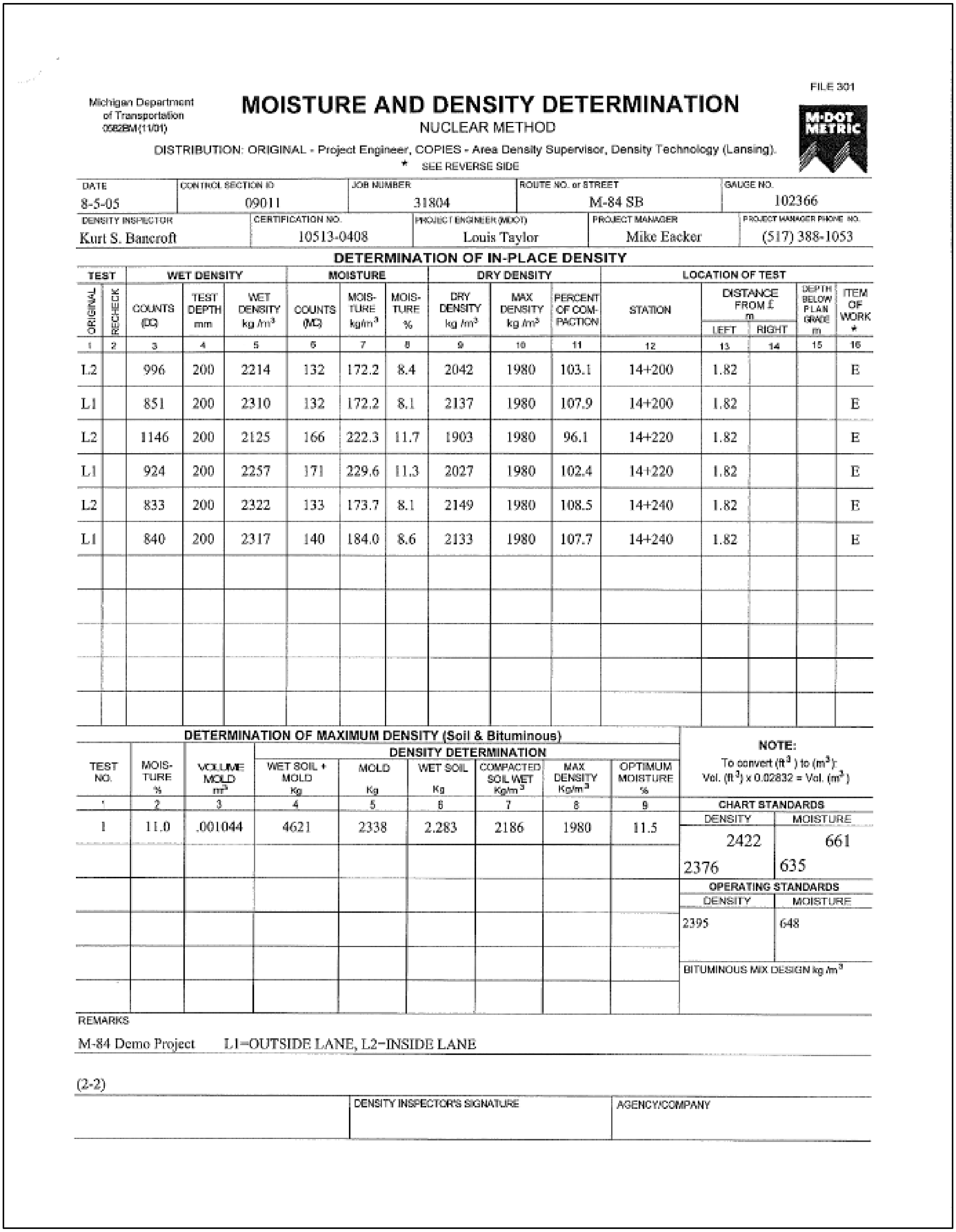
REMARKS

M-84 Demo Project MD from MDOT Inspector Gail R

(1-2) L1=OUTSIDE LANE L2=INSIDE LANE

	DENSITY INSPECTOR'S SIGNATURE	AGENCY/COMPANY

Figure 83. Moisture and density determination M-84 SB subgrade (embankment), page 1



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MOISTURE AND DENSITY DETERMINATION

NUCLEAR METHOD

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M·DOT METRIC

DATE	CONTROL SECTION ID	JOB NUMBER	ROUTE NO. or STREET	GAUGE NO.
8-5-05	09011	31804	M-84 SB	102366

DENSITY INSPECTOR	CERTIFICATION NO.	PROJECT ENGINEER (MDOT)	PROJECT MANAGER	PROJECT MANAGER PHONE NO.
Kurt S. Bancroft	10513-0408	Louis Taylor	Mike Eacker	(517) 388-1053

DETERMINATION OF IN-PLACE DENSITY

TEST		WET DENSITY			MOISTURE			DRY DENSITY			LOCATION OF TEST				
ORIGINAL	RECHECK	COUNTS (DC)	TEST DEPTH mm	WET DENSITY kg /m³	COUNTS (MC)	MOIS-TURE kg/m³	MOIS-TURE %	DRY DENSITY kg /m³	MAX DENSITY kg /m³	PERCENT OF COM-PACTION	STATION	DISTANCE FROM ℄ m LEFT	DISTANCE FROM ℄ m RIGHT	DEPTH BELOW PLAN GRADE m	ITEM OF WORK *
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
L2		996	200	2214	132	172.2	8.4	2042	1980	103.1	14+200	1.82			E
L1		851	200	2310	132	172.2	8.1	2137	1980	107.9	14+200	1.82			E
L2		1146	200	2125	166	222.3	11.7	1903	1980	96.1	14+220	1.82			E
L1		924	200	2257	171	229.6	11.3	2027	1980	102.4	14+220	1.82			E
L2		833	200	2322	133	173.7	8.1	2149	1980	108.5	14+240	1.82			E
L1		840	200	2317	140	184.0	8.6	2133	1980	107.7	14+240	1.82			E

DETERMINATION OF MAXIMUM DENSITY (Soil & Bituminous)

TEST NO.	MOIS-TURE %	VOLUME MOLD m³	DENSITY DETERMINATION WET SOIL + MOLD Kg	MOLD Kg	WET SOIL Kg	COMPACTED SOIL WET Kg/m³	MAX DENSITY Kg/m³	OPTIMUM MOISTURE %
1	2	3	4	5	6	7	8	9
1	11.0	.001044	4621	2338	2.283	2186	1980	11.5

NOTE:
To convert (ft³) to (m³):
Vol. (ft³) x 0.02832 = Vol. (m³)

CHART STANDARDS

DENSITY	MOISTURE
2422	661
2376	635

OPERATING STANDARDS

DENSITY	MOISTURE
2395	648

BITUMINOUS MIX DESIGN kg /m³

REMARKS

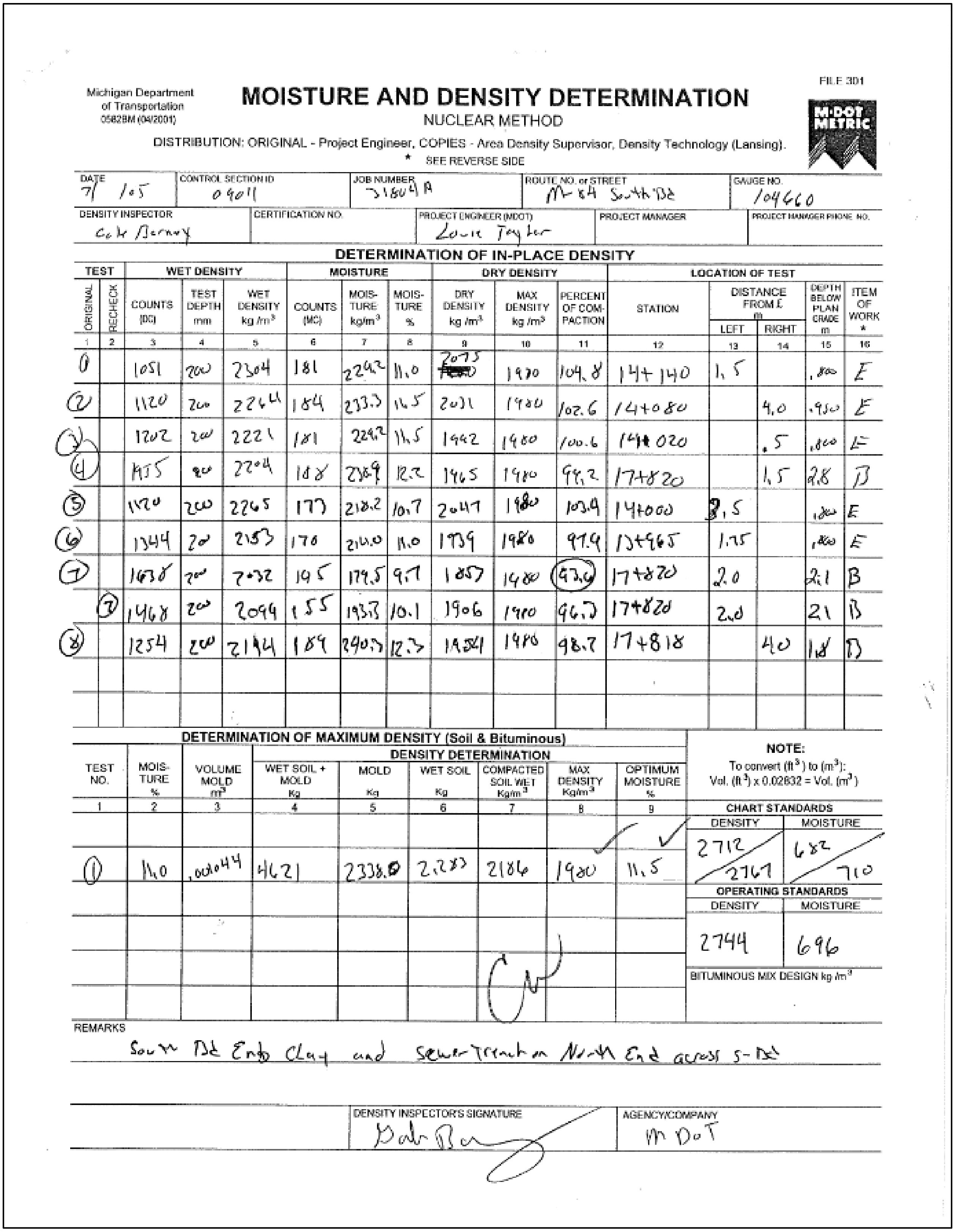
M-84 Demo Project L1=OUTSIDE LANE, L2=INSIDE LANE

(2-2)

DENSITY INSPECTOR'S SIGNATURE

AGENCY/COMPANY

Figure 84. Moisture and density determination M-84 SB subgrade (embankment), page 2



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MOISTURE AND DENSITY DETERMINATION

NUCLEAR METHOD

M-DOT METRIC

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DATE	CONTROL SECTION ID	JOB NUMBER	ROUTE NO. or STREET	GAUGE NO.
7/ /05	09011	31804 A	M-84 South BD	104660

DENSITY INSPECTOR	CERTIFICATION NO.	PROJECT ENGINEER (MDOT)	PROJECT MANAGER	PROJECT MANAGER PHONE NO.
Cole Berney		Louie Taylor		

DETERMINATION OF IN-PLACE DENSITY

TEST		WET DENSITY			MOISTURE			DRY DENSITY			LOCATION OF TEST				
ORIGINAL	RECHECK	COUNTS (DC)	TEST DEPTH mm	WET DENSITY kg/m³	COUNTS (MC)	MOISTURE kg/m³	MOISTURE %	DRY DENSITY kg/m³	MAX DENSITY kg/m³	PERCENT OF COMPACTION	STATION	DISTANCE FROM ℄ m LEFT	DISTANCE FROM ℄ m RIGHT	DEPTH BELOW PLAN GRADE m	ITEM OF WORK *
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
①		1051	200	2304	181	229.2	11.0	2073	1970	104.8	14+140	1.5		.800	E
②		1120	200	2264	184	233.3	11.5	2031	1980	102.6	14+080		4.0	.950	E
③		1202	200	2221	181	229.2	11.5	1942	1930	100.6	14+020		.5	.800	E
④		1935	200	2204	188	238.9	12.2	1965	1980	99.2	17+820		1.5	2.8	B
⑤		1120	200	2265	177	218.2	10.7	2047	1980	103.4	14+000	3.5		.800	E
⑥		1344	200	2153	170	214.0	11.0	1939	1980	97.9	13+965	1.75		.800	E
⑦		1638	200	2032	195	179.5	9.7	1857	1980	93.6	17+820	2.0		2.1	B
	⑦	1468	200	2099	155	193.3	10.1	1906	1980	96.3	17+820	2.0		2.1	B
⑧		1254	200	2194	189	240.3	12.3	1954	1980	98.7	17+818		4.0	1.8	B

DETERMINATION OF MAXIMUM DENSITY (Soil & Bituminous)

TEST NO.	MOISTURE %	VOLUME MOLD m³	DENSITY DETERMINATION WET SOIL + MOLD Kg	MOLD Kg	WET SOIL Kg	COMPACTED SOIL WET Kg/m³	MAX DENSITY Kg/m³	OPTIMUM MOISTURE %
1	2	3	4	5	6	7	8	9
							✓	✓
①	11.0	.000944	4621	2338.0	2.283	2186	1980	11.5

NOTE:
To convert (ft³) to (m³):
Vol. (ft³) x 0.02832 = Vol. (m³)

CHART STANDARDS	
DENSITY	MOISTURE
2712 / 2767	682 / 710

OPERATING STANDARDS	
DENSITY	MOISTURE
2744	696

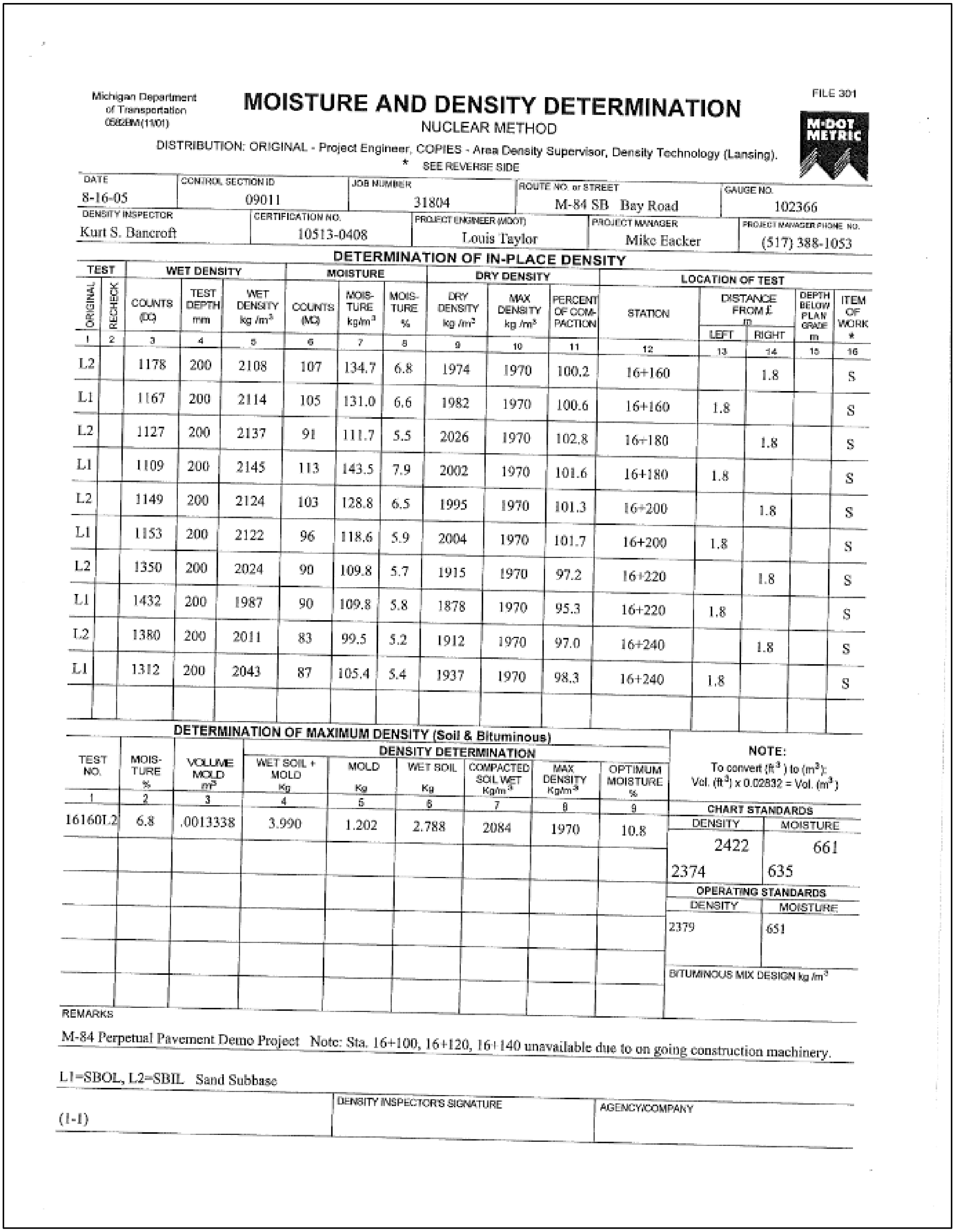
BITUMINOUS MIX DESIGN kg/m³

REMARKS
South BD Endo Clay and Sewer Trench on North End across S-BD

DENSITY INSPECTOR'S SIGNATURE

AGENCY/COMPANY
MDoT

Figure 85. Moisture and density determination M-84 SB subgrade (embankment), page 3



Michigan Department
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MOISTURE AND DENSITY DETERMINATION

NUCLEAR METHOD

FILE 301

M-DOT METRIC

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* SEE REVERSE SIDE

DATE	CONTROL SECTION ID	JOB NUMBER	ROUTE NO. or STREET	GAUGE NO.
8-16-05	09011	31804	M-84 SB Bay Road	102366

DENSITY INSPECTOR	CERTIFICATION NO.	PROJECT ENGINEER (MDOT)	PROJECT MANAGER	PROJECT MANAGER PHONE NO.
Kurt S. Bancroft	10513-0408	Louis Taylor	Mike Eacker	(517) 388-1053

DETERMINATION OF IN-PLACE DENSITY

TEST		WET DENSITY			MOISTURE			DRY DENSITY			LOCATION OF TEST				
ORIGINAL	RECHECK	COUNTS (DC)	TEST DEPTH mm	WET DENSITY kg /m³	COUNTS (MC)	MOIS-TURE kg/m³	MOIS-TURE %	DRY DENSITY kg /m³	MAX DENSITY kg /m³	PERCENT OF COM-PACTION	STATION	DISTANCE FROM ℄ m LEFT	DISTANCE FROM ℄ m RIGHT	DEPTH BELOW PLAN GRADE m	ITEM OF WORK *
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
L2		1178	200	2108	107	134.7	6.8	1974	1970	100.2	16+160		1.8		S
L1		1167	200	2114	105	131.0	6.6	1982	1970	100.6	16+160	1.8			S
L2		1127	200	2137	91	111.7	5.5	2026	1970	102.8	16+180		1.8		S
L1		1109	200	2145	113	143.5	7.9	2002	1970	101.6	16+180	1.8			S
L2		1149	200	2124	103	128.8	6.5	1995	1970	101.3	16+200		1.8		S
L1		1153	200	2122	96	118.6	5.9	2004	1970	101.7	16+200	1.8			S
L2		1350	200	2024	90	109.8	5.7	1915	1970	97.2	16+220		1.8		S
L1		1432	200	1987	90	109.8	5.8	1878	1970	95.3	16+220	1.8			S
L2		1380	200	2011	83	99.5	5.2	1912	1970	97.0	16+240		1.8		S
L1		1312	200	2043	87	105.4	5.4	1937	1970	98.3	16+240	1.8			S

DETERMINATION OF MAXIMUM DENSITY (Soil & Bituminous)

TEST NO.	MOIS-TURE %	VOLUME MOLD m³	DENSITY DETERMINATION WET SOIL + MOLD Kg	MOLD Kg	WET SOIL Kg	COMPACTED SOIL WET Kg/m³	MAX DENSITY Kg/m³	OPTIMUM MOISTURE %
1	2	3	4	5	6	7	8	9
16160L2	6.8	.0013338	3.990	1.202	2.788	2084	1970	10.8

NOTE:
To convert (ft³) to (m³):
Vol. (ft³) x 0.02832 = Vol. (m³)

CHART STANDARDS DENSITY	CHART STANDARDS MOISTURE
2422 2374	661 635

OPERATING STANDARDS DENSITY	OPERATING STANDARDS MOISTURE
2379	651

BITUMINOUS MIX DESIGN kg /m³

REMARKS

M-84 Perpetual Pavement Demo Project Note: Sta. 16+100, 16+120, 16+140 unavailable due to on going construction machinery.

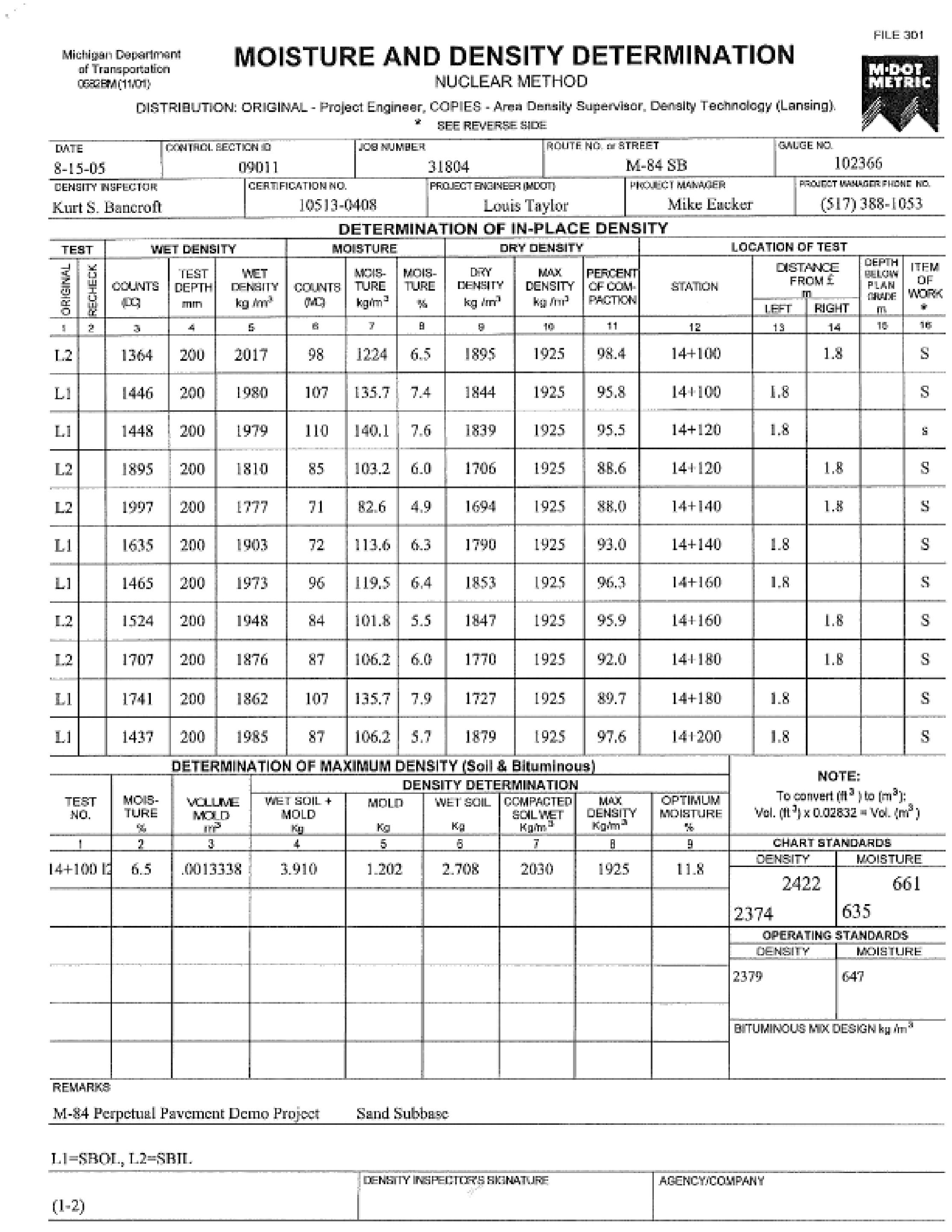
L1=SBOL, L2=SBIL Sand Subbase

(1-1)

DENSITY INSPECTOR'S SIGNATURE

AGENCY/COMPANY

Figure 86. Moisture and density determination on M-84 SB subbase, page 1



FILE 3D1

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MOISTURE AND DENSITY DETERMINATION

NUCLEAR METHOD

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M·DOT METRIC

DATE	CONTROL SECTION ID	JOB NUMBER	ROUTE NO. or STREET	GAUGE NO.
8-15-05	09011	31804	M-84 SB	102366

DENSITY INSPECTOR	CERTIFICATION NO.	PROJECT ENGINEER (MDOT)	PROJECT MANAGER	PROJECT MANAGER PHONE NO.
Kurt S. Bancroft	10513-0408	Louis Taylor	Mike Eacker	(517) 388-1053

DETERMINATION OF IN-PLACE DENSITY

TEST		WET DENSITY			MOISTURE			DRY DENSITY			LOCATION OF TEST				
ORIGINAL	RECHECK	COUNTS (DC)	TEST DEPTH mm	WET DENSITY kg /m³	COUNTS (MC)	MOIS-TURE kg/m³	MOIS-TURE %	DRY DENSITY kg /m³	MAX DENSITY kg /m³	PERCENT OF COM-PACTION	STATION	DISTANCE FROM ℄ m LEFT	DISTANCE FROM ℄ m RIGHT	DEPTH BELOW PLAN GRADE m	ITEM OF WORK *
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
L2		1364	200	2017	98	1224	6.5	1895	1925	98.4	14+100		1.8		S
L1		1446	200	1980	107	135.7	7.4	1844	1925	95.8	14+100	1.8			S
L1		1448	200	1979	110	140.1	7.6	1839	1925	95.5	14+120	1.8			s
L2		1895	200	1810	85	103.2	6.0	1706	1925	88.6	14+120		1.8		S
L2		1997	200	1777	71	82.6	4.9	1694	1925	88.0	14+140		1.8		S
L1		1635	200	1903	72	113.6	6.3	1790	1925	93.0	14+140	1.8			S
L1		1465	200	1973	96	119.5	6.4	1853	1925	96.3	14+160	1.8			S
L2		1524	200	1948	84	101.8	5.5	1847	1925	95.9	14+160		1.8		S
L2		1707	200	1876	87	106.2	6.0	1770	1925	92.0	14+180		1.8		S
L1		1741	200	1862	107	135.7	7.9	1727	1925	89.7	14+180	1.8			S
L1		1437	200	1985	87	106.2	5.7	1879	1925	97.6	14+200	1.8			S

DETERMINATION OF MAXIMUM DENSITY (Soil & Bituminous)

			DENSITY DETERMINATION					
TEST NO.	MOIS-TURE %	VOLUME MOLD m³	WET SOIL + MOLD Kg	MOLD Kg	WET SOIL Kg	COMPACTED SOIL WET Kg/m³	MAX DENSITY Kg/m³	OPTIMUM MOISTURE %
1	2	3	4	5	6	7	8	9
14+100 L2	6.5	.0013338	3.910	1.202	2.708	2030	1925	11.8

NOTE:

To convert (ft³) to (m³):
Vol. (ft³) x 0.02832 = Vol. (m³)

CHART STANDARDS	
DENSITY	MOISTURE
2422 2374	661 635

OPERATING STANDARDS	
DENSITY	MOISTURE
2379	647

BITUMINOUS MIX DESIGN kg /m³

REMARKS

M-84 Perpetual Pavement Demo Project Sand Subbase

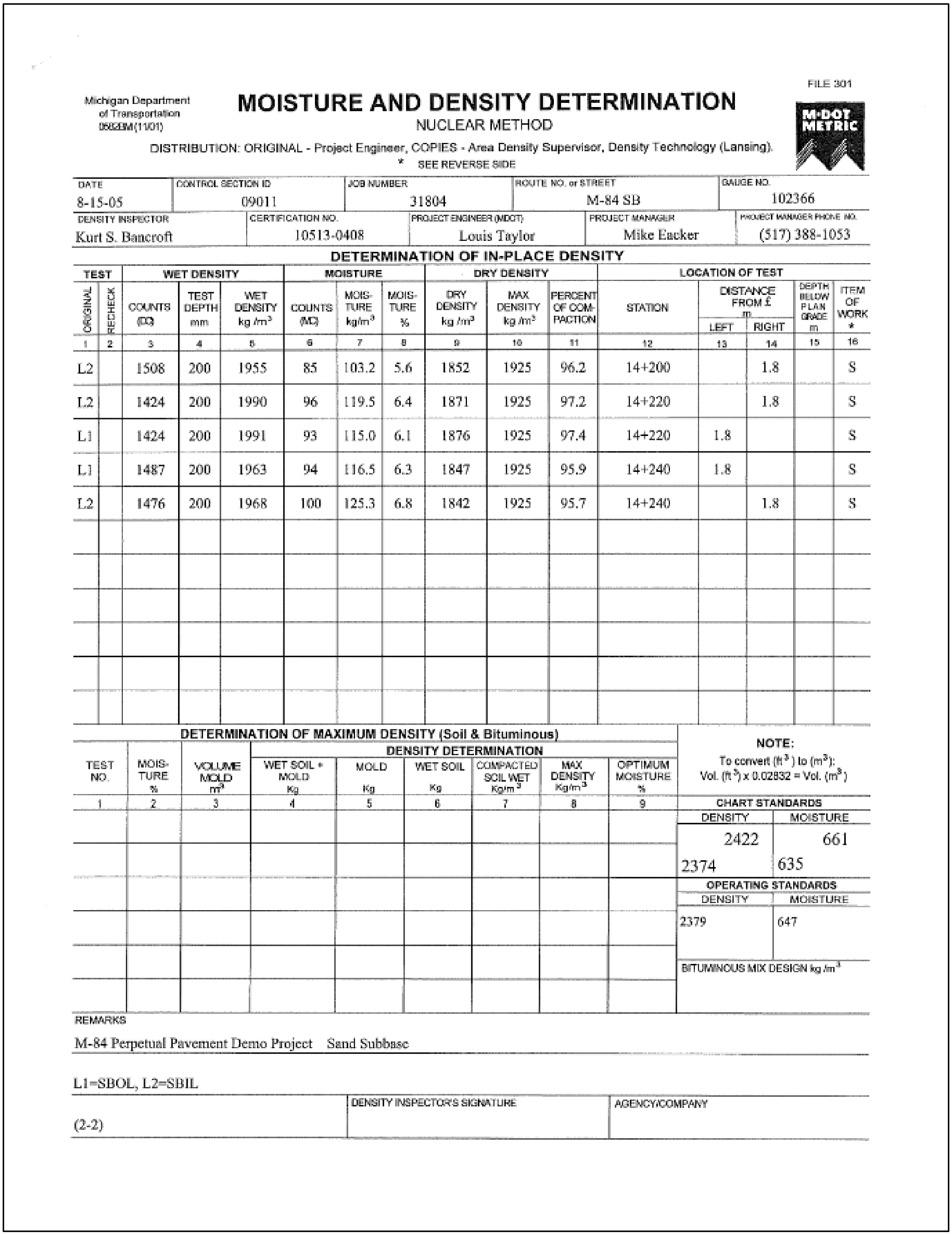
L1=SBOL, L2=SBIL

(1-2)

DENSITY INSPECTOR'S SIGNATURE

AGENCY/COMPANY

Figure 87. Moisture and density determination on M-84 SB subbase, page 2



Michigan Department
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FILE 301

M•DOT METRIC

MOISTURE AND DENSITY DETERMINATION

NUCLEAR METHOD

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DATE	CONTROL SECTION ID	JOB NUMBER	ROUTE NO. or STREET	GAUGE NO.
8-15-05	09011	31804	M-84 SB	102366

DENSITY INSPECTOR	CERTIFICATION NO.	PROJECT ENGINEER (MDOT)	PROJECT MANAGER	PROJECT MANAGER PHONE NO.
Kurt S. Bancroft	10513-0408	Louis Taylor	Mike Eacker	(517) 388-1053

DETERMINATION OF IN-PLACE DENSITY

TEST		WET DENSITY			MOISTURE			DRY DENSITY			LOCATION OF TEST				
ORIGINAL	RECHECK	COUNTS (DC)	TEST DEPTH mm	WET DENSITY kg /m³	COUNTS (MC)	MOISTURE kg/m³	MOISTURE %	DRY DENSITY kg /m³	MAX DENSITY kg /m³	PERCENT OF COMPACTION	STATION	DISTANCE FROM ℄ m LEFT	DISTANCE FROM ℄ m RIGHT	DEPTH BELOW PLAN GRADE m	ITEM OF WORK *
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
L2		1508	200	1955	85	103.2	5.6	1852	1925	96.2	14+200		1.8		S
L2		1424	200	1990	96	119.5	6.4	1871	1925	97.2	14+220		1.8		S
L1		1424	200	1991	93	115.0	6.1	1876	1925	97.4	14+220	1.8			S
L1		1487	200	1963	94	116.5	6.3	1847	1925	95.9	14+240	1.8			S
L2		1476	200	1968	100	125.3	6.8	1842	1925	95.7	14+240		1.8		S

DETERMINATION OF MAXIMUM DENSITY (Soil & Bituminous)

TEST NO.	MOISTURE %	VOLUME MOLD m³	DENSITY DETERMINATION WET SOIL + MOLD Kg	MOLD Kg	WET SOIL Kg	COMPACTED SOIL WET Kg/m³	MAX DENSITY Kg/m³	OPTIMUM MOISTURE %
1	2	3	4	5	6	7	8	9

NOTE:

To convert (ft³) to (m³):
Vol. (ft³) x 0.02832 = Vol. (m³)

CHART STANDARDS	
DENSITY	MOISTURE
2422 2374	661 635

OPERATING STANDARDS	
DENSITY	MOISTURE
2379	647

BITUMINOUS MIX DESIGN kg /m³

REMARKS

M-84 Perpetual Pavement Demo Project   Sand Subbase

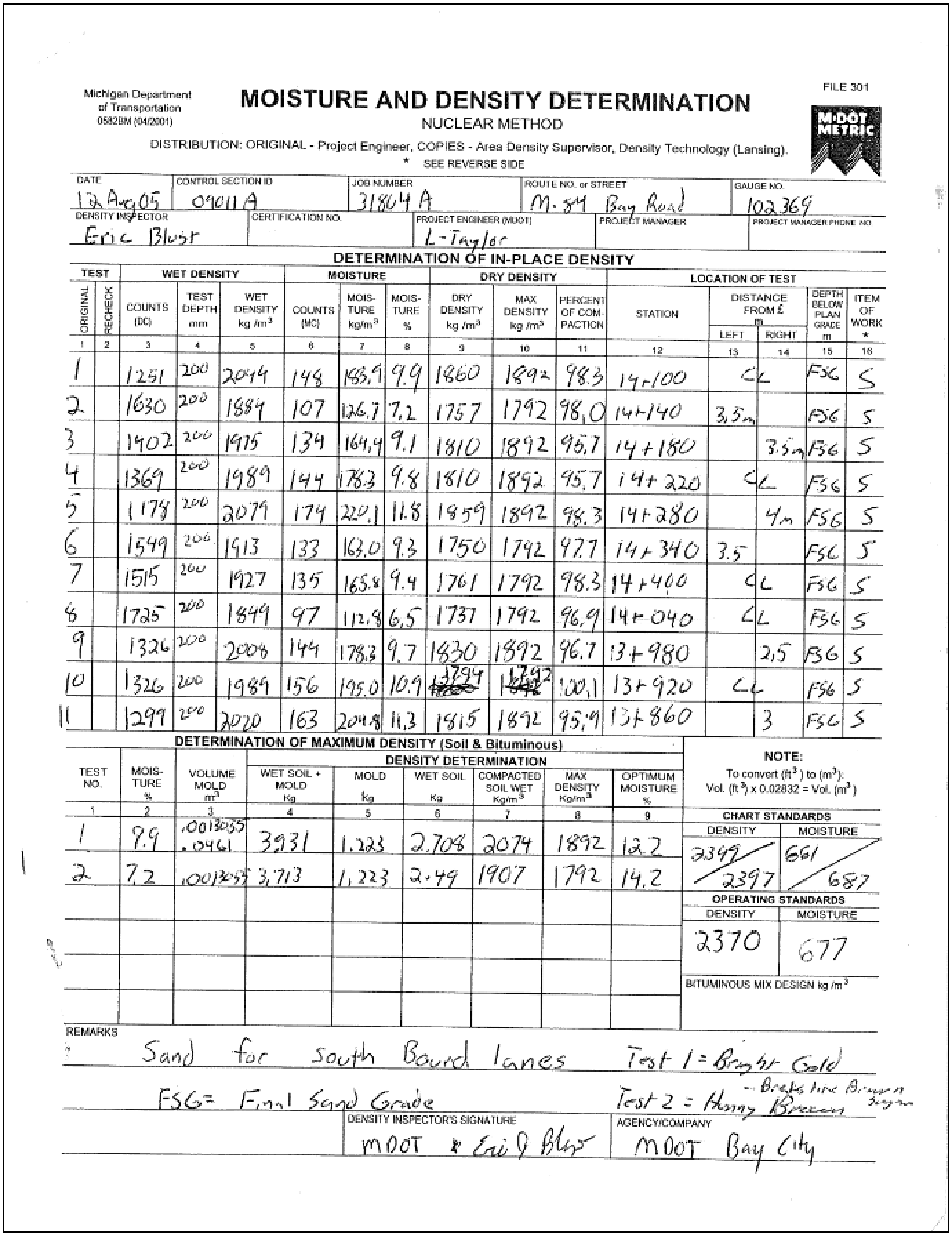
L1=SBOL, L2=SBIL

(2-2)

DENSITY INSPECTOR'S SIGNATURE

AGENCY/COMPANY

Figure 88. Moisture and density determination on M-84 SB subbase, page 3



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FILE 301

MOISTURE AND DENSITY DETERMINATION
NUCLEAR METHOD

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* SEE REVERSE SIDE

DATE	CONTROL SECTION ID	JOB NUMBER	ROUTE NO. or STREET	GAUGE NO.
12 Aug 05	09011 A	31804 A	M-84 Bay Road	102369

DENSITY INSPECTOR	CERTIFICATION NO.	PROJECT ENGINEER (MDOT)	PROJECT MANAGER	PROJECT MANAGER PHONE NO.
Eric Blust		L-Taylor		

DETERMINATION OF IN-PLACE DENSITY

TEST		WET DENSITY			MOISTURE			DRY DENSITY			LOCATION OF TEST				
ORIGINAL	RECHECK	COUNTS (DC)	TEST DEPTH mm	WET DENSITY kg/m³	COUNTS (MC)	MOISTURE kg/m³	MOISTURE %	DRY DENSITY kg/m³	MAX DENSITY kg/m³	PERCENT OF COMPACTION	STATION	DISTANCE FROM ℄ m LEFT	DISTANCE FROM ℄ m RIGHT	DEPTH BELOW PLAN GRADE m	ITEM OF WORK *
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1		1251	200	2044	148	183.9	9.9	1860	1892	98.3	14+100	CL		FSG	S
2		1630	200	1884	107	126.7	7.2	1757	1792	98.0	14+140	3.5m		FSG	S
3		1402	200	1975	134	164.4	9.1	1810	1892	95.7	14+180		3.5m	FSG	S
4		1369	200	1989	144	178.3	9.8	1810	1892	95.7	14+220	CL		FSG	S
5		1178	200	2079	179	220.1	11.8	1859	1892	98.3	14+280		4m	FSG	S
6		1549	200	1913	133	163.0	9.3	1750	1792	97.7	14+340	3.5		FSG	S
7		1515	200	1927	135	165.8	9.4	1761	1792	98.3	14+400	CL		FSG	S
8		1725	200	1849	97	112.8	6.5	1737	1792	96.9	14+040	CL		FSG	S
9		1326	200	2008	144	178.3	9.7	1830	1892	96.7	13+980		2.5	FSG	S
10		1326	200	1989	156	195.0	10.9	1794	1792	100.1	13+920	CL		FSG	S
11		1299	200	2020	163	204.8	11.3	1815	1892	95.9	13+860		3	FSG	S

DETERMINATION OF MAXIMUM DENSITY (Soil & Bituminous)

			DENSITY DETERMINATION					
TEST NO.	MOISTURE %	VOLUME MOLD m³	WET SOIL + MOLD Kg	MOLD Kg	WET SOIL Kg	COMPACTED SOIL WET Kg/m³	MAX DENSITY Kg/m³	OPTIMUM MOISTURE %
1	2	3	4	5	6	7	8	9
1	9.9	.0013055 .0461	3931	1.223	2.708	2074	1892	12.2
2	7.2	.0013055	3.713	1.223	2.49	1907	1792	14.2

NOTE:
To convert (ft³) to (m³):
Vol. (ft³) x 0.02832 = Vol. (m³)

CHART STANDARDS	
DENSITY	MOISTURE
2349 / 2397	661 / 687

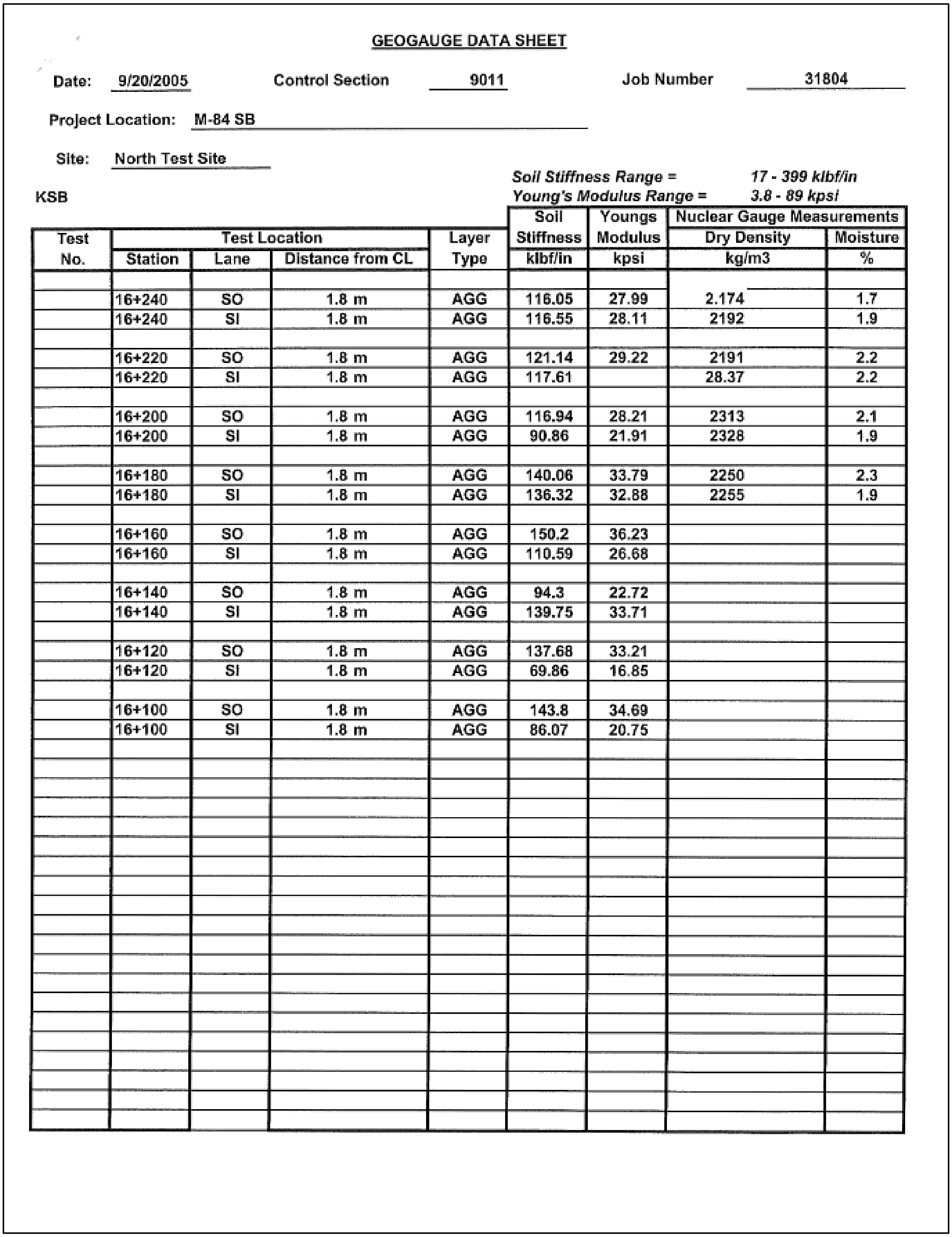
OPERATING STANDARDS	
DENSITY	MOISTURE
2370	677

BITUMINOUS MIX DESIGN kg/m³

REMARKS
Sand for south Bound lanes Test 1 = Bright Gold
FSG = Final Sand Grade Test 2 = Heavy Brown ← Breaks like Brown Sugar

DENSITY INSPECTOR'S SIGNATURE: MDOT * Eric J Blust
AGENCY/COMPANY: MDOT Bay City

Figure 89. Moisture and density determination on M-84 SB subbase, page 4



GEOGAUGE DATA SHEET

Date: 9/20/2005 Control Section 9011 Job Number 31804

Project Location: M-84 SB

Site: North Test Site

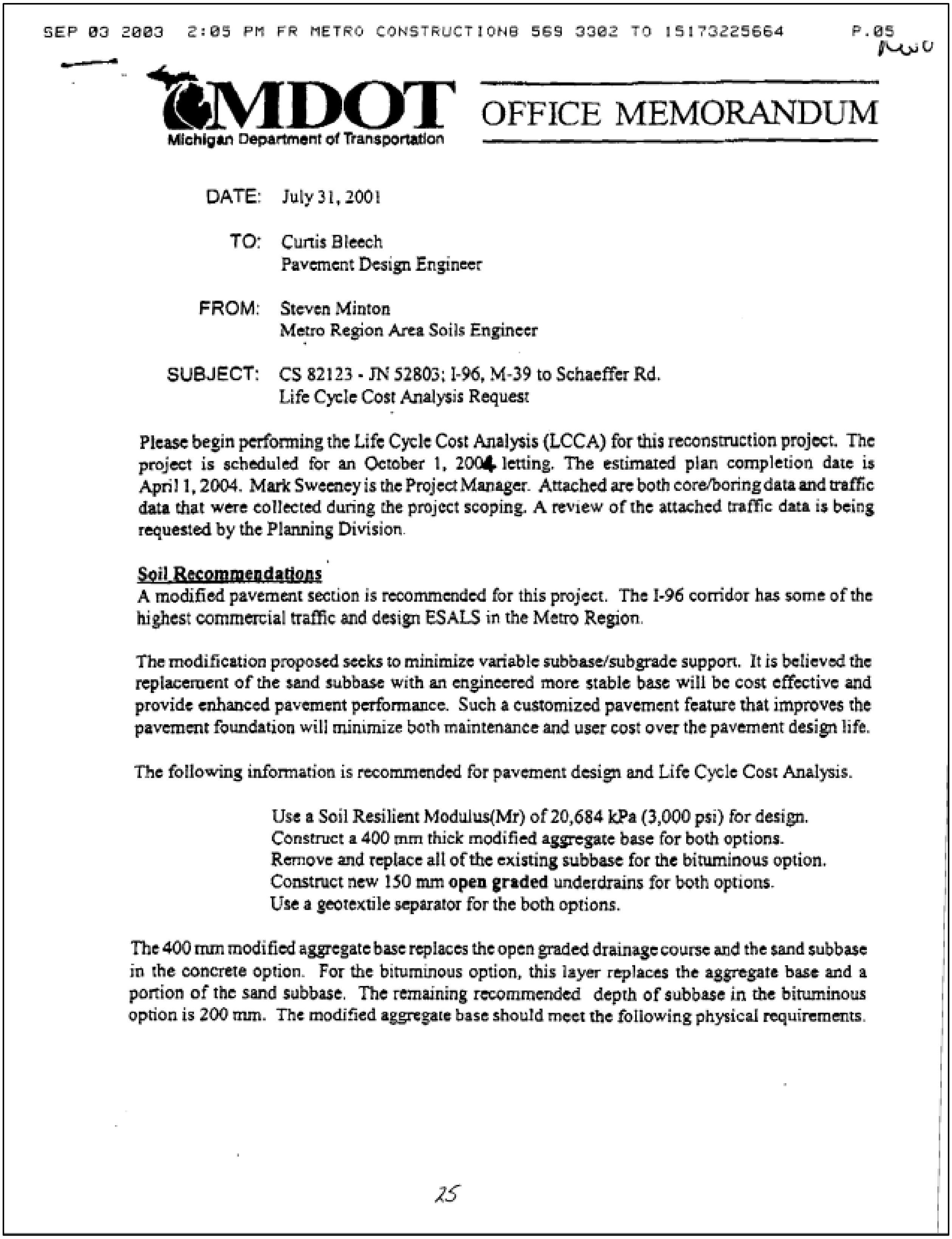
Soil Stiffness Range = 17 - 399 klbf/in

Young's Modulus Range = 3.8 - 89 kpsi

KSB

					Soil	Youngs	Nuclear Gauge Measurements	
Test	Test Location			Layer	Stiffness	Modulus	Dry Density	Moisture
No.	Station	Lane	Distance from CL	Type	klbf/in	kpsi	kg/m3	%
	16+240	SO	1.8 m	AGG	116.05	27.99	2.174	1.7
	16+240	SI	1.8 m	AGG	116.55	28.11	2192	1.9
	16+220	SO	1.8 m	AGG	121.14	29.22	2191	2.2
	16+220	SI	1.8 m	AGG	117.61		28.37	2.2
	16+200	SO	1.8 m	AGG	116.94	28.21	2313	2.1
	16+200	SI	1.8 m	AGG	90.86	21.91	2328	1.9
	16+180	SO	1.8 m	AGG	140.06	33.79	2250	2.3
	16+180	SI	1.8 m	AGG	136.32	32.88	2255	1.9
	16+160	SO	1.8 m	AGG	150.2	36.23		
	16+160	SI	1.8 m	AGG	110.59	26.68		
	16+140	SO	1.8 m	AGG	94.3	22.72		
	16+140	SI	1.8 m	AGG	139.75	33.71		
	16+120	SO	1.8 m	AGG	137.68	33.21		
	16+120	SI	1.8 m	AGG	69.86	16.85		
	16+100	SO	1.8 m	AGG	143.8	34.69		
	16+100	SI	1.8 m	AGG	86.07	20.75		

Figure 90. Soil stiffness and Young's modulus results on M-84 SB aggregate base layer



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MDOT
Michigan Department of Transportation

OFFICE MEMORANDUM

DATE: July 31, 2001

TO: Curtis Bleech
Pavement Design Engineer

FROM: Steven Minton
Metro Region Area Soils Engineer

SUBJECT: CS 82123 - JN 52803; I-96, M-39 to Schaeffer Rd.
Life Cycle Cost Analysis Request

Please begin performing the Life Cycle Cost Analysis (LCCA) for this reconstruction project. The project is scheduled for an October 1, 2004 letting. The estimated plan completion date is April 1, 2004. Mark Sweeney is the Project Manager. Attached are both core/boring data and traffic data that were collected during the project scoping. A review of the attached traffic data is being requested by the Planning Division.

Soil Recommendations

A modified pavement section is recommended for this project. The I-96 corridor has some of the highest commercial traffic and design ESALS in the Metro Region.

The modification proposed seeks to minimize variable subbase/subgrade support. It is believed the replacement of the sand subbase with an engineered more stable base will be cost effective and provide enhanced pavement performance. Such a customized pavement feature that improves the pavement foundation will minimize both maintenance and user cost over the pavement design life.

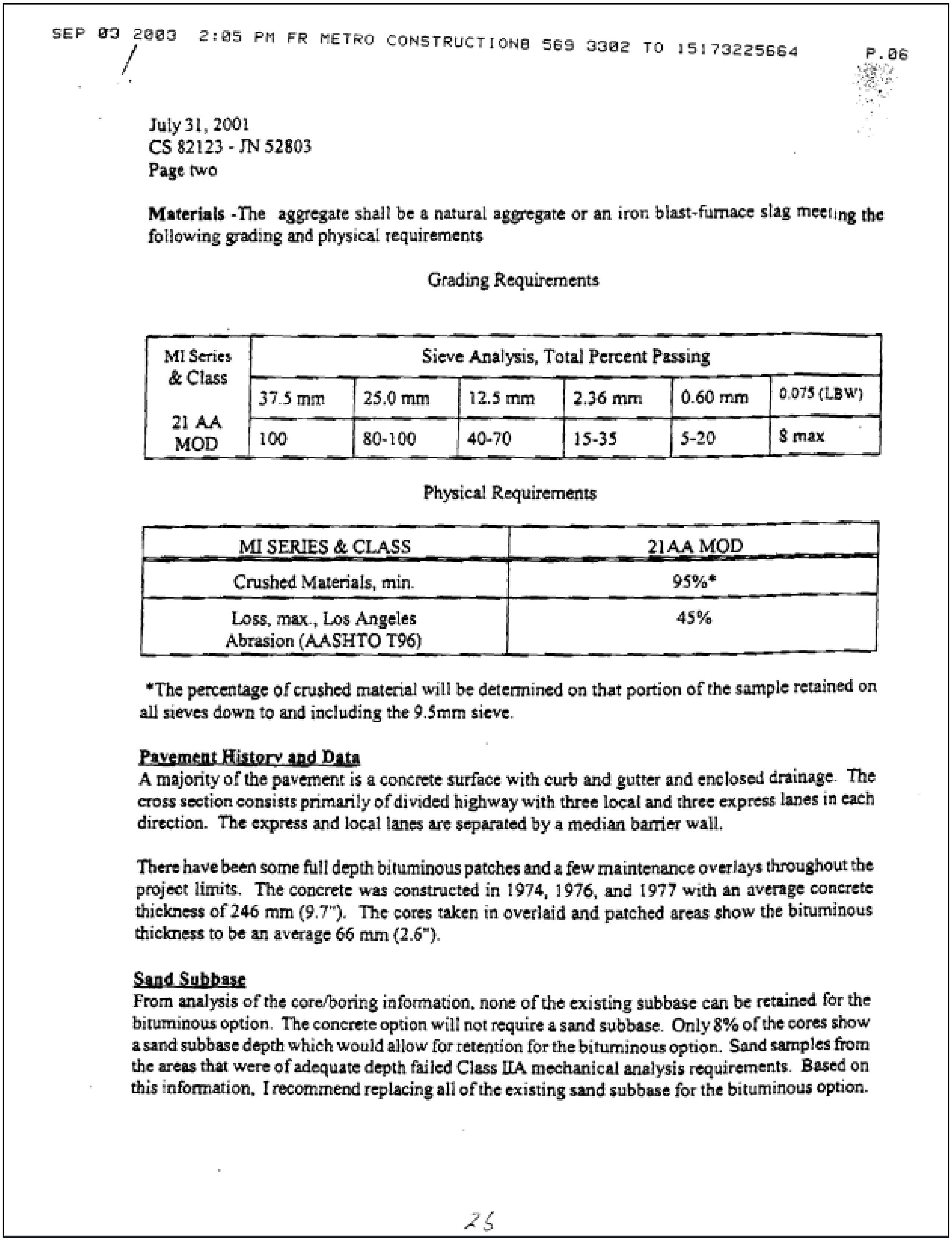
The following information is recommended for pavement design and Life Cycle Cost Analysis.

Use a Soil Resilient Modulus(Mr) of 20,684 kPa (3,000 psi) for design.
Construct a 400 mm thick modified aggregate base for both options.
Remove and replace all of the existing subbase for the bituminous option.
Construct new 150 mm **open graded** underdrains for both options.
Use a geotextile separator for the both options.

The 400 mm modified aggregate base replaces the open graded drainage course and the sand subbase in the concrete option. For the bituminous option, this layer replaces the aggregate base and a portion of the sand subbase. The remaining recommended depth of subbase in the bituminous option is 200 mm. The modified aggregate base should meet the following physical requirements.

25

Figure 91. Office memorandum on I-96 soil recommendations, page 1



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July 31, 2001
CS 82123 - JN 52803
Page two

Materials -The aggregate shall be a natural aggregate or an iron blast-furnace slag meeting the following grading and physical requirements

Grading Requirements

MI Series & Class	Sieve Analysis, Total Percent Passing					
	37.5 mm	25.0 mm	12.5 mm	2.36 mm	0.60 mm	0.075 (LBW)
21 AA MOD	100	80-100	40-70	15-35	5-20	8 max

Physical Requirements

MI SERIES & CLASS	21AA MOD
Crushed Materials, min.	95%*
Loss, max., Los Angeles Abrasion (AASHTO T96)	45%

*The percentage of crushed material will be determined on that portion of the sample retained on all sieves down to and including the 9.5mm sieve.

Pavement History and Data

A majority of the pavement is a concrete surface with curb and gutter and enclosed drainage. The cross section consists primarily of divided highway with three local and three express lanes in each direction. The express and local lanes are separated by a median barrier wall.

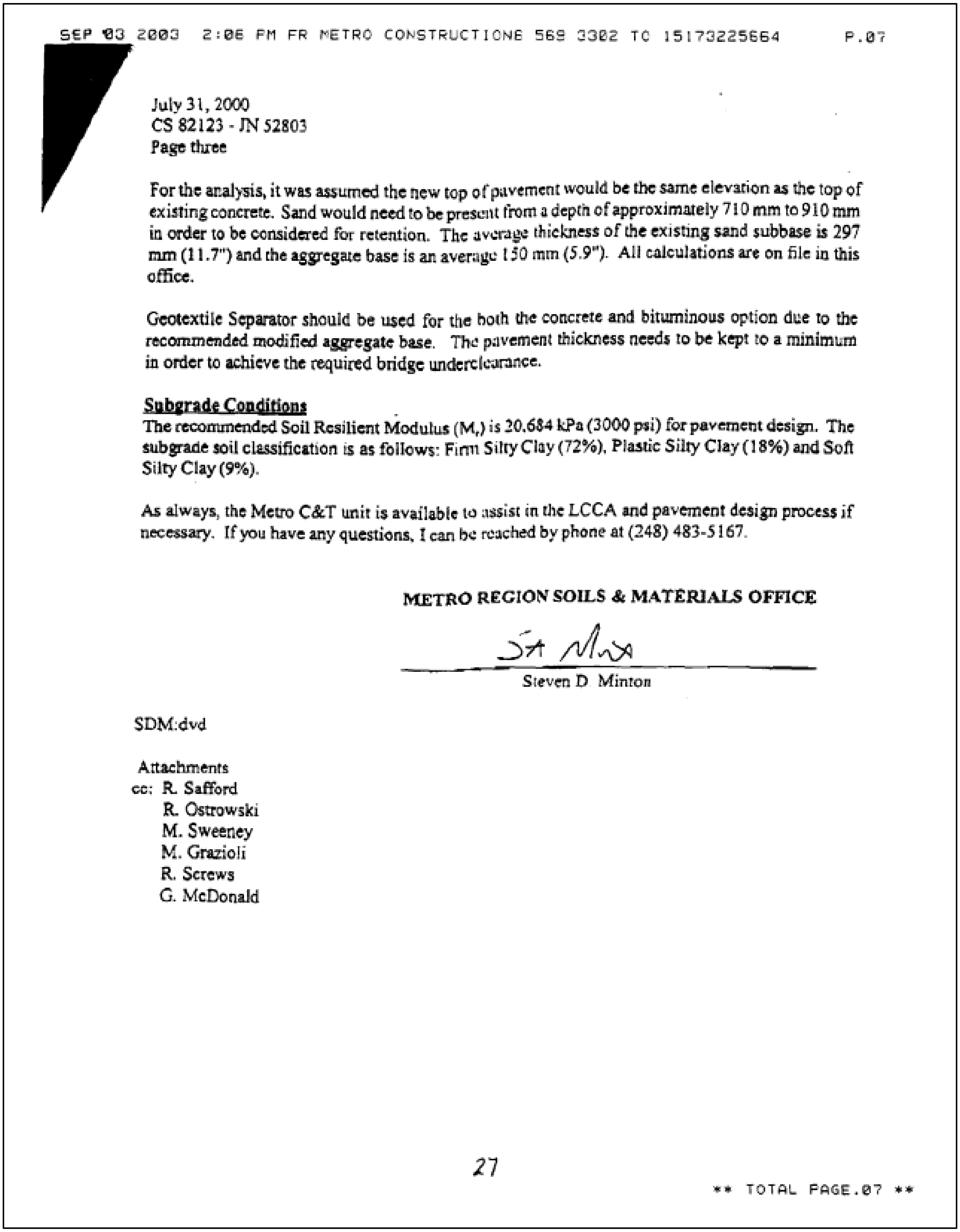
There have been some full depth bituminous patches and a few maintenance overlays throughout the project limits. The concrete was constructed in 1974, 1976, and 1977 with an average concrete thickness of 246 mm (9.7"). The cores taken in overlaid and patched areas show the bituminous thickness to be an average 66 mm (2.6").

Sand Subbase

From analysis of the core/boring information, none of the existing subbase can be retained for the bituminous option. The concrete option will not require a sand subbase. Only 8% of the cores show a sand subbase depth which would allow for retention for the bituminous option. Sand samples from the areas that were of adequate depth failed Class IIA mechanical analysis requirements. Based on this information, I recommend replacing all of the existing sand subbase for the bituminous option.

25

Figure 92. Office memorandum on I-96 soil recommendations, page 2



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July 31, 2000
CS 82123 - JN 52803
Page three

For the analysis, it was assumed the new top of pavement would be the same elevation as the top of existing concrete. Sand would need to be present from a depth of approximately 710 mm to 910 mm in order to be considered for retention. The average thickness of the existing sand subbase is 297 mm (11.7") and the aggregate base is an average 150 mm (5.9"). All calculations are on file in this office.

Geotextile Separator should be used for the both the concrete and bituminous option due to the recommended modified aggregate base. The pavement thickness needs to be kept to a minimum in order to achieve the required bridge underclearance.

Subgrade Conditions
The recommended Soil Resilient Modulus (M,) is 20.684 kPa (3000 psi) for pavement design. The subgrade soil classification is as follows: Firm Silty Clay (72%), Plastic Silty Clay (18%) and Soft Silty Clay (9%).

As always, the Metro C&T unit is available to assist in the LCCA and pavement design process if necessary. If you have any questions, I can be reached by phone at (248) 483-5167.

METRO REGION SOILS & MATERIALS OFFICE

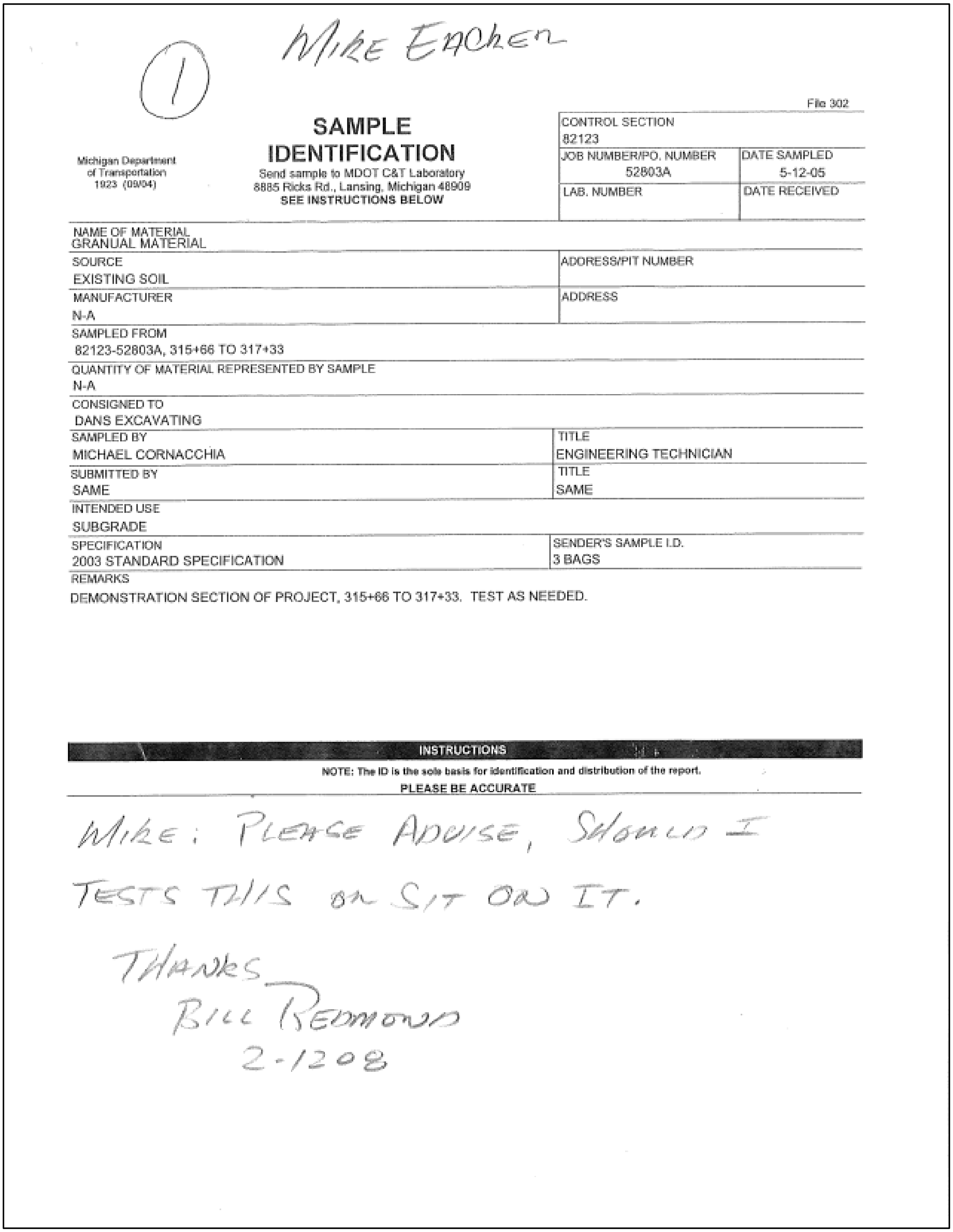
Steven D. Minton

SDM:dvd

Attachments
cc: R. Safford
R. Ostrowski
M. Sweeney
M. Grazioli
R. Screws
G. McDonald

** TOTAL PAGE.07 **

Figure 93. Office memorandum on I-96 soil recommendations, page 3



Mike Eachen

①

File 302

Michigan Department
of Transportation
1923 (09/04)

SAMPLE IDENTIFICATION

Send sample to MDOT C&T Laboratory
8885 Ricks Rd., Lansing, Michigan 48909
SEE INSTRUCTIONS BELOW

CONTROL SECTION 82123	
JOB NUMBER/PO. NUMBER 52803A	DATE SAMPLED 5-12-05
LAB. NUMBER	DATE RECEIVED

NAME OF MATERIAL GRANUAL MATERIAL	
SOURCE EXISTING SOIL	ADDRESS/PIT NUMBER
MANUFACTURER N-A	ADDRESS
SAMPLED FROM 82123-52803A, 315+66 TO 317+33	
QUANTITY OF MATERIAL REPRESENTED BY SAMPLE N-A	
CONSIGNED TO DANS EXCAVATING	
SAMPLED BY MICHAEL CORNACCHIA	TITLE ENGINEERING TECHNICIAN
SUBMITTED BY SAME	TITLE SAME
INTENDED USE SUBGRADE	
SPECIFICATION 2003 STANDARD SPECIFICATION	SENDER'S SAMPLE I.D. 3 BAGS

REMARKS
DEMONSTRATION SECTION OF PROJECT, 315+66 TO 317+33. TEST AS NEEDED.

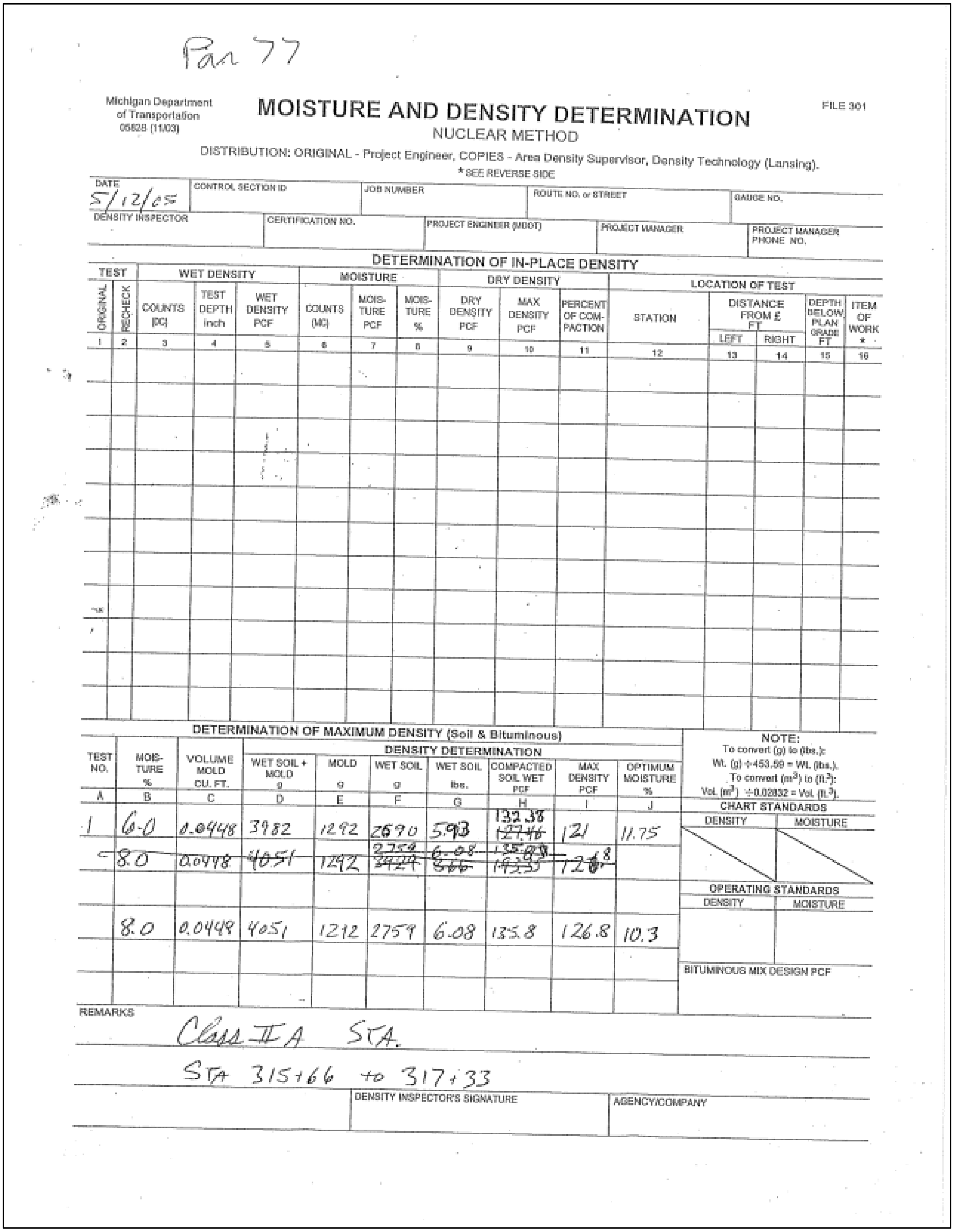
INSTRUCTIONS

NOTE: The ID is the sole basis for identification and distribution of the report.
PLEASE BE ACCURATE

Mike: Please Advise, Should I
Tests this or Sit on It.

Thanks
Bill Redmond
2-1208

Figure 94. Sample identification note on I-96 WB existing soil



Par 77

Michigan Department
of Transportation
0582B (11/03)

MOISTURE AND DENSITY DETERMINATION

NUCLEAR METHOD

FILE 301

DISTRIBUTION: ORIGINAL - Project Engineer, COPIES - Area Density Supervisor, Density Technology (Lansing).

*SEE REVERSE SIDE

DATE 5/12/05

CONTROL SECTION ID

JOB NUMBER

ROUTE NO. or STREET

GAUGE NO.

DENSITY INSPECTOR

CERTIFICATION NO.

PROJECT ENGINEER (MDOT)

PROJECT MANAGER

PROJECT MANAGER PHONE NO.

DETERMINATION OF IN-PLACE DENSITY

TEST		WET DENSITY			MOISTURE			DRY DENSITY			LOCATION OF TEST				
ORIGINAL	RECHECK	COUNTS (DC)	TEST DEPTH inch	WET DENSITY PCF	COUNTS (MC)	MOISTURE PCF	MOISTURE %	DRY DENSITY PCF	MAX DENSITY PCF	PERCENT OF COMPACTION	STATION	DISTANCE FROM ℄ FT LEFT	DISTANCE FROM ℄ FT RIGHT	DEPTH BELOW PLAN GRADE FT	ITEM OF WORK *
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

DETERMINATION OF MAXIMUM DENSITY (Soil & Bituminous)

TEST NO.	MOISTURE %	VOLUME MOLD CU. FT.	DENSITY DETERMINATION WET SOIL + MOLD g	MOLD g	WET SOIL g	WET SOIL lbs.	COMPACTED SOIL WET PCF	MAX DENSITY PCF	OPTIMUM MOISTURE %
A	B	C	D	E	F	G	H	I	J
1	6.0	0.0448	3982	1292	2690	5.93	132.38 ~~127.46~~	121	11.75
	~~8.0~~	~~0.0448~~	~~4051~~	~~1292~~	~~2759~~ ~~3424~~	~~6.08~~ ~~5.66~~	~~135.89~~ ~~143.33~~	~~128~~	
	8.0	0.0449	4051	1212	2759	6.08	135.8	126.8	10.3

NOTE:
To convert (g) to (lbs.):
Wt. (g) ÷ 453.59 = Wt. (lbs.).
To convert (m³) to (ft.³):
Vol. (m³) ÷ 0.02832 = Vol. (ft.³).

CHART STANDARDS

DENSITY	MOISTURE

OPERATING STANDARDS

DENSITY	MOISTURE

BITUMINOUS MIX DESIGN PCF

REMARKS

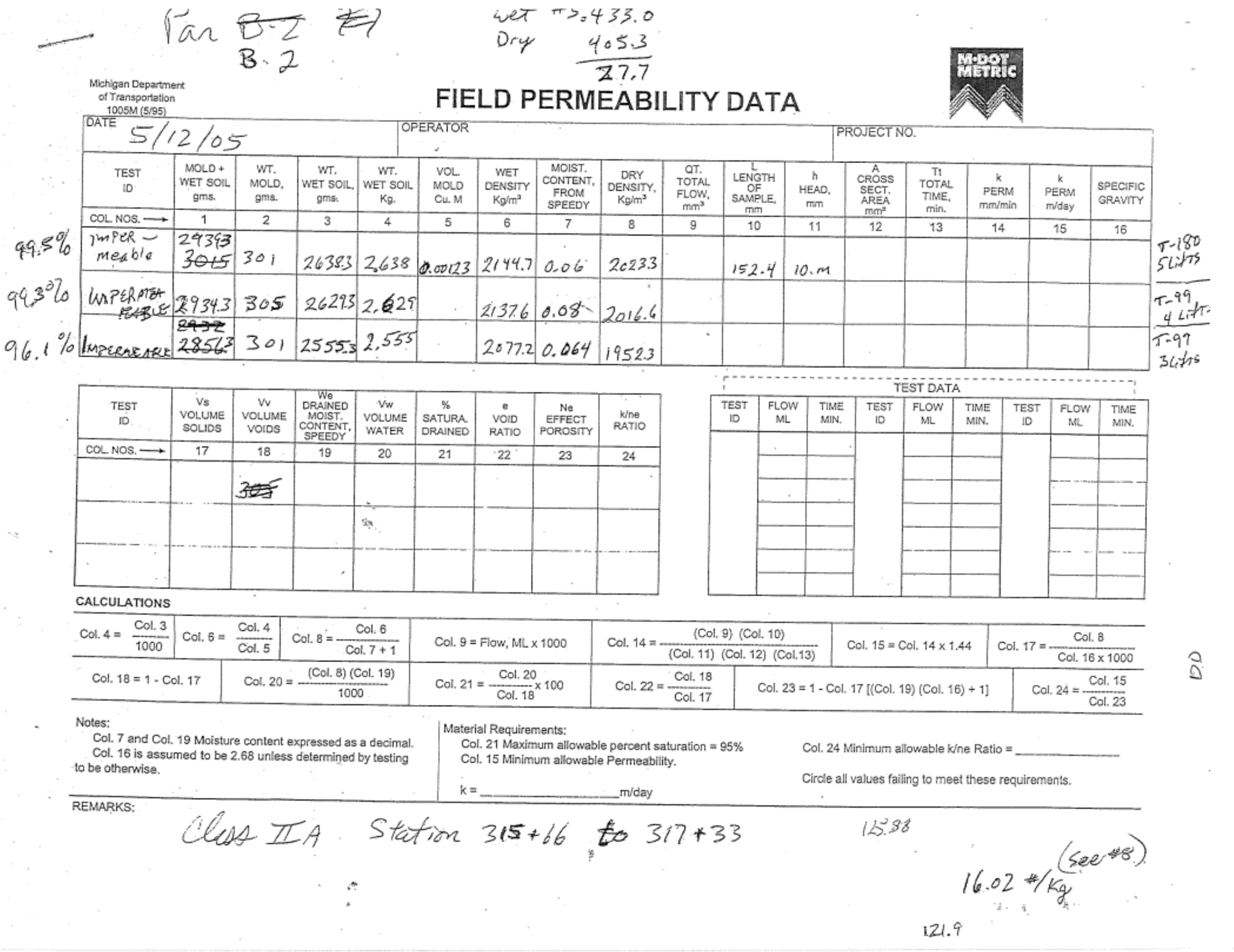
Class II A STA.

STA 315+66 to 317+33

DENSITY INSPECTOR'S SIGNATURE

AGENCY/COMPANY

Figure 95. Moisture and density determination on I-96 WB existing subbase



Par ~~B-2~~ ~~E1~~
B-2

wet #2=433.0
Dry 405.3
27.7

Michigan Department
of Transportation
1005M (5/95)

FIELD PERMEABILITY DATA

M-DOT METRIC

DATE 5/12/05

OPERATOR

PROJECT NO.

TEST ID	MOLD + WET SOIL gms.	WT. MOLD, gms.	WT. WET SOIL, gms.	WT. WET SOIL Kg.	VOL. MOLD Cu. M	WET DENSITY Kg/m³	MOIST. CONTENT, FROM SPEEDY	DRY DENSITY, Kg/m³	QT. TOTAL FLOW, mm³	L LENGTH OF SAMPLE, mm	h HEAD, mm	A CROSS SECT. AREA mm²	Tt TOTAL TIME, min.	k PERM mm/min	k PERM m/day	SPECIFIC GRAVITY
COL. NOS. ⟶	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
impermeable	29393 ~~3015~~	301	2638.3	2.638	0.00123	2144.7	0.06	2023.3		152.4	10.m					
IMPERMEABLE	2934.3	305	2629.3	2.629		2137.6	0.08	2016.6								
IMPERMEABLE	~~2932~~ 2856.3	301	2555.3	2.555		2077.2	0.064	1952.3								

99.5%
99.3%
96.1%

T-180 5 Lifts
T-99 4 Lifts
T-99 3 Lifts

TEST ID	Vs VOLUME SOLIDS	Vv VOLUME VOIDS	We DRAINED MOIST. CONTENT, SPEEDY	Vw VOLUME WATER	% SATURA. DRAINED	e VOID RATIO	Ne EFFECT POROSITY	k/ne RATIO
COL. NOS. ⟶	17	18	19	20	21	22	23	24
		~~305~~						

TEST DATA

TEST ID	FLOW ML	TIME MIN.	TEST ID	FLOW ML	TIME MIN.	TEST ID	FLOW ML	TIME MIN.

CALCULATIONS

$\text{Col. 4} = \frac{\text{Col. 3}}{1000}$ | $\text{Col. 6} = \frac{\text{Col. 4}}{\text{Col. 5}}$ | $\text{Col. 8} = \frac{\text{Col. 6}}{\text{Col. 7} + 1}$ | Col. 9 = Flow, ML x 1000 | $\text{Col. 14} = \frac{(\text{Col. 9})\ (\text{Col. 10})}{(\text{Col. 11})\ (\text{Col. 12})\ (\text{Col.13})}$ | Col. 15 = Col. 14 x 1.44 | $\text{Col. 17} = \frac{\text{Col. 8}}{\text{Col. 16} \times 1000}$

Col. 18 = 1 - Col. 17 | $\text{Col. 20} = \frac{(\text{Col. 8})\ (\text{Col. 19})}{1000}$ | $\text{Col. 21} = \frac{\text{Col. 20}}{\text{Col. 18}} \times 100$ | $\text{Col. 22} = \frac{\text{Col. 18}}{\text{Col. 17}}$ | Col. 23 = 1 - Col. 17 [(Col. 19) (Col. 16) + 1] | $\text{Col. 24} = \frac{\text{Col. 15}}{\text{Col. 23}}$

Notes:
Col. 7 and Col. 19 Moisture content expressed as a decimal.
Col. 16 is assumed to be 2.68 unless determined by testing to be otherwise.

Material Requirements:
Col. 21 Maximum allowable percent saturation = 95%
Col. 15 Minimum allowable Permeability.
k = ____________ m/day

Col. 24 Minimum allowable k/ne Ratio = ____________

Circle all values failing to meet these requirements.

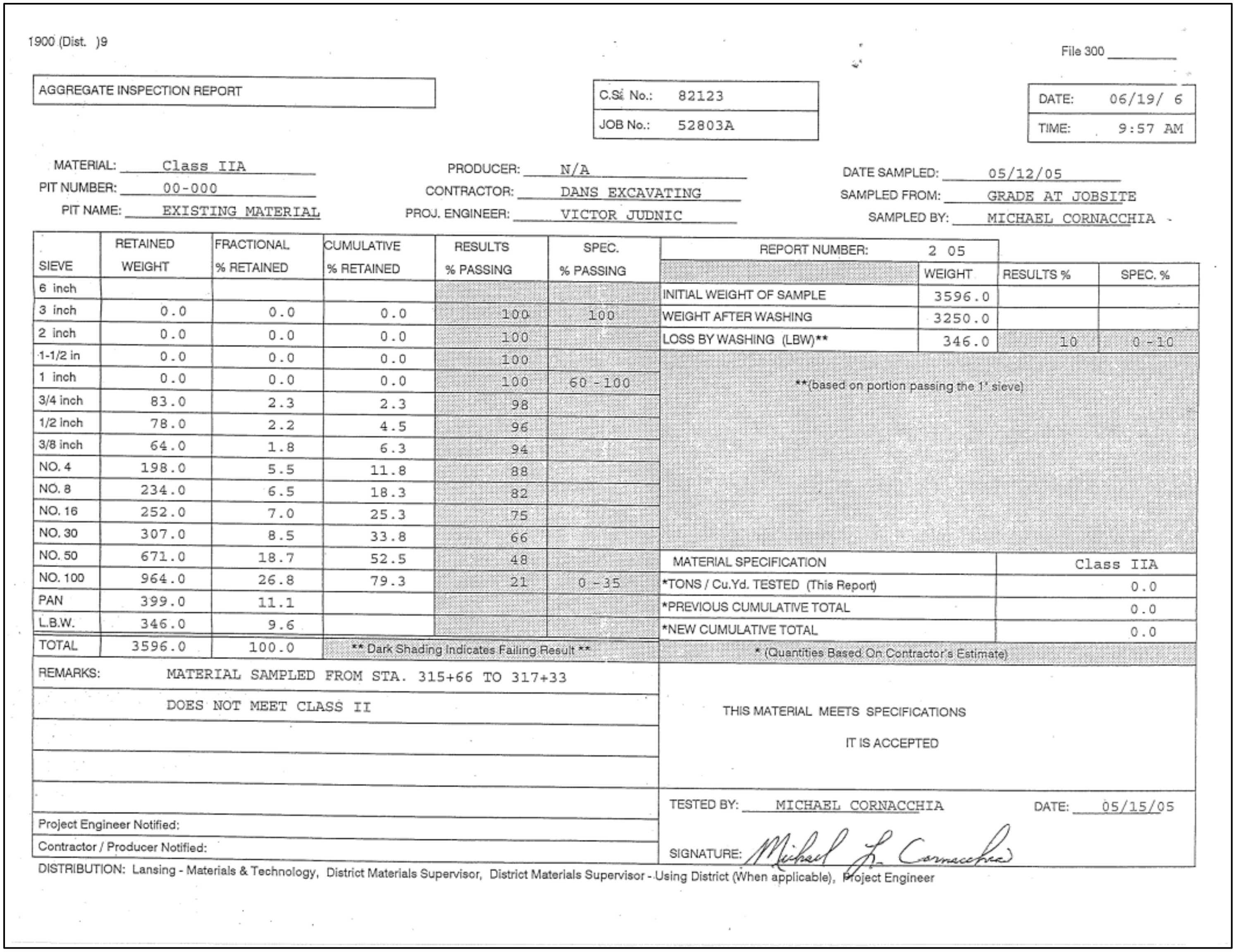
REMARKS:
Class IIA Station 315+66 to 317+33

125.38

(see #8)
16.02 #/Kg

121.9

Figure 96. Field permeability data on I-96 WB existing subbase



1900 (Dist.)9

File 300 ______

AGGREGATE INSPECTION REPORT

C.S. No.: 82123
JOB No.: 52803A

DATE: 06/19/ 6
TIME: 9:57 AM

MATERIAL: Class IIA
PIT NUMBER: 00-000
PIT NAME: EXISTING MATERIAL

PRODUCER: N/A
CONTRACTOR: DANS EXCAVATING
PROJ. ENGINEER: VICTOR JUDNIC

DATE SAMPLED: 05/12/05
SAMPLED FROM: GRADE AT JOBSITE
SAMPLED BY: MICHAEL CORNACCHIA

SIEVE	RETAINED WEIGHT	FRACTIONAL % RETAINED	CUMULATIVE % RETAINED	RESULTS % PASSING	SPEC. % PASSING
6 inch					
3 inch	0.0	0.0	0.0	100	100
2 inch	0.0	0.0	0.0	100	
1-1/2 in	0.0	0.0	0.0	100	
1 inch	0.0	0.0	0.0	100	60 - 100
3/4 inch	83.0	2.3	2.3	98	
1/2 inch	78.0	2.2	4.5	96	
3/8 inch	64.0	1.8	6.3	94	
NO. 4	198.0	5.5	11.8	88	
NO. 8	234.0	6.5	18.3	82	
NO. 16	252.0	7.0	25.3	75	
NO. 30	307.0	8.5	33.8	66	
NO. 50	671.0	18.7	52.5	48	
NO. 100	964.0	26.8	79.3	21	0 - 35
PAN	399.0	11.1			
L.B.W.	346.0	9.6			
TOTAL	3596.0	100.0	** Dark Shading Indicates Failing Result **		

REPORT NUMBER: 2 05

	WEIGHT	RESULTS %	SPEC. %
INITIAL WEIGHT OF SAMPLE	3596.0		
WEIGHT AFTER WASHING	3250.0		
LOSS BY WASHING (LBW)**	346.0	10	0 - 10

**(based on portion passing the 1" sieve)

MATERIAL SPECIFICATION	Class IIA
*TONS / Cu.Yd. TESTED (This Report)	0.0
*PREVIOUS CUMULATIVE TOTAL	0.0
*NEW CUMULATIVE TOTAL	0.0

* (Quantities Based On Contractor's Estimate)

REMARKS: MATERIAL SAMPLED FROM STA. 315+66 TO 317+33
DOES NOT MEET CLASS II

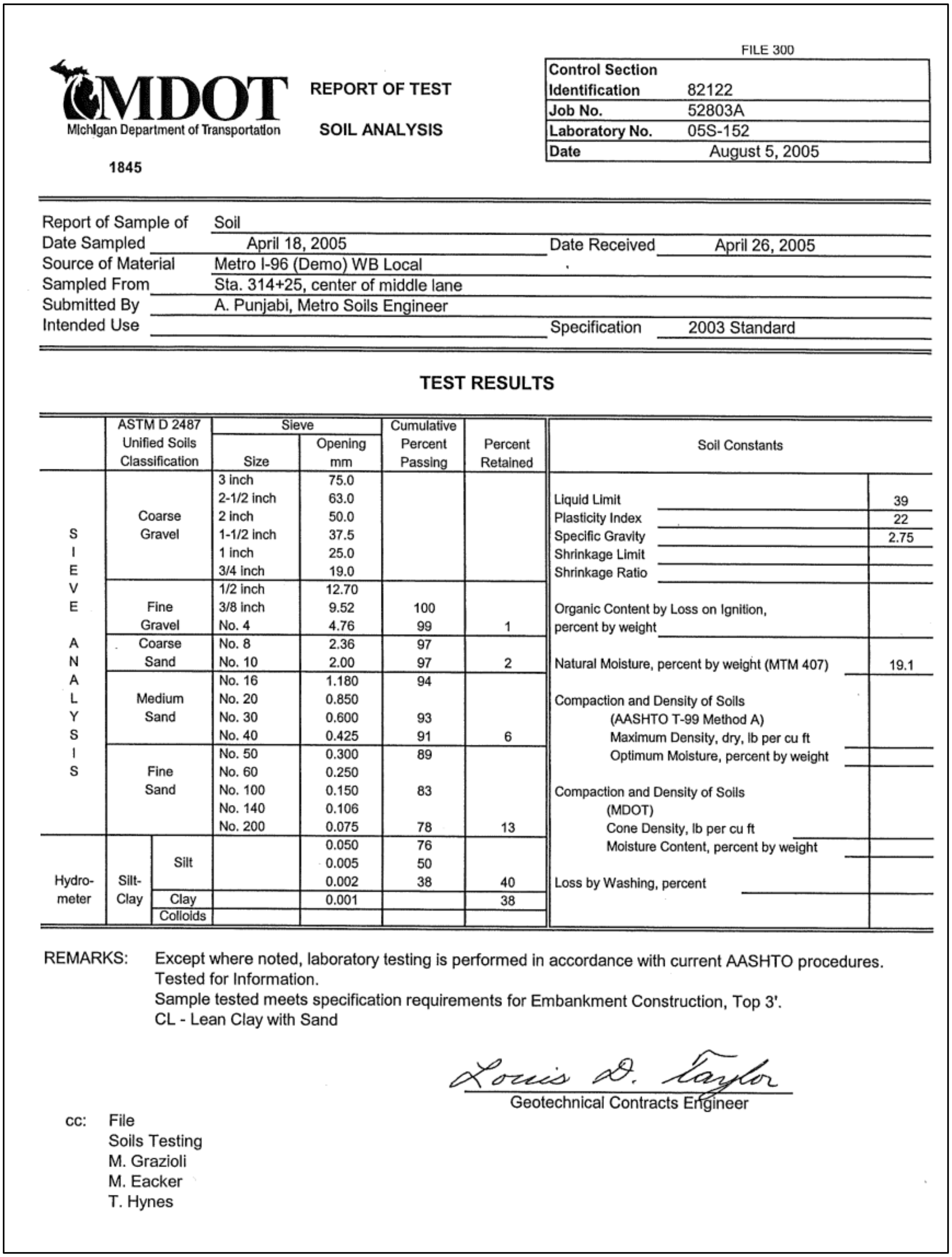
Project Engineer Notified:
Contractor / Producer Notified:

THIS MATERIAL MEETS SPECIFICATIONS
IT IS ACCEPTED

TESTED BY: MICHAEL CORNACCHIA
DATE: 05/15/05
SIGNATURE: Michael L. Cornacchia

DISTRIBUTION: Lansing - Materials & Technology, District Materials Supervisor, District Materials Supervisor - Using District (When applicable), Project Engineer

Figure 97. Aggregate inspection report on I-96 WB existing subbase



FILE 300

MDOT
Michigan Department of Transportation

1845

REPORT OF TEST

SOIL ANALYSIS

Control Section Identification	82122
Job No.	52803A
Laboratory No.	05S-152
Date	August 5, 2005

Report of Sample of Soil
Date Sampled April 18, 2005 Date Received April 26, 2005
Source of Material Metro I-96 (Demo) WB Local
Sampled From Sta. 314+25, center of middle lane
Submitted By A. Punjabi, Metro Soils Engineer
Intended Use Specification 2003 Standard

TEST RESULTS

	ASTM D 2487 Unified Soils Classification		Sieve		Cumulative Percent Passing	Percent Retained
			Size	Opening mm		
SIEVE ANALYSIS	Coarse Gravel		3 inch	75.0		
			2-1/2 inch	63.0		
			2 inch	50.0		
			1-1/2 inch	37.5		
			1 inch	25.0		
			3/4 inch	19.0		
	Fine Gravel		1/2 inch	12.70		
			3/8 inch	9.52	100	
			No. 4	4.76	99	1
	Coarse Sand		No. 8	2.36	97	
			No. 10	2.00	97	2
	Medium Sand		No. 16	1.180	94	
			No. 20	0.850		
			No. 30	0.600	93	
			No. 40	0.425	91	6
	Fine Sand		No. 50	0.300	89	
			No. 60	0.250		
			No. 100	0.150	83	
			No. 140	0.106		
			No. 200	0.075	78	13
Hydro-meter	Silt-Clay	Silt		0.050	76	
				0.005	50	
				0.002	38	40
		Clay		0.001		38
		Colloids				

Soil Constants

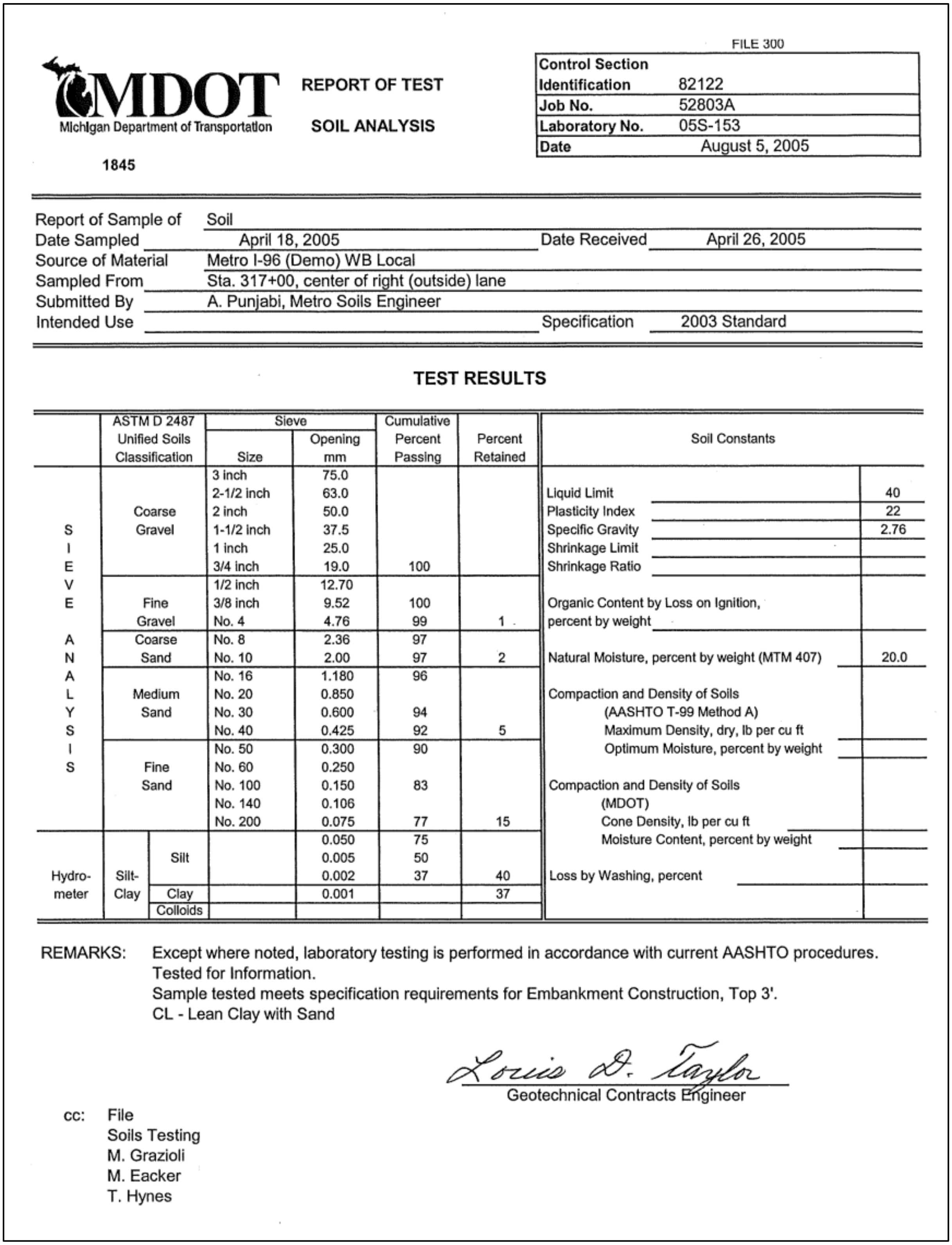
Liquid Limit	39
Plasticity Index	22
Specific Gravity	2.75
Shrinkage Limit	
Shrinkage Ratio	
Organic Content by Loss on Ignition, percent by weight	
Natural Moisture, percent by weight (MTM 407)	19.1
Compaction and Density of Soils (AASHTO T-99 Method A) Maximum Density, dry, lb per cu ft	
Optimum Moisture, percent by weight	
Compaction and Density of Soils (MDOT) Cone Density, lb per cu ft	
Moisture Content, percent by weight	
Loss by Washing, percent	

REMARKS: Except where noted, laboratory testing is performed in accordance with current AASHTO procedures.
Tested for Information.
Sample tested meets specification requirements for Embankment Construction, Top 3'.
CL - Lean Clay with Sand

Louis D. Taylor
Geotechnical Contracts Engineer

cc: File
Soils Testing
M. Grazioli
M. Eacker
T. Hynes

Figure 98. Subgrade soil information for the I-96 WB project, page 1



FILE 300

MDOT
Michigan Department of Transportation
1845

REPORT OF TEST

SOIL ANALYSIS

Control Section Identification	82122
Job No.	52803A
Laboratory No.	05S-153
Date	August 5, 2005

Report of Sample of: Soil
Date Sampled: April 18, 2005 Date Received: April 26, 2005
Source of Material: Metro I-96 (Demo) WB Local
Sampled From: Sta. 317+00, center of right (outside) lane
Submitted By: A. Punjabi, Metro Soils Engineer
Intended Use: Specification: 2003 Standard

TEST RESULTS

	ASTM D 2487 Unified Soils Classification	Sieve Size	Sieve Opening mm	Cumulative Percent Passing	Percent Retained
SIEVE ANALYSIS	Coarse Gravel	3 inch	75.0		
		2-1/2 inch	63.0		
		2 inch	50.0		
		1-1/2 inch	37.5		
		1 inch	25.0		
		3/4 inch	19.0	100	
	Fine Gravel	1/2 inch	12.70		
		3/8 inch	9.52	100	
		No. 4	4.76	99	1
	Coarse Sand	No. 8	2.36	97	
		No. 10	2.00	97	2
	Medium Sand	No. 16	1.180	96	
		No. 20	0.850		
		No. 30	0.600	94	
		No. 40	0.425	92	5
	Fine Sand	No. 50	0.300	90	
		No. 60	0.250		
		No. 100	0.150	83	
		No. 140	0.106		
		No. 200	0.075	77	15
Hydro-meter	Silt-Clay: Silt		0.050	75	
			0.005	50	
			0.002	37	40
	Silt-Clay: Clay		0.001		37
	Silt-Clay: Colloids				

Soil Constants

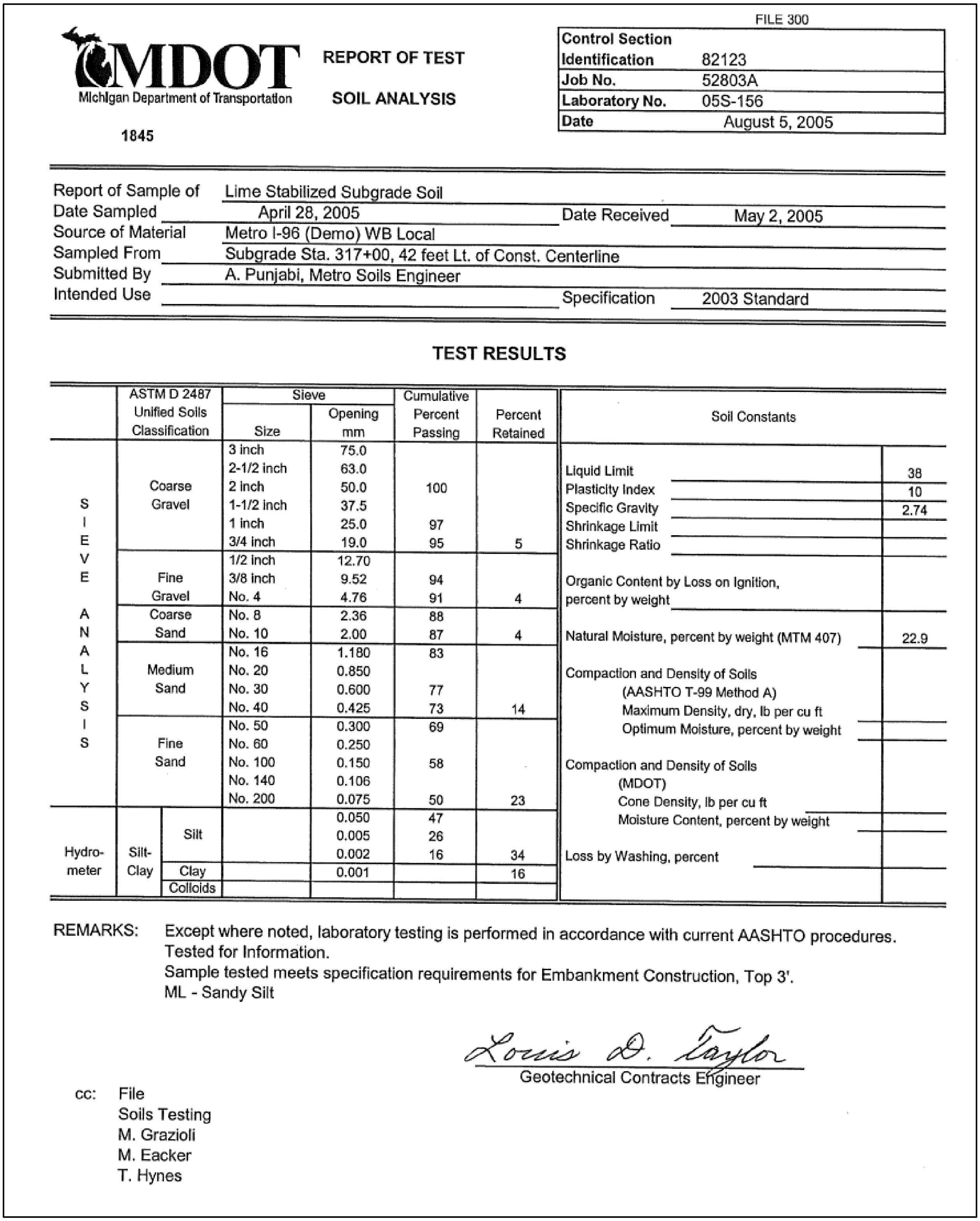
Liquid Limit	40
Plasticity Index	22
Specific Gravity	2.76
Shrinkage Limit	
Shrinkage Ratio	
Organic Content by Loss on Ignition, percent by weight	
Natural Moisture, percent by weight (MTM 407)	20.0
Compaction and Density of Soils (AASHTO T-99 Method A) Maximum Density, dry, lb per cu ft	
Optimum Moisture, percent by weight	
Compaction and Density of Soils (MDOT) Cone Density, lb per cu ft	
Moisture Content, percent by weight	
Loss by Washing, percent	

REMARKS: Except where noted, laboratory testing is performed in accordance with current AASHTO procedures.
Tested for Information.
Sample tested meets specification requirements for Embankment Construction, Top 3'.
CL - Lean Clay with Sand

Louis D. Taylor
Geotechnical Contracts Engineer

cc: File
Soils Testing
M. Grazioli
M. Eacker
T. Hynes

Figure 99. Subgrade soil information for the I-96 WB project, page 2



FILE 300

Control Section Identification	82123
Job No.	52803A
Laboratory No.	05S-156
Date	August 5, 2005

MDOT
Michigan Department of Transportation

1845

REPORT OF TEST

SOIL ANALYSIS

Report of Sample of: Lime Stabilized Subgrade Soil
Date Sampled: April 28, 2005
Date Received: May 2, 2005
Source of Material: Metro I-96 (Demo) WB Local
Sampled From: Subgrade Sta. 317+00, 42 feet Lt. of Const. Centerline
Submitted By: A. Punjabi, Metro Soils Engineer
Intended Use:
Specification: 2003 Standard

TEST RESULTS

	ASTM D 2487 Unified Soils Classification		Sieve		Cumulative Percent Passing	Percent Retained
			Size	Opening mm		
SIEVE ANALYSIS	Coarse Gravel		3 inch	75.0		
			2-1/2 inch	63.0		
			2 inch	50.0	100	
			1-1/2 inch	37.5		
			1 inch	25.0	97	
			3/4 inch	19.0	95	5
	Fine Gravel		1/2 inch	12.70		
			3/8 inch	9.52	94	
			No. 4	4.76	91	4
	Coarse Sand		No. 8	2.36	88	
			No. 10	2.00	87	4
	Medium Sand		No. 16	1.180	83	
			No. 20	0.850		
			No. 30	0.600	77	
			No. 40	0.425	73	14
	Fine Sand		No. 50	0.300	69	
			No. 60	0.250		
			No. 100	0.150	58	
			No. 140	0.106		
			No. 200	0.075	50	23
Hydro-meter	Silt-Clay	Silt		0.050	47	
				0.005	26	
				0.002	16	34
		Clay		0.001		16
		Colloids				

Soil Constants

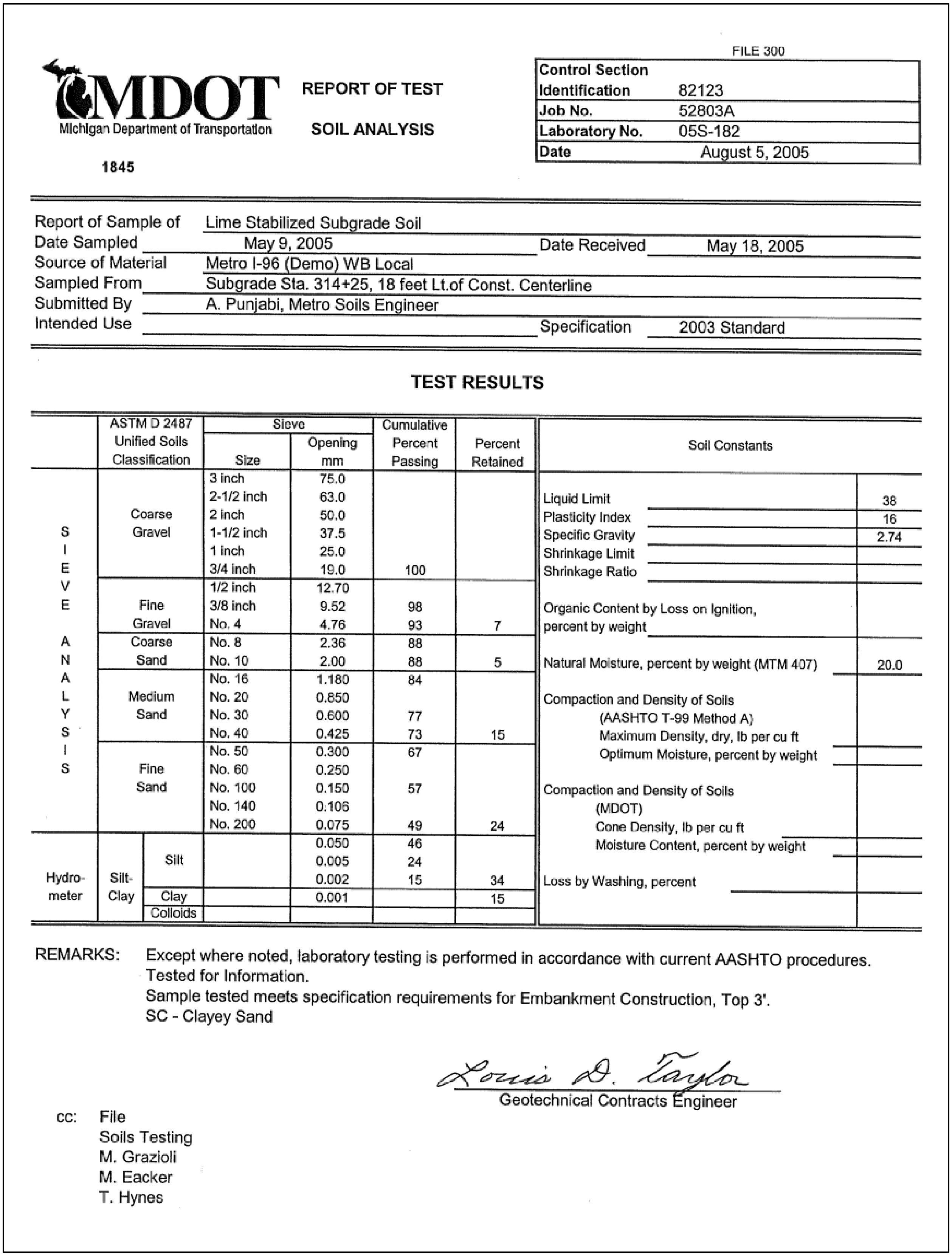
Liquid Limit	38
Plasticity Index	10
Specific Gravity	2.74
Shrinkage Limit	
Shrinkage Ratio	
Organic Content by Loss on Ignition, percent by weight	
Natural Moisture, percent by weight (MTM 407)	22.9
Compaction and Density of Soils (AASHTO T-99 Method A) Maximum Density, dry, lb per cu ft	
Optimum Moisture, percent by weight	
Compaction and Density of Soils (MDOT) Cone Density, lb per cu ft	
Moisture Content, percent by weight	
Loss by Washing, percent	

REMARKS: Except where noted, laboratory testing is performed in accordance with current AASHTO procedures.
Tested for Information.
Sample tested meets specification requirements for Embankment Construction, Top 3'.
ML - Sandy Silt

Louis D. Taylor
Geotechnical Contracts Engineer

cc: File
Soils Testing
M. Grazioli
M. Eacker
T. Hynes

Figure 100. Stabilized subgrade soil information for the I-96 WB project, page 1



FILE 300

Control Section Identification	82123
Job No.	52803A
Laboratory No.	05S-182
Date	August 5, 2005

Michigan Department of Transportation

1845

REPORT OF TEST

SOIL ANALYSIS

Report of Sample of: Lime Stabilized Subgrade Soil
Date Sampled: May 9, 2005
Date Received: May 18, 2005
Source of Material: Metro I-96 (Demo) WB Local
Sampled From: Subgrade Sta. 314+25, 18 feet Lt.of Const. Centerline
Submitted By: A. Punjabi, Metro Soils Engineer
Intended Use:
Specification: 2003 Standard

TEST RESULTS

	ASTM D 2487 Unified Soils Classification		Sieve		Cumulative Percent Passing	Percent Retained
			Size	Opening mm		
SIEVE ANALYSIS	Coarse Gravel		3 inch	75.0		
			2-1/2 inch	63.0		
			2 inch	50.0		
			1-1/2 inch	37.5		
			1 inch	25.0		
			3/4 inch	19.0	100	
	Fine Gravel		1/2 inch	12.70		
			3/8 inch	9.52	98	
			No. 4	4.76	93	7
	Coarse Sand		No. 8	2.36	88	
			No. 10	2.00	88	5
	Medium Sand		No. 16	1.180	84	
			No. 20	0.850		
			No. 30	0.600	77	
			No. 40	0.425	73	15
	Fine Sand		No. 50	0.300	67	
			No. 60	0.250		
			No. 100	0.150	57	
			No. 140	0.106		
			No. 200	0.075	49	24
Hydro-meter	Silt-Clay	Silt		0.050	46	
				0.005	24	
				0.002	15	34
		Clay		0.001		15
		Colloids				

Soil Constants

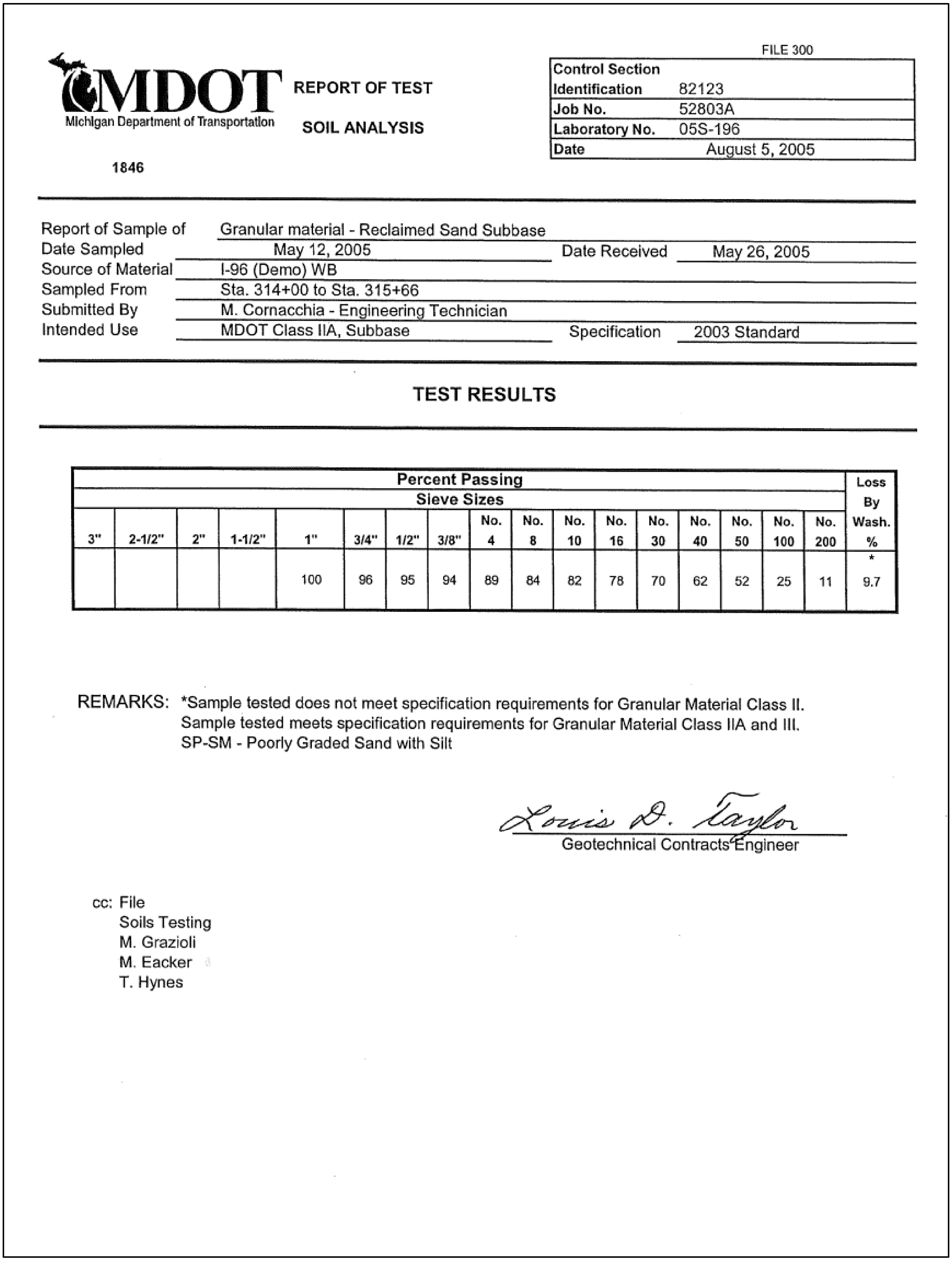
Liquid Limit	38
Plasticity Index	16
Specific Gravity	2.74
Shrinkage Limit	
Shrinkage Ratio	
Organic Content by Loss on Ignition, percent by weight	
Natural Moisture, percent by weight (MTM 407)	20.0
Compaction and Density of Soils (AASHTO T-99 Method A)	
Maximum Density, dry, lb per cu ft	
Optimum Moisture, percent by weight	
Compaction and Density of Soils (MDOT)	
Cone Density, lb per cu ft	
Moisture Content, percent by weight	
Loss by Washing, percent	

REMARKS: Except where noted, laboratory testing is performed in accordance with current AASHTO procedures.
Tested for Information.
Sample tested meets specification requirements for Embankment Construction, Top 3'.
SC - Clayey Sand

Louis D. Taylor
Geotechnical Contracts Engineer

cc: File
Soils Testing
M. Grazioli
M. Eacker
T. Hynes

Figure 101. Stabilized subgrade soil information for the I-96 WB project, page 2



FILE 300

MDOT
Michigan Department of Transportation
1846

REPORT OF TEST

SOIL ANALYSIS

Control Section Identification	82123
Job No.	52803A
Laboratory No.	05S-196
Date	August 5, 2005

Report of Sample of: Granular material - Reclaimed Sand Subbase
Date Sampled: May 12, 2005 Date Received: May 26, 2005
Source of Material: I-96 (Demo) WB
Sampled From: Sta. 314+00 to Sta. 315+66
Submitted By: M. Cornacchia - Engineering Technician
Intended Use: MDOT Class IIA, Subbase Specification: 2003 Standard

TEST RESULTS

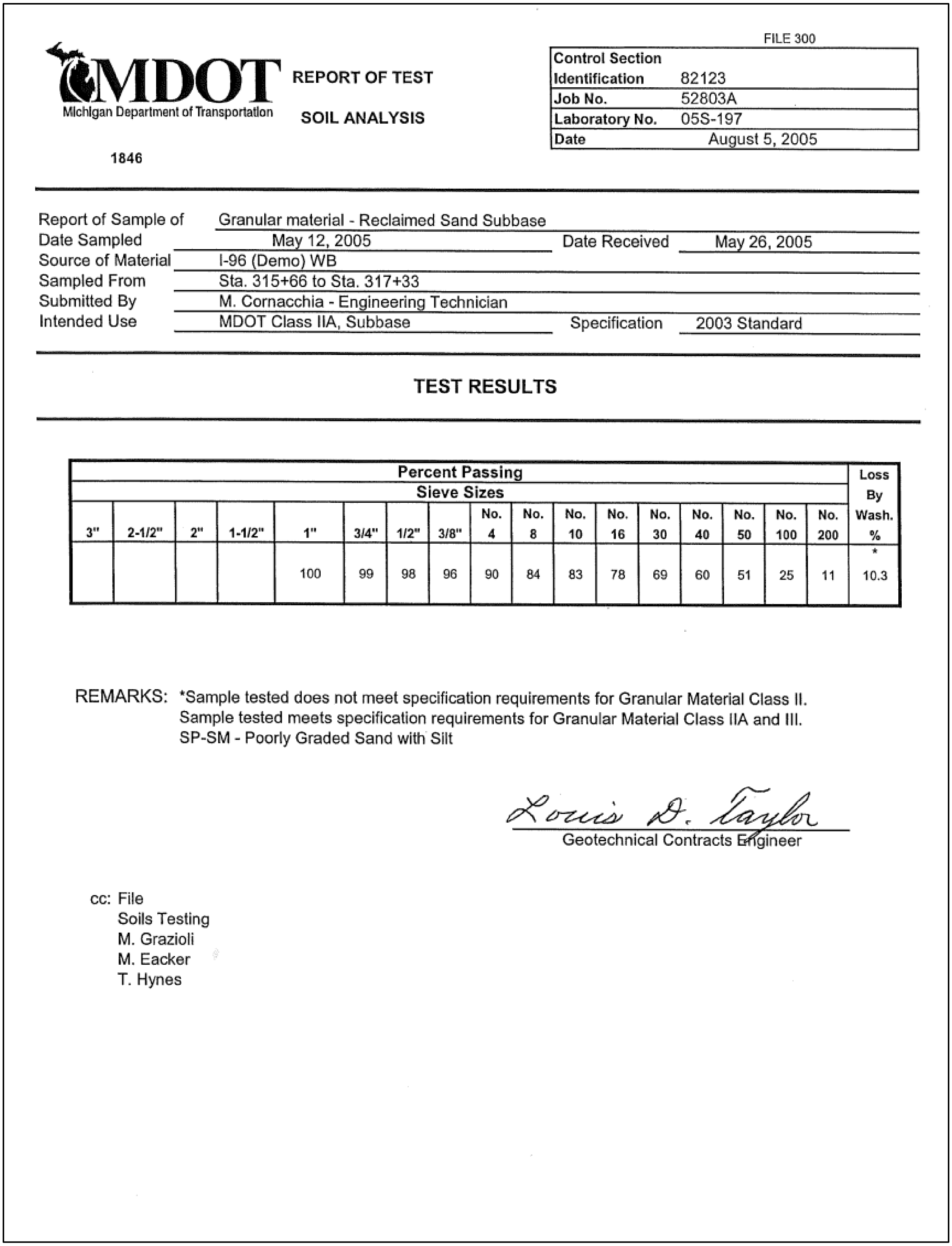
Percent Passing																	Loss By Wash. %
Sieve Sizes																	
3"	2-1/2"	2"	1-1/2"	1"	3/4"	1/2"	3/8"	No. 4	No. 8	No. 10	No. 16	No. 30	No. 40	No. 50	No. 100	No. 200	
				100	96	95	94	89	84	82	78	70	62	52	25	11	* 9.7

REMARKS: *Sample tested does not meet specification requirements for Granular Material Class II.
Sample tested meets specification requirements for Granular Material Class IIA and III.
SP-SM - Poorly Graded Sand with Silt

Louis D. Taylor
Geotechnical Contracts Engineer

cc: File
Soils Testing
M. Grazioli
M. Eacker
T. Hynes

Figure 102. Reclaimed (existing) subbase material information for I-96 WB, page 1



FILE 300

MDOT

Michigan Department of Transportation

1846

REPORT OF TEST

SOIL ANALYSIS

Control Section Identification	82123
Job No.	52803A
Laboratory No.	05S-197
Date	August 5, 2005

Report of Sample of: Granular material - Reclaimed Sand Subbase

Date Sampled: May 12, 2005 Date Received: May 26, 2005

Source of Material: I-96 (Demo) WB

Sampled From: Sta. 315+66 to Sta. 317+33

Submitted By: M. Cornacchia - Engineering Technician

Intended Use: MDOT Class IIA, Subbase Specification: 2003 Standard

TEST RESULTS

Percent Passing																	**Loss By Wash. %**
Sieve Sizes																	
3"	**2-1/2"**	**2"**	**1-1/2"**	**1"**	**3/4"**	**1/2"**	**3/8"**	**No. 4**	**No. 8**	**No. 10**	**No. 16**	**No. 30**	**No. 40**	**No. 50**	**No. 100**	**No. 200**	
				100	99	98	96	90	84	83	78	69	60	51	25	11	* 10.3

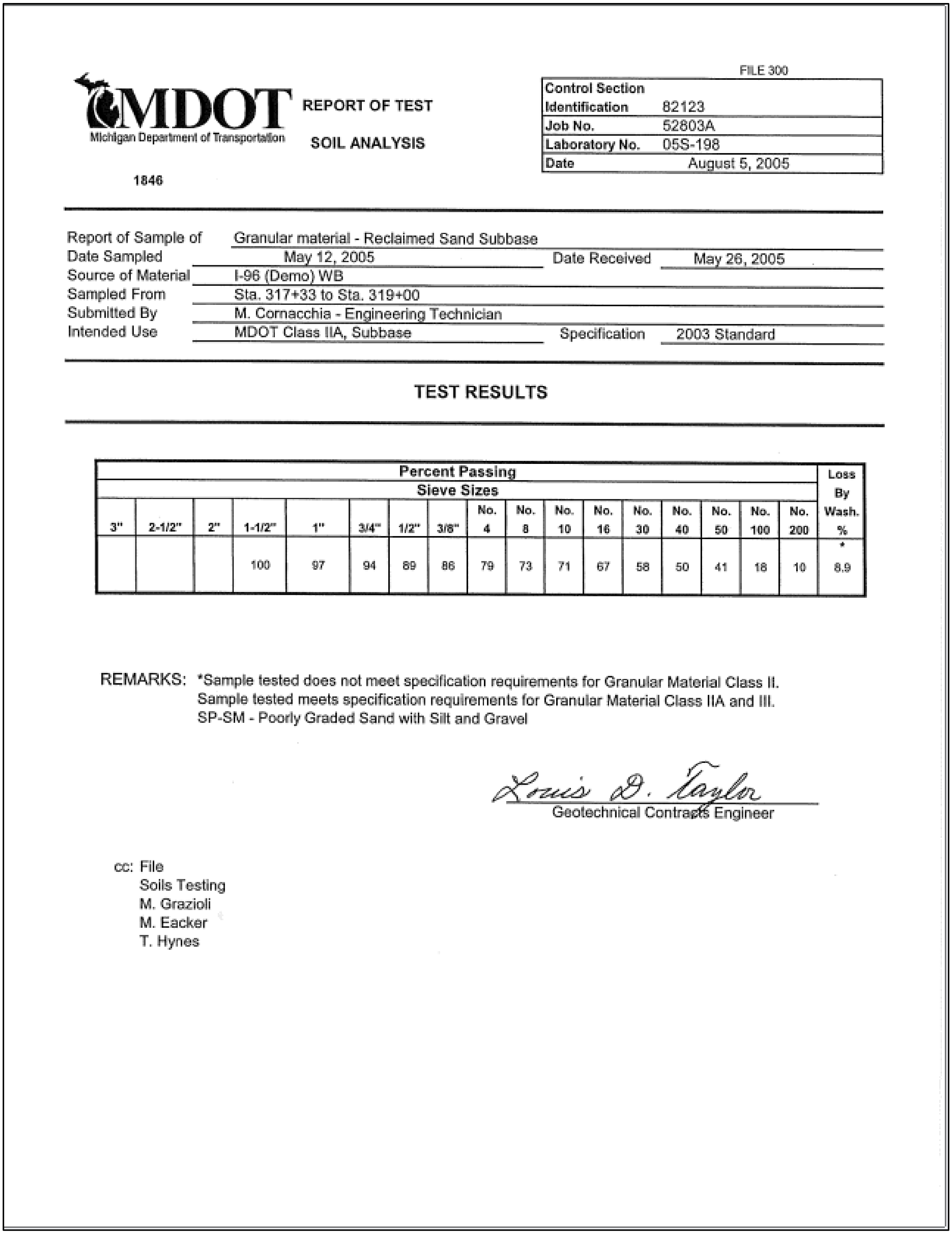
REMARKS: *Sample tested does not meet specification requirements for Granular Material Class II.
Sample tested meets specification requirements for Granular Material Class IIA and III.
SP-SM - Poorly Graded Sand with Silt

Louis D. Taylor

Geotechnical Contracts Engineer

cc: File
Soils Testing
M. Grazioli
M. Eacker
T. Hynes

Figure 103. Reclaimed (existing) subbase material information for I-96 WB, page 2



MDOT
Michigan Department of Transportation

1846

REPORT OF TEST

SOIL ANALYSIS

FILE 300

Control Section Identification	82123
Job No.	52803A
Laboratory No.	05S-198
Date	August 5, 2005

Report of Sample of: Granular material - Reclaimed Sand Subbase
Date Sampled: May 12, 2005 Date Received: May 26, 2005
Source of Material: I-96 (Demo) WB
Sampled From: Sta. 317+33 to Sta. 319+00
Submitted By: M. Cornacchia - Engineering Technician
Intended Use: MDOT Class IIA, Subbase Specification: 2003 Standard

TEST RESULTS

Percent Passing Sieve Sizes															Loss By Wash. %
3"	2-1/2"	2"	1-1/2"	1"	3/4"	1/2"	3/8"	No. 4	No. 8	No. 10	No. 16	No. 30	No. 40	No. 50	No. 100	No. 200	
			100	97	94	89	86	79	73	71	67	58	50	41	18	10	* 8.9

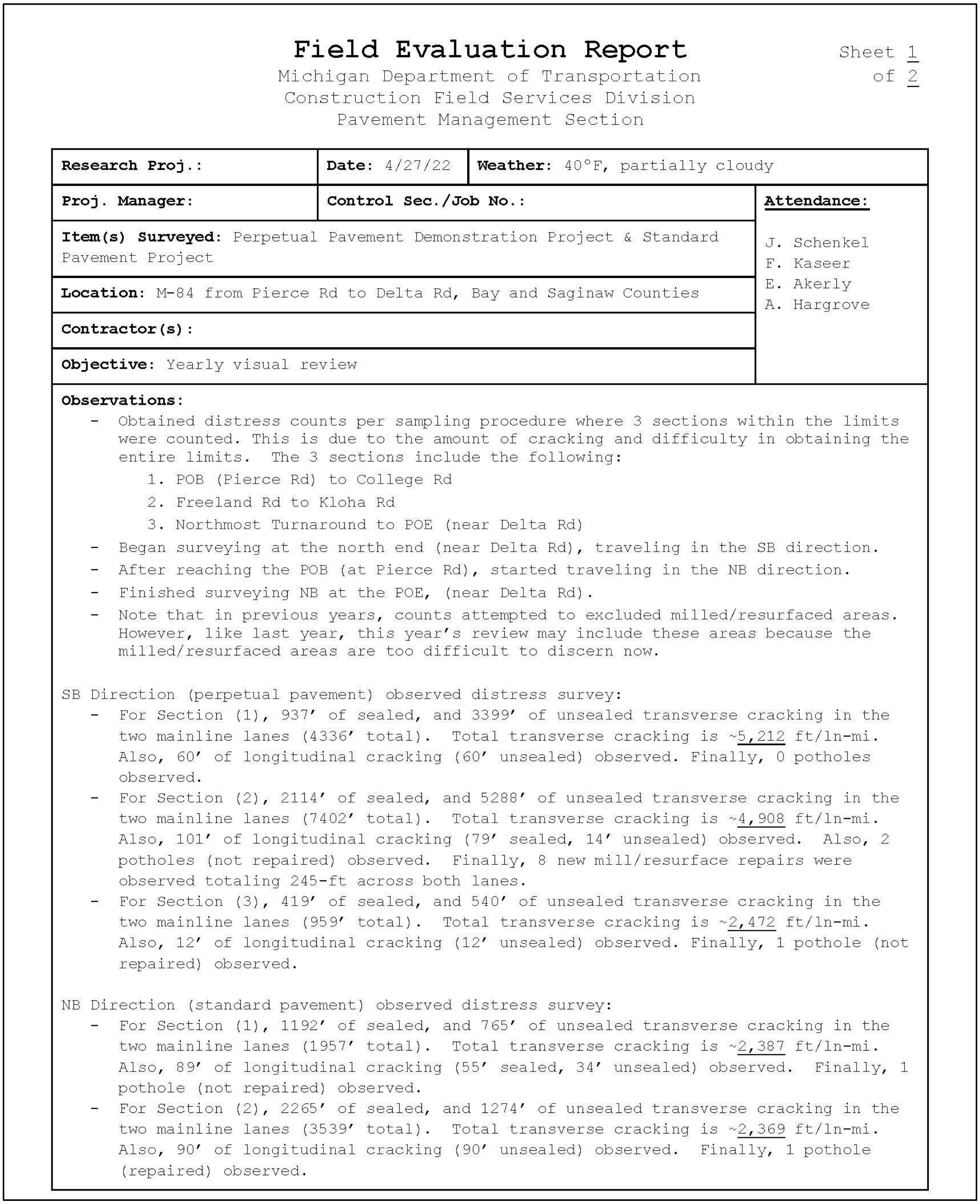
REMARKS: *Sample tested does not meet specification requirements for Granular Material Class II.
Sample tested meets specification requirements for Granular Material Class IIA and III.
SP-SM - Poorly Graded Sand with Silt and Gravel

Louis D. Taylor
Geotechnical Contracts Engineer

cc: File
Soils Testing
M. Grazioli
M. Eacker
T. Hynes

Figure 104. Reclaimed (existing) subbase material information for I-96 WB, page 3

Appendix E: Field Evaluation Reports



Field Evaluation Report

Michigan Department of Transportation
Construction Field Services Division
Pavement Management Section

Sheet 1 of 2

Research Proj.:

Date: 4/27/22

Weather: 40°F, partially cloudy

Proj. Manager:

Control Sec./Job No.:

Item(s) Surveyed: Perpetual Pavement Demonstration Project & Standard Pavement Project

Location: M-84 from Pierce Rd to Delta Rd, Bay and Saginaw Counties

Contractor(s):

Objective: Yearly visual review

Attendance:

J. Schenkel
F. Kaseer
E. Akerly
A. Hargrove

Observations:

- Obtained distress counts per sampling procedure where 3 sections within the limits were counted. This is due to the amount of cracking and difficulty in obtaining the entire limits. The 3 sections include the following:
    1. POB (Pierce Rd) to College Rd
    2. Freeland Rd to Kloha Rd
    3. Northmost Turnaround to POE (near Delta Rd)
- Began surveying at the north end (near Delta Rd), traveling in the SB direction.
- After reaching the POB (at Pierce Rd), started traveling in the NB direction.
- Finished surveying NB at the POE, (near Delta Rd).
- Note that in previous years, counts attempted to excluded milled/resurfaced areas. However, like last year, this year's review may include these areas because the milled/resurfaced areas are too difficult to discern now.

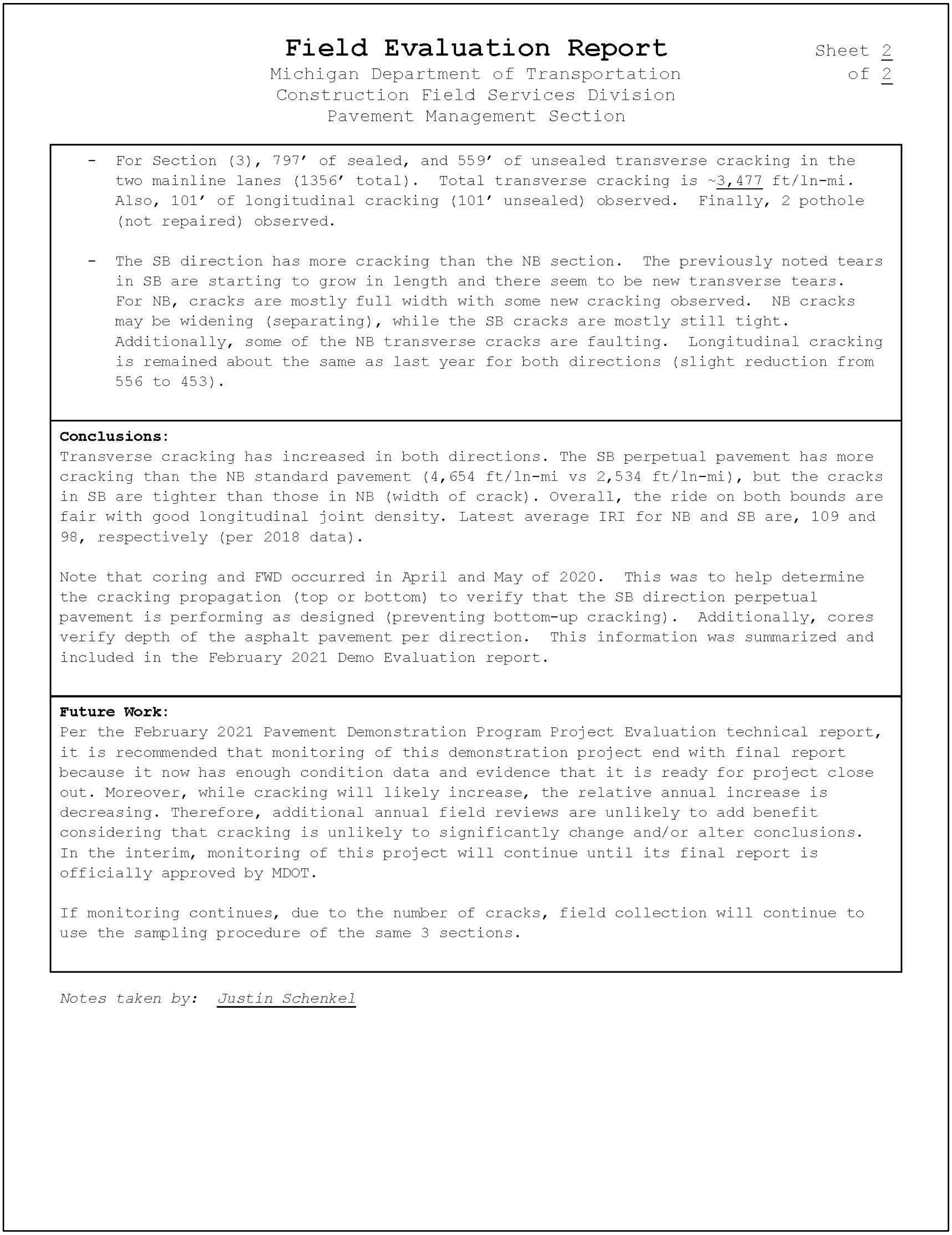
SB Direction (perpetual pavement) observed distress survey:

- For Section (1), 937′ of sealed, and 3399′ of unsealed transverse cracking in the two mainline lanes (4336′ total). Total transverse cracking is ~5,212 ft/ln-mi. Also, 60′ of longitudinal cracking (60′ unsealed) observed. Finally, 0 potholes observed.
- For Section (2), 2114′ of sealed, and 5288′ of unsealed transverse cracking in the two mainline lanes (7402′ total). Total transverse cracking is ~4,908 ft/ln-mi. Also, 101′ of longitudinal cracking (79′ sealed, 14′ unsealed) observed. Also, 2 potholes (not repaired) observed. Finally, 8 new mill/resurface repairs were observed totaling 245-ft across both lanes.
- For Section (3), 419′ of sealed, and 540′ of unsealed transverse cracking in the two mainline lanes (959′ total). Total transverse cracking is ~2,472 ft/ln-mi. Also, 12′ of longitudinal cracking (12′ unsealed) observed. Finally, 1 pothole (not repaired) observed.

NB Direction (standard pavement) observed distress survey:

- For Section (1), 1192′ of sealed, and 765′ of unsealed transverse cracking in the two mainline lanes (1957′ total). Total transverse cracking is ~2,387 ft/ln-mi. Also, 89′ of longitudinal cracking (55′ sealed, 34′ unsealed) observed. Finally, 1 pothole (not repaired) observed.
- For Section (2), 2265′ of sealed, and 1274′ of unsealed transverse cracking in the two mainline lanes (3539′ total). Total transverse cracking is ~2,369 ft/ln-mi. Also, 90′ of longitudinal cracking (90′ unsealed) observed. Finally, 1 pothole (repaired) observed.

Figure 105. Field evaluation report of M-84 in 2022, page 1



Field Evaluation Report

Michigan Department of Transportation
Construction Field Services Division
Pavement Management Section

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of 2

- For Section (3), 797′ of sealed, and 559′ of unsealed transverse cracking in the two mainline lanes (1356′ total). Total transverse cracking is ~3,477 ft/ln-mi. Also, 101′ of longitudinal cracking (101′ unsealed) observed. Finally, 2 pothole (not repaired) observed.

- The SB direction has more cracking than the NB section. The previously noted tears in SB are starting to grow in length and there seem to be new transverse tears. For NB, cracks are mostly full width with some new cracking observed. NB cracks may be widening (separating), while the SB cracks are mostly still tight. Additionally, some of the NB transverse cracks are faulting. Longitudinal cracking is remained about the same as last year for both directions (slight reduction from 556 to 453).

Conclusions:
Transverse cracking has increased in both directions. The SB perpetual pavement has more cracking than the NB standard pavement (4,654 ft/ln-mi vs 2,534 ft/ln-mi), but the cracks in SB are tighter than those in NB (width of crack). Overall, the ride on both bounds are fair with good longitudinal joint density. Latest average IRI for NB and SB are, 109 and 98, respectively (per 2018 data).

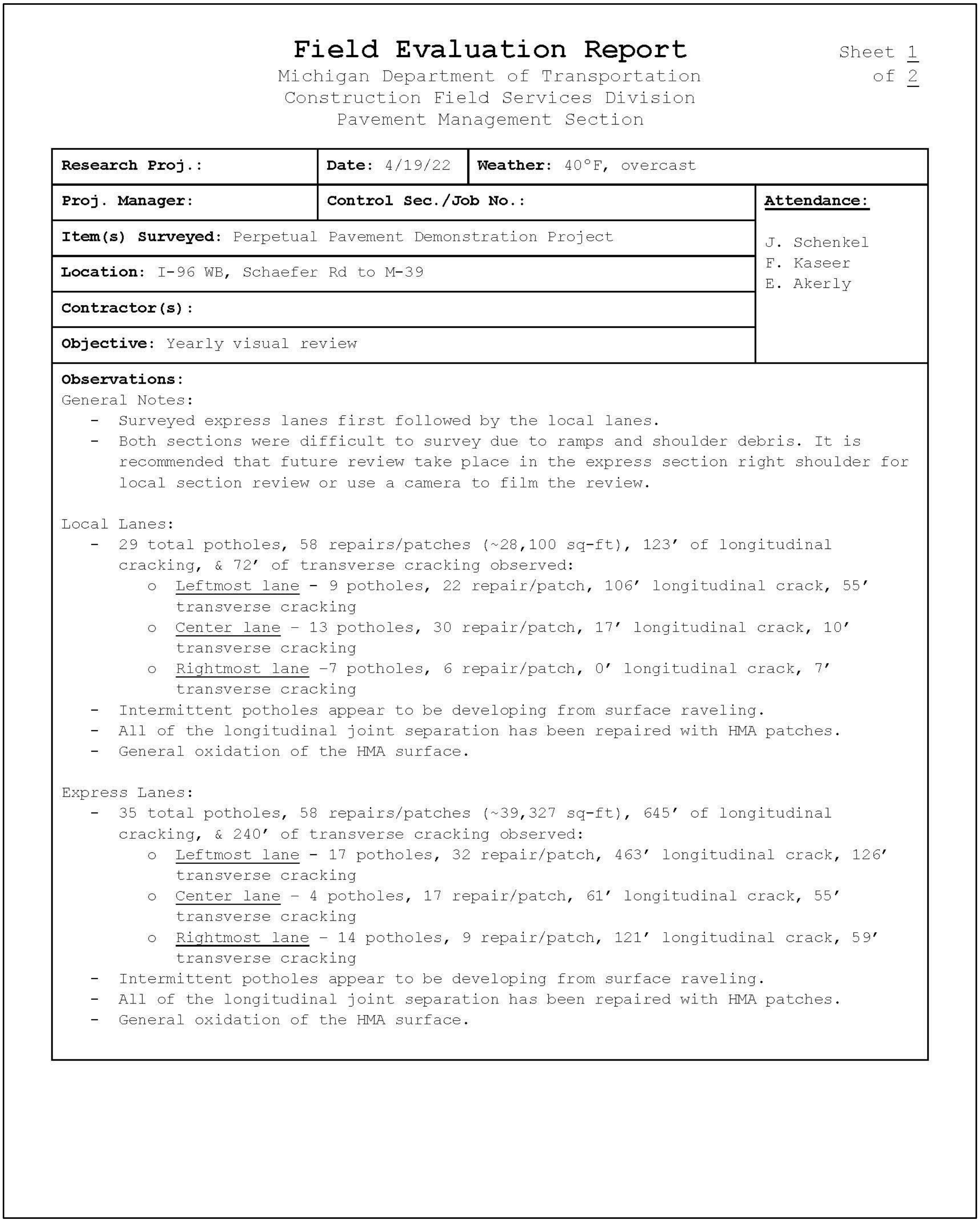
Note that coring and FWD occurred in April and May of 2020. This was to help determine the cracking propagation (top or bottom) to verify that the SB direction perpetual pavement is performing as designed (preventing bottom-up cracking). Additionally, cores verify depth of the asphalt pavement per direction. This information was summarized and included in the February 2021 Demo Evaluation report.

Future Work:
Per the February 2021 Pavement Demonstration Program Project Evaluation technical report, it is recommended that monitoring of this demonstration project end with final report because it now has enough condition data and evidence that it is ready for project close out. Moreover, while cracking will likely increase, the relative annual increase is decreasing. Therefore, additional annual field reviews are unlikely to add benefit considering that cracking is unlikely to significantly change and/or alter conclusions. In the interim, monitoring of this project will continue until its final report is officially approved by MDOT.

If monitoring continues, due to the number of cracks, field collection will continue to use the sampling procedure of the same 3 sections.

Notes taken by: *Justin Schenkel*

Figure 106. Field evaluation report of M-84 in 2022, page 2



Field Evaluation Report

Michigan Department of Transportation
Construction Field Services Division
Pavement Management Section

Sheet 1
of 2

Research Proj.:	**Date:** 4/19/22	**Weather:** 40°F, overcast	
Proj. Manager:	**Control Sec./Job No.:**		**Attendance:** J. Schenkel F. Kaseer E. Akerly
Item(s) Surveyed: Perpetual Pavement Demonstration Project			
Location: I-96 WB, Schaefer Rd to M-39			
Contractor(s):			
Objective: Yearly visual review			

Observations:

General Notes:

- Surveyed express lanes first followed by the local lanes.
- Both sections were difficult to survey due to ramps and shoulder debris. It is recommended that future review take place in the express section right shoulder for local section review or use a camera to film the review.

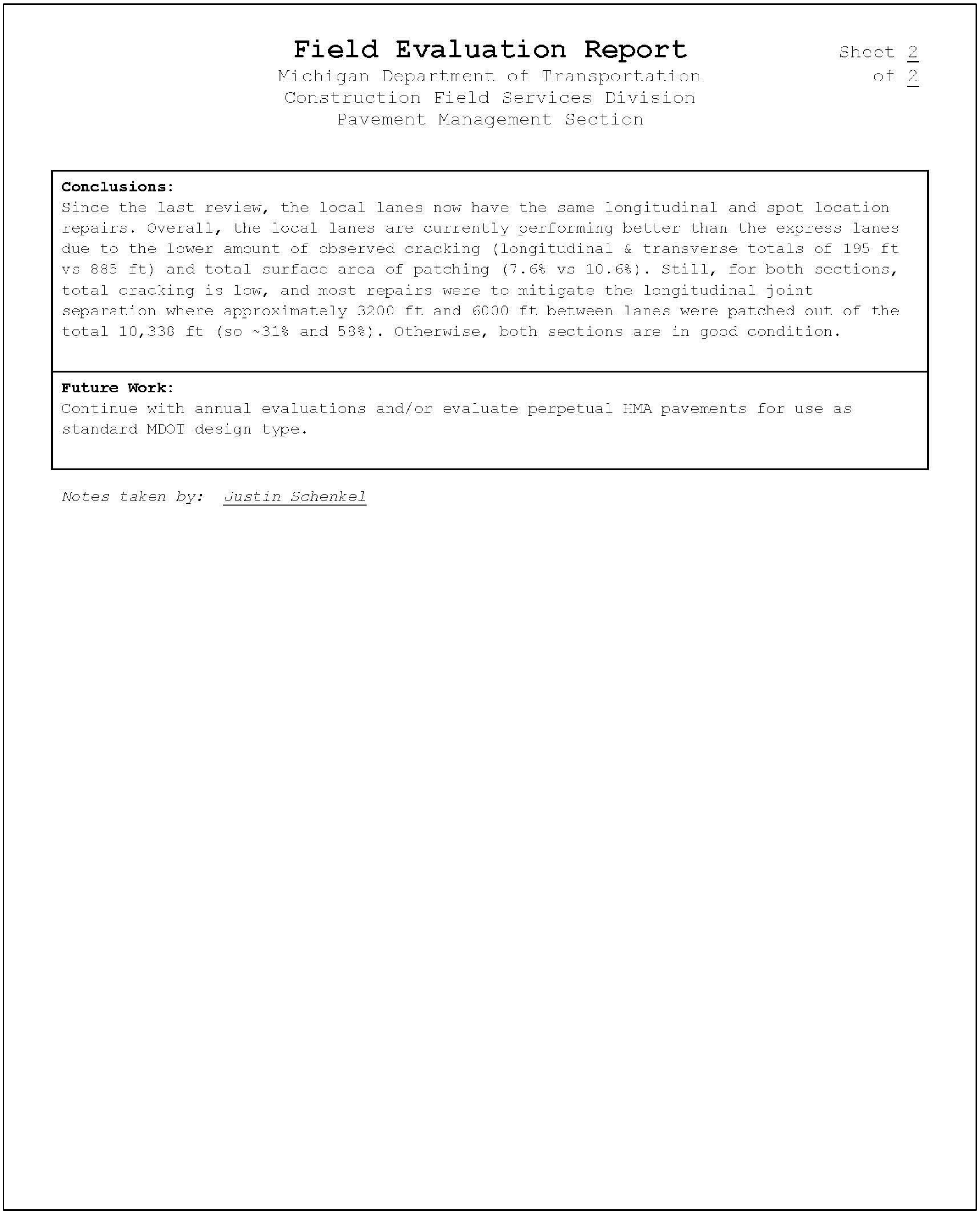
Local Lanes:

- 29 total potholes, 58 repairs/patches (~28,100 sq-ft), 123′ of longitudinal cracking, & 72′ of transverse cracking observed:
  - Leftmost lane - 9 potholes, 22 repair/patch, 106′ longitudinal crack, 55′ transverse cracking
  - Center lane – 13 potholes, 30 repair/patch, 17′ longitudinal crack, 10′ transverse cracking
  - Rightmost lane –7 potholes, 6 repair/patch, 0′ longitudinal crack, 7′ transverse cracking
- Intermittent potholes appear to be developing from surface raveling.
- All of the longitudinal joint separation has been repaired with HMA patches.
- General oxidation of the HMA surface.

Express Lanes:

- 35 total potholes, 58 repairs/patches (~39,327 sq-ft), 645′ of longitudinal cracking, & 240′ of transverse cracking observed:
  - Leftmost lane - 17 potholes, 32 repair/patch, 463′ longitudinal crack, 126′ transverse cracking
  - Center lane – 4 potholes, 17 repair/patch, 61′ longitudinal crack, 55′ transverse cracking
  - Rightmost lane – 14 potholes, 9 repair/patch, 121′ longitudinal crack, 59′ transverse cracking
- Intermittent potholes appear to be developing from surface raveling.
- All of the longitudinal joint separation has been repaired with HMA patches.
- General oxidation of the HMA surface.

Figure 107. Field evaluation report of I-96 in 2022, page 1



Field Evaluation Report

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of 2

Conclusions:
Since the last review, the local lanes now have the same longitudinal and spot location repairs. Overall, the local lanes are currently performing better than the express lanes due to the lower amount of observed cracking (longitudinal & transverse totals of 195 ft vs 885 ft) and total surface area of patching (7.6% vs 10.6%). Still, for both sections, total cracking is low, and most repairs were to mitigate the longitudinal joint separation where approximately 3200 ft and 6000 ft between lanes were patched out of the total 10,338 ft (so ~31% and 58%). Otherwise, both sections are in good condition.

Future Work:
Continue with annual evaluations and/or evaluate perpetual HMA pavements for use as standard MDOT design type.

Notes taken by: *Justin Schenkel*

Figure 108. Field evaluation report of I-96 in 2022, page 2

Appendix F: Field Evaluation Figures

Figure 109. Field evaluation of M-84 on 07-14-2005

Figure 110. Field evaluation of M-84 on 01-28-2010

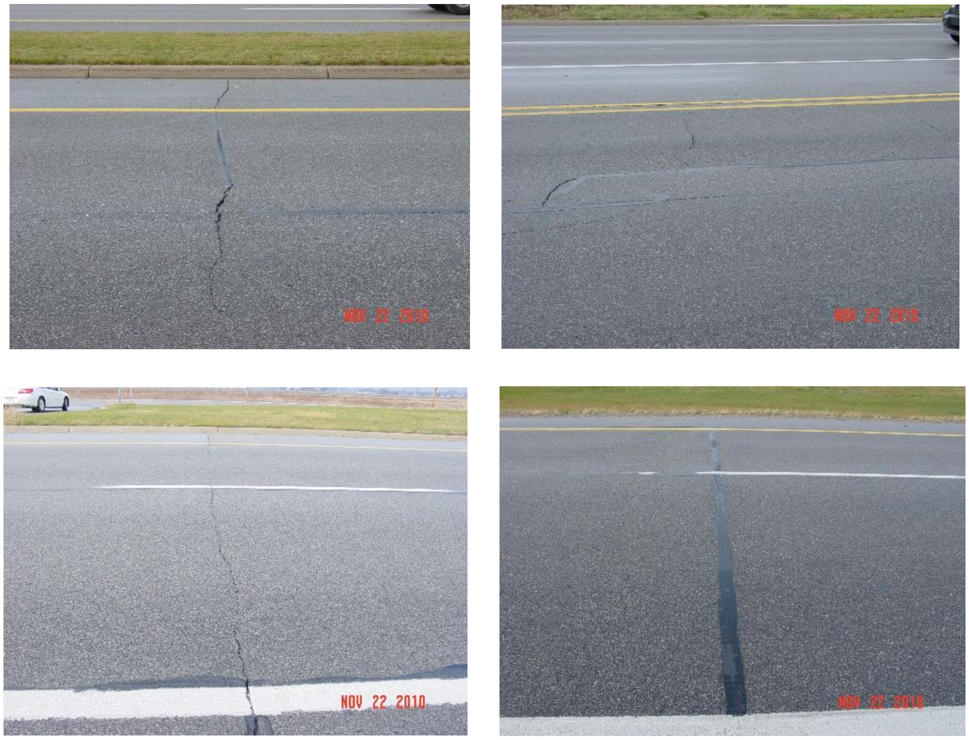

Figure 111. Field evaluation of M-84 on 11-22-2010

Figure 112. Field evaluation of M-84 on 12-08-2011

Figure 113. Field evaluation of M-84 on 12-18-2012

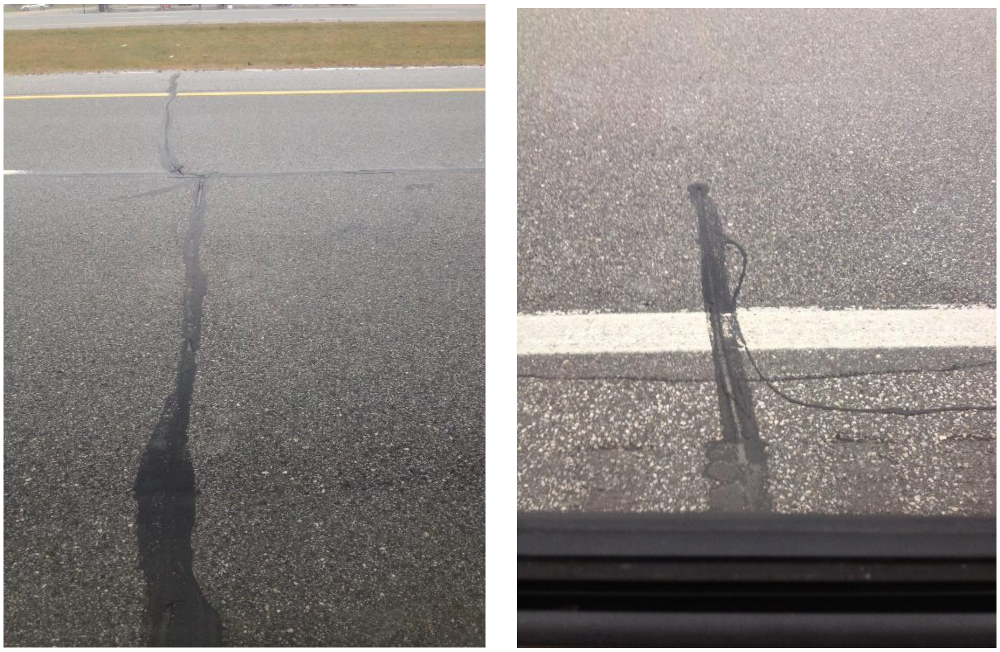

Figure 114. Field evaluation of M-84 on 12-04-2013

Figure 115. Field evaluation of M-84 on 12-23-2014

Figure 116. Field evaluation of M-84 on 12-16-2015

Figure 117. Field evaluation of M-84 on 12-21-2016

Figure 118. Field evaluation of M-84 on 04-24-2018

Figure 119. Field evaluation of M-84 on 04-01-2019

Figure 120. Field evaluation of M-84 on 04-22-2020

Figure 121. Field evaluation of M-84 on 05-03-2021

Figure 122. Field evaluation of M-84 on 01-23-2022

Figure 123. Field evaluation of I-96 on 10-07-2005

Figure 124. Field evaluation of I-96 on 11-09-2007

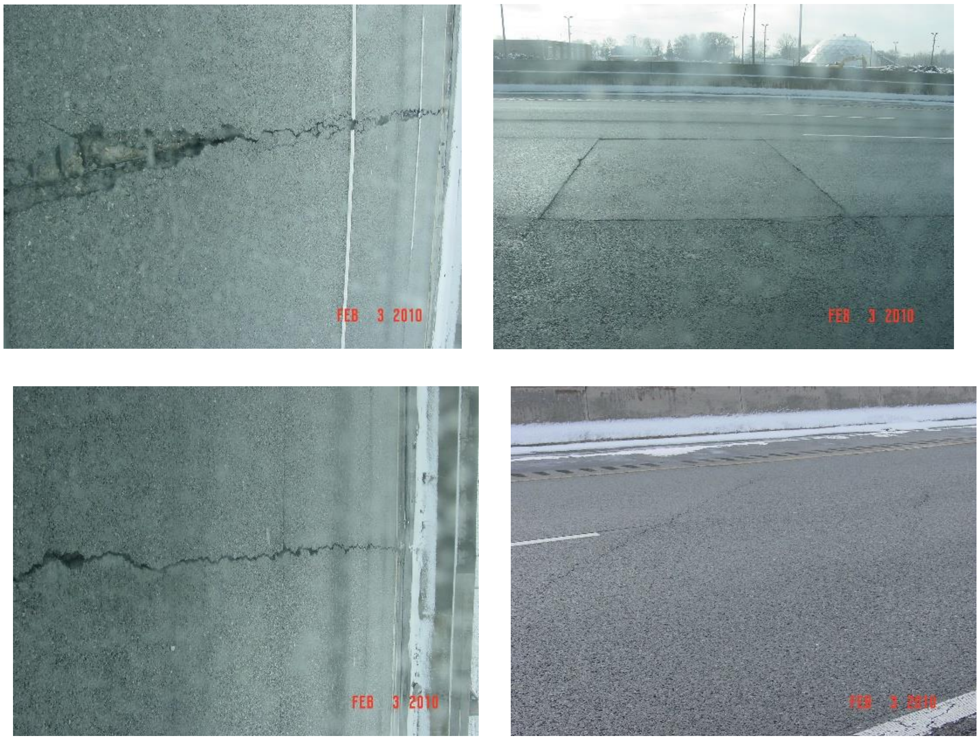

Figure 125. Field evaluation of I-96 on 02-03-2010

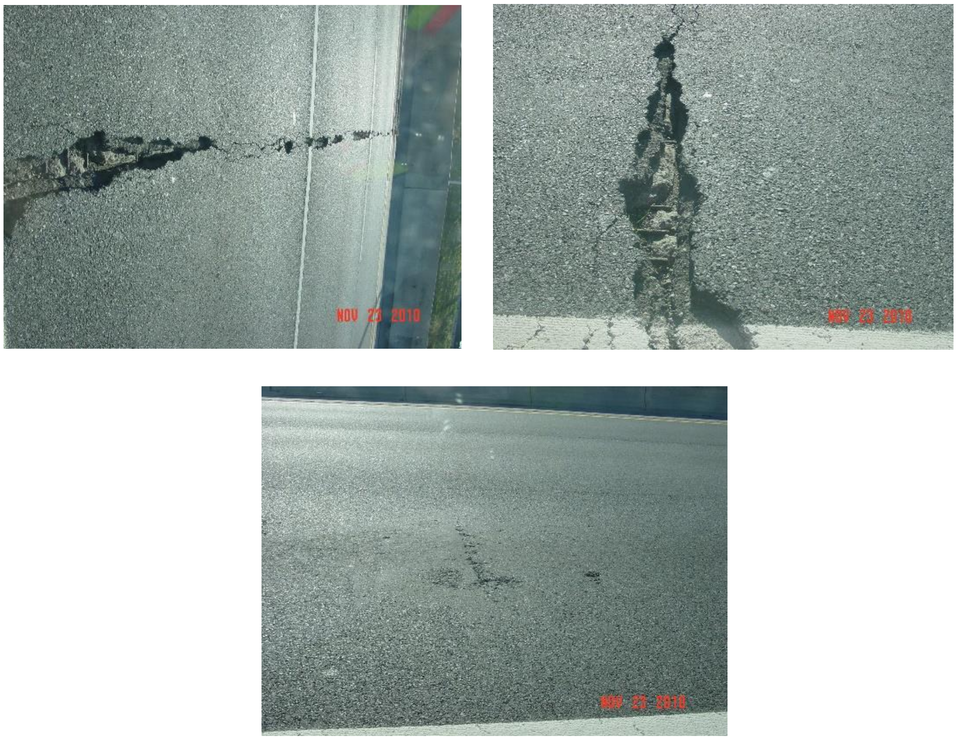

Figure 126. Field evaluation of I-96 on 11-23-2010

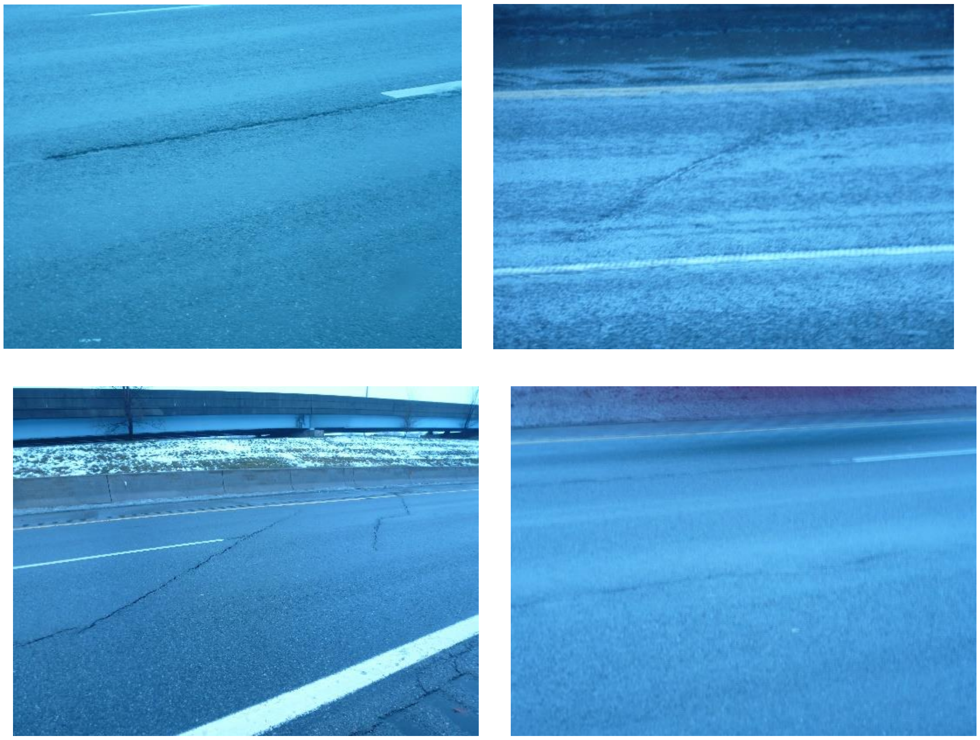

Figure 127. Field evaluation of I-96 on 12-20-2013

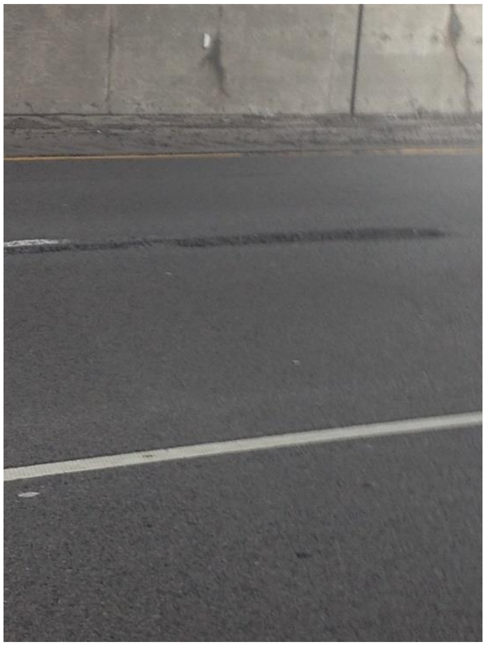

Figure 128. Field evaluation of I-96 on 12-11-2014

Figure 129. Field evaluation of I-96 on 11-21-2016

Figure 130. Field evaluation of I-96 on 03-25-2019

Figure 131. Field evaluation of I-96 on 05-04-2020

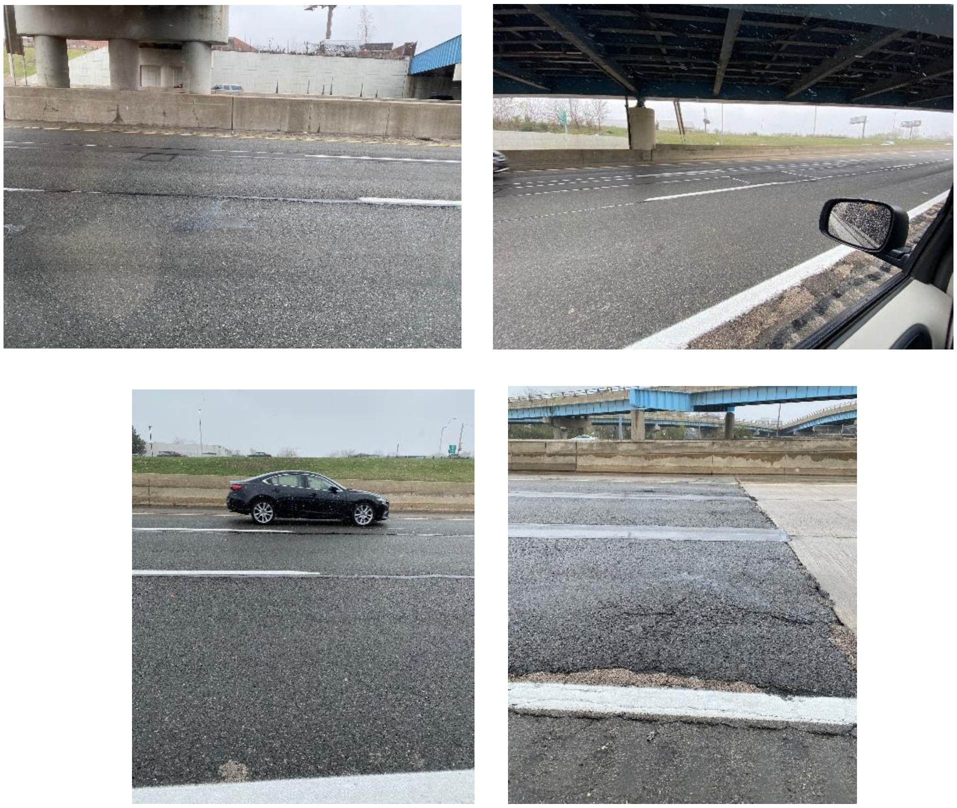

Figure 132. Field evaluation of I-96 on 04-21-2021